The effect of different concentrations of three types of emulsifier on color of an industrial-made dark chocolate

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Abstract -- **Dark chocolate is a suspension of solid particles from sugar and cocoa dispersed in a fat continuous phase in a process assisted by emulsifiers, usually a combination of lecithin and polyglycerolpolyricinoleate. Some humectant materials such as glycerin are added to the chocolate ingredients. Brown color of chocolates, which is one of the most quality attributes, affected by chocolate formulation and processing. The aim of this study was to follow color changes on the surface of industrial-made dark chocolate under different concentration of three types of lecithin, polyglycerolpolyricinoleate (both on 0.25 –0.5 %) and glycerin (0.1 –0.25 %), and under two levels of cooling temperature (7and -18 °C). A Minolta colorimeter was used to determine color of samples and the parameters measured were L, a and b. Whiteness index was calculated by a formula using L, a and b values. The results showed that the emulsifiers had a strong interactions and a considerable effect on color indices. Based on the results the cooling temperature exerts a great effect on the color parameters.**

Keywords: chocolate; emulsifier; color

I. INTRODUCTION

Dark chocolate is a suspension of solid particles from sugar and cocoa dispersed in a fat continuous phase in a process assisted by emulsifiers, usually a combination of lecithin and polyglycerolpolyricinoleate (PGPR). Some humectant materials such as glycerin are added to the chocolate ingredients. The materials used have physical specifications that can vary significantly within a relatively small temperature range.

An emulsifier is a surfactant or surface active substance that can help stabilize an emulsion by increasing its kinetic stability and decreasing interfacial tension to prevent the emulsion from changing significantly (1). By diminishing interfacial tension, emulsifiers help disperse particles in the continuous phase. The most common emulsifiers used in the food manufacturing are small molecule surfactants phospholipids, proteins, and polysaccharides. Some cases of natural food emulsifiers are egg yolk (containing lecithin), honey, mustard, and proteins. The type of emulsifier selected is based on its interaction with other components in the food system. Thus, emulsifiers are categorized according to their electric charge and their solubility in various polar and nonpolar solvents determined by the ratio of lipophilic and hydrophilic molecules (9). It is important to select an appropriate emulsifier based upon HLB values for a specific formulation to ensure optimal emulsion stability. Emulsion stability refers to the ability of an emulsion to resist change in its properties over time (5). Each emulsifier has different properties due to its structure and intermolecular interactions with both sugar particles and continuous fat phase in chocolate. Further investigations are needed to better understand the impact these specific emulsifiers have on physical properties in dark chocolate, allowing for optimization of quality during storage. This will provide insight into emulsifier selection for chocolate manufacturing. Additionally, the emulsifiers may influence some properties of solidified chocolate such as susceptibility to fat bloom, stability to fat migration from fillings, and oxidation , flow properties the sensitivity to moisture and temperature, and the tempering behavior (8, 3 & 10). Emulsifiers have also been used to influence structural properties impacting consumer perception of chocolate texture and flavor (7).

Bloom is the main reason of quality loss in the chocolate industry (National Confectioners Association, 2005). This phenomenon has an intense impact on chocolate sales. Exact market loss due to fat bloom is difficult to verify, since changes may arise many months after processing. Several studies have investigated the mechanism of fat bloom formation (2, 6 & 4). Blooming results in color changes and development of non-uniform color patterns. These phenomena were assessed during storage of milk chocolate tablets. Furthermore blooming induces a non-uniform pattern of colors over the surface of a chocolate bar. The role emulsifiers take on fat bloom formation is still unclear, but emulsifiers have potential as specific inhibitors of this phenomenon. On the other word blooming is a complex color phenomenon that encompasses all surfaces of a chocolate tablet and has to be analyzed accordingly. Color measuring, computer vision and image analysis are appropriate methods to measure and analyze color evolution during blooming development. In addition, temperature variations have a great impact on appearance, texture, and exacerbated microstructural changes in dark chocolate (2). Appearance involves all visual phenomena characterizing objects, including gloss, color, shape, roughness, surface texture, shininess, haze and translucency. The appearance of a food is the result of a complex interaction of the incident light, its optical characteristics and human perception. Lightening of chocolate on the surface indicated fat bloom formation. However limited information could be found in the literature on the influence emulsifiers on cocoa butter stability textural insights, and overall influence on fat bloom formation.

The objective of this study was to follow color changes on the surface of industrial-made dark chocolate under different concentration of three types of lecithin, polyglycerolpolyricinoleate (both on 0.25 –0.5 %) and glycerin (0.1 –0.25 %), and under two levels of cooling temperature (7and -18 °C).

II. MATERIALS AND METHODS

A. Chocolate Materials

Dark chocolate was formulated using liquor containing 50% cocoa butter, 48% total sugar and three types of emulsifier in a chocolate manufacturing company. The emulsifiers including lecithin and PGPR, and glycerin as a humectant were added in the formulation. Two concentration of 0.25 –0.5 % were used for lecithin and PGPR, and glycerin was added by 0.1 – 0.25 %. These variables have been shown in Table 1 as coded data. To produce the product, a defined manual mixing procedure and conching with three-stage tempering protocol was used. The mass was poured directly into disc-shaped plastic molds of 5 cm diameter and 7 mm thickness. These chocolate tablets were allowed to cool at temperatures +7 and -18 °C.

B. Color Determination

The color of the surface of the six chocolate tablets for each run (Table 1) was measured using a Minolta colorimeter model CR-400 (Japan) after calibration with a standard white reflective plate. The color of back and front of the chocolate tablets were examined. Measurements were recorded in **L** (lightness, from 0 to 100), **a** (redness from -60 to +60) and **b** (yellowness from -60 to +60) values for each sample, which were converted to whiteness index (WI) values according to the expression:

$$\text{Whiteness Index (WI)} = 100 - [(100 - \mathbf{L})^2 + \mathbf{a}^2 + \mathbf{b}^2]^{0.5}.$$

The lightening of chocolate can be measured by WI which can be an indicator of fat bloom formation.

Table1. CODE OF VARIABLE CHOSEN FOR EXPERIMENTAL DESIGN

Run	Lecithin	Glycerin	PGPR	T (°C)
3	1	1	2	+7
4	1	1	2	-18
1	2	1	2	+7
2	2	1	2	-18
5	1	2	2	+7
6	1	2	2	-18
7	2	2	2	+7
8	2	2	2	-18
11	1	1	1	+7
12	1	1	1	-18
9	2	1	1	+7
10	2	1	1	-18
15	1	2	1	+7
16	1	2	1	-18
13	2	2	1	+7
14	2	2	1	-18

C. *Statistical analysis*

Statistical analysis was done using STATISTICA software, Version 8.0 (StatSoft, Inc, 2007, USA). Methods applied were analysis of variance and factorial analysis with 95% confidence level.

III. RESULTS AND DISCUSSION

In this study, 8 types of chocolate formulated with different concentrations of lecithin, PGPR and glycerin, each one at two levels, and the tables tempered at two temperatures of 7 and -18 °C. To evaluate the color of the chocolates, 96 tables of the chocolates were used to color determination tests. As sown in Table 2 the results showed that the emulsifiers had a strong interactions and a considerable effect on color indices (Lightness and WI).

Table2. ANALYSIS OF VARIANCE OF EMULSIFIERS EFFECT ON LIGHTNESS OF CHOCOLATE TABLES

Effect	Wilks value	F	P
Lecithin	0.855	4.71	0.004*
Glycerin	0.775	8.02	0.000*
PGPR	0.543	23.24	0.000*
T (°C)	0.890	3.40	0.021*
Lecithin × Glycerin	0.980	0.55	0.647
Lecithin × PGPR	0.678	13.17	0.000*
Glycerin × PGPR	0.746	9.41	0.000*
Lecithin × T (°C)	0.868	4.22	0.008*
Glycerin × T (°C)	0.950	1.44	0.236
PGPR × T (°C)	0.835	5.45	0.002*

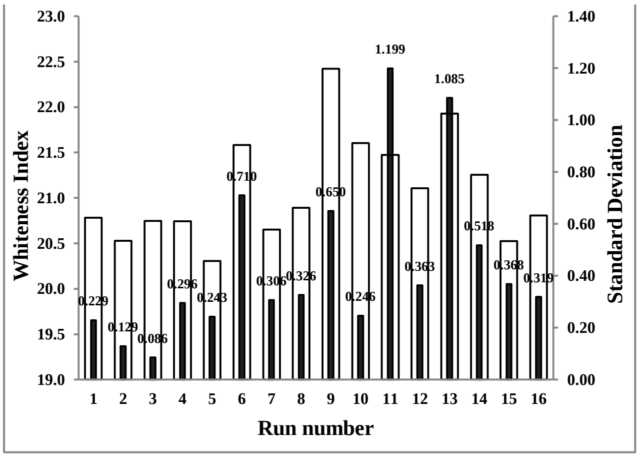


Figure1. Whiteness indices of various formulated chocolate and their standard deviations

As seen in Table 2 the cooling temperature exerts a great effect on the color parameters. The results showed that an interaction effect between the cooling temperature and lightness of the chocolate, too. Figure 1 shows that the highest lightness in run 9 in which lecithin was applied in minimum concentration and, PGPR and glycerin were used in maximum concentration into the formulation. In this run the chocolate samples have been cooled at 7 °C. Furthermore, Figure 1 shows the standard deviations (S.D.) of lightness values. When minimum concentrations of the emulsifiers (run 11 in Table 1) were used in the chocolate formulation, the lightness of the product varied in an extensive range. Lightness and WI of chocolate tablets showed a linear relation (as shown in Figure 2) due to small amounts of **a** and **b** (Table 3). Consequently lightness and WI have been shown to similar variations influenced by the formulations. No significant differences were observed in the amounts of **L**, **a** and **b** for both sides of the chocolates. Emulsifiers facilitate the interactions between sugar and fat through adsorption on the sugar crystal surface. The addition of emulsifier decreases chocolate viscosity and may also affect bloom.

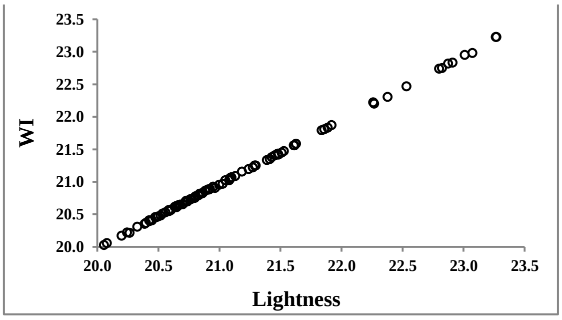
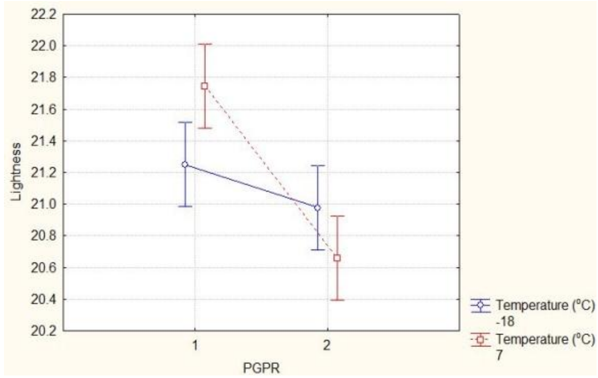


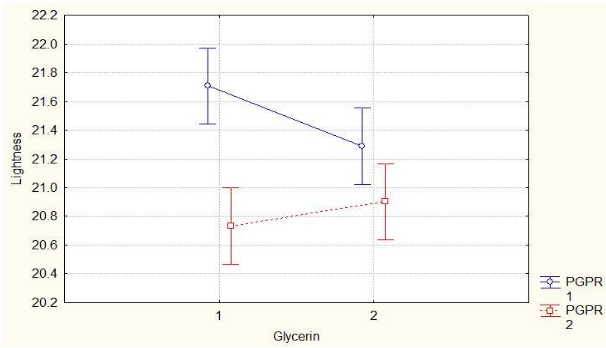
Figure2. Relationship between lightness and whiteness in dark chocolate

Table3. DESCRIPTIVE STATISTICS OF COLOR INDICES OF DARK CHOCLATE

Position	Index	Mean	Min.	Max.	S.D.
Front of tablet	**L**	20.75	19.10	24.91	1.10
	a	2.30	1.67	3.32	0.39
	b	2.24	1.31	3.86	0.63
Back of tablet	**L**	21.57	19.87	27.77	1.01
	a	1.81	1.45	2.66	0.17
	b	1.25	0.88	2.94	0.31



(A)



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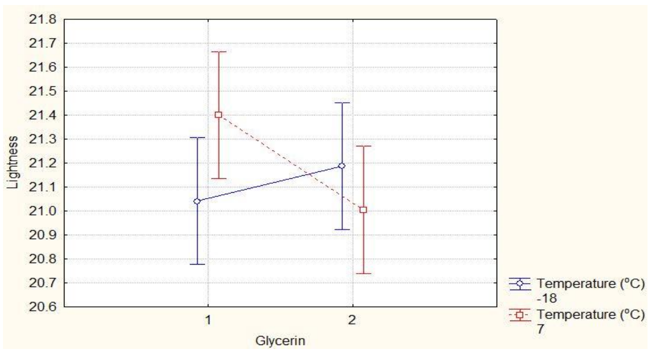
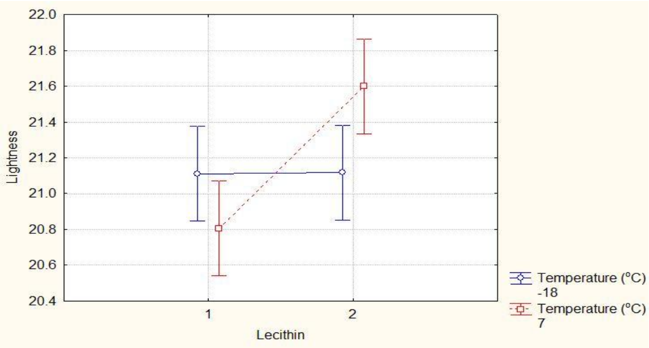
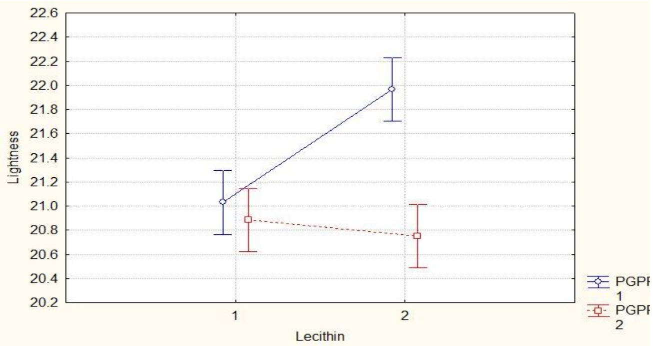


(C)



(D)



(E)

Figure3. Interactions among Lecithin, Glycerin, PGPR, and Temperature with Lightness in dark chocolate: (A); PGPR-T °C, (B); Glycerin-PGPR, (C); Glycerin- T °C, (D); Lecithin- T °C, and (E); Lecithin-PGPR.

Figure 3 shows lightness amounts under different concentration of lecithin, glycerin, PGPR and cooling temperature in details. Interactions among these variables are clear in the Figures 3; A to E. The results demonstrated in Table 2 verify lightness differences shown in the Figure 3 (A-E). As previously revealed in the section describing bloom enhancers, the tempering and cooling steps are very significant to controlling bloom formation. Storage conditions are important in inhibiting or promoting bloom formation, too. As previously discussed, cooling that is too slow or too quick can persuade bloom. Proper cooling of chocolates and compound coatings is needed to protect against early bloom formation.

IV. CONCLUSION

The findings indicate that emulsifiers affect the color of the chocolate tablets. Interactions among the emulsifiers and temperature affect also the color of the surface of the chocolate tablets. The results showed that the highest lightness made when lecithin was applied in minimum concentration and, PGPR and glycerin were used in maximum concentration into the formulation. Therefore the results validate that both factors type and concentration of the emulsifier have sensitive impact on the lightness properties of chocolate and so formulation of the chocolate allows producers to adjust processing parameters to their specific needs. They can prevent discoloration of the product during storage and affect lightness of chocolate.

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