The effect of storage temperature and production method of chocolate confectionery on changes in its quality

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Abstract: The aim of the study was to assess the dynamics of changes in the quality of certain types of chocolate confectionary over the storage period, the main attention being paid to the formation and development of fat bloom in chocolate products, whether or not treated by retempering. Six products were chosen from the product range of and in cooperation with Zora Olomouc, a chocolate factory controlled by Nestlé Czech Ltd. The samples were stored at four types of temperature modes: 6°C, 12°C, 20°C and 30°C, and periodically sampled for analysis. Each sampling was followed by sensory assessment by trained assessment specialists, identification of changes in colour using Konica Minolta Spectrophotometer CM-3500d and physical analysis of the product texture using the TIRAtest unit. The results showed a significant effect of the storage temperature on the intensity of changes. There was a product-specific intensity of positive effects of retempering observed in the products.

Key-Words: chocolate, storage temperature, fat bloom, sensory assessment, texture, colour

Introduction

The taste and aroma of chocolate should be pleasant, aromatic and should resemble the raw materials used. The surface of the chocolate should be glossy; there should be no stains or coatings. Failure to follow production practices, improper storage or transportation may cause defects of chocolate.

Typically, there are two basic types of defects - fat bloom and sugar bloom, with the material losing its sheen and is covered with a fine whitish layer [1]. Since the fat bloom is a much more feared phenomenon, highly undesirable in the chocolate industry, its prevention is the subject of increased attention within the industry [2]. The bloom looks similar to the blooms of certain fruit species such as plum or common grapevine; it is of a greasy nature when touched [3]. The bloom usually covers the entire surface, thus making the product unacceptable for sale or consumption. Although grey chocolate does not constitute a threat to the public or consumer health, the process converts the product to being unattractive and therefore inedible [1].

Causes for the fat bloom to occur can be technological – poor chocolate tempering, incorrect cooling methods, the presence of soft fat in the fillings of chocolate products or addition of fats incompatible with cocoa butter; the bloom may also occur through improper storage at higher or fluctuating temperatures [3]. Currently, essential for chocolate to be of high quality are particularly a crystalline form of cocoa butter and the percentage of solid fat during production [1]. Cocoa butter exhibits polymorphism, which involves the capability of crystallising (conditions-dependent) to create several crystalline forms based on the temperature and the cooling rate of the melt. Of these, the lipid crystalline form V (β_2) is desirable for the production and prevails in a well-tempered chocolate [4, 5]. Cocoa butter is the major factor for the stability at room temperature and is responsible for the characteristics of melting and hardness in the mouth. The crystalline structure of fat thus determines the macroscopic properties of chocolate and sensory perception [6, 7].

Incomplete tempering can produce a large amount of unstable modifications with a low melting point, these dissolving under warm storage conditions and then rise to the surface where the molten fraction of cocoa butter solidifies in the form of fatty coating. The same defect can also be caused by the fat filling used in chocolate confectionery [8].

To consumers, the appearance and texture form the main attributes for the selection and acceptability of chocolate; the taste is considered to be important when identifying the product. The final texture (hardness) of chocolate is influenced by several factors including formulations, production techniques, tempering, polymorphism (fat crystal stability) and cooling temperatures.

Visual information describing objects, starting with sheen, colour, shape, roughness, texture, reflections and translucency are summarised in the attributes of appearance. These attributes result from complex interactions of incident light, the optical properties and human perception. Relevant information can be obtained from modern technology, such as computer imaging analysis with colour calibration, HunterLab and CIELAB models. Given that chocolate should be meeting consumer expectations previously acquired, the appearance traits may possess significant commercial implications [1].

Texture and appearance also play an important role in the sensory assessment of chocolate. Sensory analysis is an objective method of analysis which employs trained staff instead of devices. The method is important in that it covers such quantitative indicators which cannot be directly characterised by instrument methods, establishing a set of factors that determine the final impression of the consumer [9].

Therefore, this study was carried out to determine the effect of fat migration on texture, bloom formation and sensory attributes of chocolate at different storage temperatures.

Materials and methods

Six brands in two variants were chosen from the product range of and in cooperation with Zora Olomouc, a chocolate factory controlled by Nestlé Czech Ltd. These involved *Kaštany ledové*, *Milena*, *Margot Artemis*, *Orion Krémová oříšková*, *BOCI fekete erdö* (a dark chocolate with cherry filling) and dessert candies called *Black magic - Orange Sensation* (a dark chocolate filled with orange fondant).

Each of the products was made in two variants of R and N, where R refers to retempered and N to not retempered products. The difference in this regard consists in the last production step where the process of retempering refers to exposing the packed, normally produced articles to an ideal temperature for a certain period to create a perfect structure of cocoa butter crystalline grid.

Sample storage and analysis

The prepared products were taken to stock at Mendel University in Brno and an assessment was carried out, including determining the colour using Konica Minolta Spectrophotometer CM-3500d and making a physical analysis of the product texture using the TIRAtest unit. Simultaneously, a part of the samples was deep-frozen to (-18°C) for later use as "standards" in the sensory analysis, while the remainder was split into controlled temperature regimes - warehouses with cooling temperatures of 6°C and 12°C, a laboratory room with constant temperature of 20°C and the thermostat set to 30°C and then stored under such settings without any temperature fluctuations. The second set of samples was taken two weeks after the production date, now from the various storage temperature settings, and again subjected to sensory assessment and identifying the colour changes and changes in texture. The same was done for the third sampling after six weeks and the fourth sampling after ten weeks of production date. Before each analysis, the samples were equilibrated to room temperature.

Sensory assessment

The sensory profile method was used to determine the sensory attributes of chocolate products with respect to storage time and temperature. Each of the assessments was carried out by at least eight trained assessment specialists. The sensory protocols for each product contained the same descriptors. To measure the perceptions, unstructured graphical scales were used with the verbal description of the endpoints, the scale length being 10 cm. All of the sensory assessments were underway in a specialised laboratory under standard conditions.

Measuring colour

Konica Minolta Spectrophotometer CM 3500d was used for determining the colour and its changes during the storage time of each sample. The unit is connected to a computer with installed software (CMS-100W SpectraMagic NX) in which different modes can be set for data processing and export, e.g. selecting desired values (L*a*b*, L*C*h, Hunter Lab). The modes selected for the colorimetric determination of colour for chocolate products were as follows:

- Reflectance
- Geometry d/8 (the instrument measures the reflected light at an angle of 8°)
- SCE (specular component excluded - eliminating sheen)
- D 65 (illumination mode; 6,500 Kelvin)
- 8 mm slot

Measurements were done each time three times on the cavity and three times on the coating in two samples per group.

Analysing texture
Texture measurements used a universal instrument for the measurement of physical characteristics - Tira test (type 27025). It is a desktop single-column unit with a maximum load of 2.5 kN. The high-quality sensors of values along with the microprocessor-controlled equipment achieve the maximum precision.

The penetration test used for assessing the chocolate products involved a probe of a stick shape which penetrated into the sample, so obtaining a record of the force necessary to push the punch to a selected depth (in Newton). The selected criteria for the penetration test of chocolate products:
Type of test: pressure testing
Type of attachment: straight ending
Probe diameter: 3 mm
Force sensor: 200 N
Test speed: v_1 = 100 mm per min
End of test: 7 mm track

Results and Discussion
The acquired data were analysed using MS Excel. The statistical analysis of all the sourced data was carried out using STATISTICA version 12 - analysis of variance (ANOVA).

Sensory assessment
The results of the graphical scales were obtained by measuring the distance of the mark from the right scale end (in cm) and are graphically rendered in the form of radar charts as an average rating of all assessment specialists (n = 8). "10" refers to the highest/best quality at the scale left end, while "0" is the least favourable / lowest quality at the right end. The radar charts thus graphically express the sensory profiles of the products during storage, clearly illustrating the differences between each of the production variants as well as between the temperature modes.

The results make it apparent that all the products and their variants stored at 6°C and 12°C did not show any deterioration in the descriptors even after ten weeks of the production date. Their attributes (both visual and taste characteristics) were comparable to the standards, achieving the overall sample rating of the same extent.

During the storage period at 20°C, the not retempered *Margot* products started to show signs of fat bloom already on sampling 3. On sampling 4, the fat bloom was found in the retempered products as well. This means that the influence of technology in these products is evident - retempered products resist longer to the development of fat bloom.

On sampling 4, the fat bloom was found even on the surface of the cavity in the not retempered *Kaštany* products. Significant presence of the same was found in the filling as well. This reconfirms the benefit of retempering. Deterioration was generally found in multiple sensory descriptors at these storage temperatures in chocolate bars, which specially involved sheen or even aroma for the *Margot* product. Table chocolates (*Boci*, *Orion Krémová oříšková*) did not show any deficiencies in this type of storage; the same applies to fondants. The worst changes during such storage temperature were observed for the *Margot* and *Milena* products as early as on sampling 1, the samples being repulsive in terms of both appearance and taste. In addition, *Milena* was found to have a dry filling. Observed in both of the products was also overall hardening, manifest in loose and crumbly consistency.

Results for individual products as well as their variants stored at 30°C show a clear deterioration of all the sensory descriptors. The same results were achieved by Ali et al [10] who state that the migration of fat under these temperatures adversely affects the product integrity and appearance. In chocolate products, the typical deterioration associated with fat migration is manifest in softening, fat bloom and unacceptable textural changes within the product due to the leakage of liquid glycerides from the filling onto the surface of the product. All of this reduces the product acceptability for the consumer. As a conclusion of studying the sensory changes in colour and texture of chocolate products, the authors report that the storage temperature at 30°C is significantly ($P < 0.05$) less advisable than that of 18°C.

The results were also confirmed in their study by Bui et Coad [11] when storing temperature above 30°C caused the chocolates to significantly decrease their sensory quality. The largest losses in terms of quality occurred with respect to appearance and the overall acceptance of the products. Although milk chocolate is usually considered resistant to fat bloom with the inhibitory effects of milk fat, the fact that milk fat content is negligible in the current production as a result of using dry skimmed milk resulted in rapid blooming due to storage conditions.

Sample sensory profile - *Kaštany*
The results of sensory rating in the *Kaštany* chocolate product after the end of the experiment (10 weeks of the production date) is presented on Fig. 1 and Fig. 2. The charts show the differences among the storage temperatures as well as between the retempered and the not retempered products.

Fig. 1 Sensory profile – *Kaštany retempered*

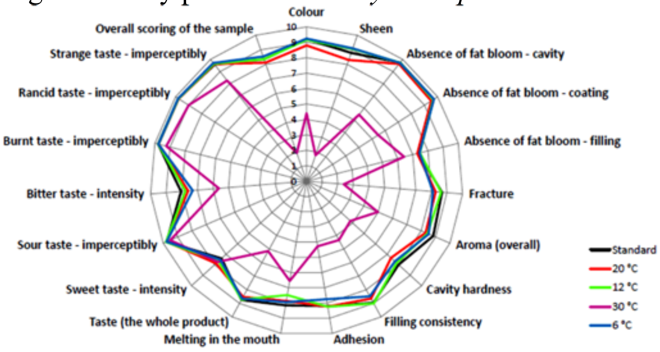
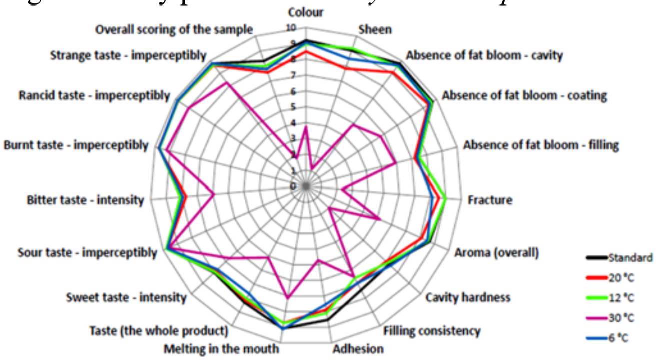


Fig. 2 Sensory profile – *Kaštany not retempered*

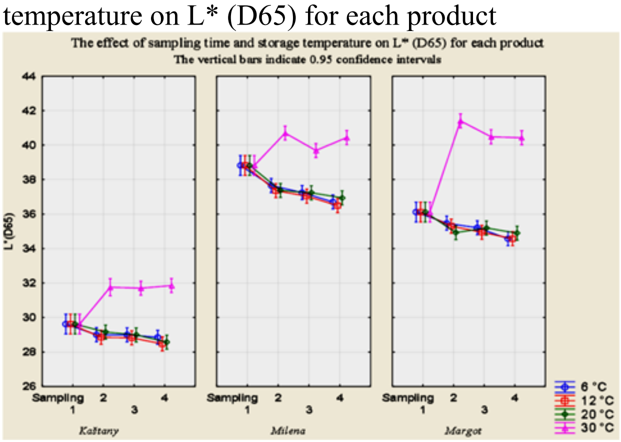


Measuring colour

The CM-S100w program enables expression of colour in a colour space CIELAB (balls) according to the International Commission on Illumination. The values of L* (lightness) represent the range from "0" (black) to "100" (white). The colour coordinates a* and b* take positive or negative values depending on the location within the three-dimensional system.

Since the effect of the temperatures during the storage period on the change in colour was significant chiefly in chocolate bars, results are provided for this very type of product.

Fig. 3 The effect of sampling time and storage temperature on L* (D65) for each product



L* (lightness) was the value selected for the statistical evaluation as it best characterises the colour changes per sample during the analysis. All of the results were statistically significant.

Significant changes in lightness were observed as part of the measurement of colour during the storage time, particularly for 30 °C temperatures. The lightness L* (D65) was significantly increased in all of the samples, mostly for *Margot* products. A noteworthy colour difference was observed in the other temperature modes when linearly, depending on the time, darkening occurred for all of the products. Between the modes of storage (6, 12 and 20°C), however, apparent difference in L* values were not observed. The effect of technology on the lightness L* was not significant.

Changes in the colour of the surface of the chocolate at the storage temperature of 18°C and 28°C over 52 days in milk chocolates were also studied by Briones et Aguilera [12], where significant changes in colour occurred after 33 days of storing. Initially, white spots appeared on the surface probably due to the rapid migration of the liquid fat through defects or pores in the surface layer. Adenier et al [13] report that initially the fat bloom occurs at the edges or along cracks on the surface layer of the chocolate to gradually replace the original brown surface of the chocolate table. Thus, fat blooming as a result of product exposure to high temperatures causes the chocolate to change its colour with time, as well as lose sheen and turn grey along the surface [12].

Changes in colour between the experimental and control samples during storage at 30°C were noted in their study by Bui et Coad [11] as well. The authors found that storage time mostly influenced the L* value. For a* value, the change was not demonstrated, i.e., there was no shift from red to green. The upward shift occurred for the b* value, indicating movement along the axis from the blue towards the yellow, meaning that the products became brighter over time. The shift of the axis to the yellow colour characterises the development of fat bloom, with however the changes being still not noticeable to the naked eye. These findings are reconfirmed in our results.

Bui et Coad [12] also compared the relationships between the sensory attributes and instrumental measurements of colour. All of the differences between the sensory and colour changes they found were statistically significant ($p < 0.001$). The correlation was the strongest for colour (L* and b*) and for texture. Other variables strongly correlated with colour (L* and b*) involved taste (0.96 to 0.97), overall acceptance (0.96 with b*) and percentage of fat bloom (0.96 with b*). These results conclude that as the fat blooming evolved, the products became brighter, their taste and texture turned worse and the product became generally less acceptable.

Analysing texture
All of the results were statistically significant.

Fig. 4 The effect of storing temperature on the hardness of each product

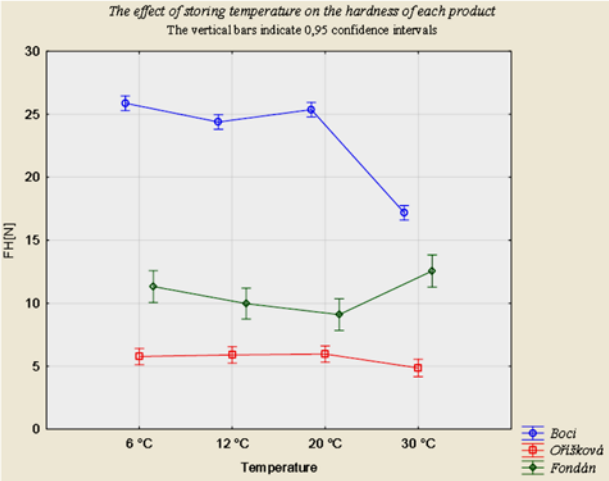
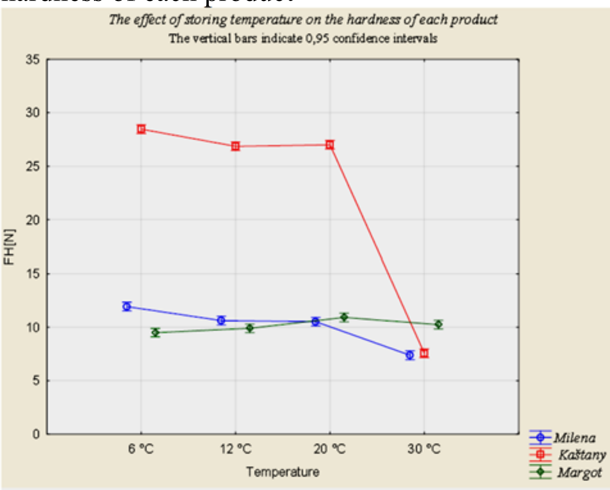


Fig. 5 The effect of storing temperature on the hardness of each product



The chart shows that the hardness of *Boci* – the filled chocolate - was significantly lower when stored at 30°C than that of other temperature modes (Fig. 4). For the *Orion Krémová oříšková* chocolate, the decrease in hardness was not so significant. The liquid filling in *Boci* thus may be causing softening in this type of chocolate. Ali et al [10] also report in their results that filled chocolates stored at 30°C were significantly softer than those stored at 18°C. This is explained by a significant migration of fat from fillings into the chocolate layer. An even more significant softening occurred in the *Kaštany* products (Fig. 5), which is probably due to the significantly different composition of fatty acids in the filling. According to Ali et al [10], in filled chocolate products where the filling contains lipids with a low melting point, these lipids tend over time to migrate to the surface of products, which initially most likely involves lipids with the lowest melting point and the highest fluidity. This migration may cause the chocolate to become sticky and soft, while the filling becomes stiffer; the migration has even an impact on the structure of the surface. Fat migration can largely occur already at room temperature (17-23°C); it accelerates as the temperature increases and becomes reduced as the solid fraction of lipids increases.

On the contrary, increase in hardness was seen in fondant products at storage temperatures of 30°C. Drying and subsequent hardening thus probably occurs in the products.

Storage temperatures of 6, 12 and 20°C were not clearly affecting the hardness of the products, with differences varying only in units of Newton. A significant process of softening thus does not occur under such conditions. A conclusion is also possible based on the study of Ali et al [10] that the migration of fats with rather lower melting points was very slow at storage temperatures of 18°C and the changes were minimal with respect to chemical composition, hardness, sheen and polymorphic stability.

Miquel et Hall [14] studied the migration of fat from chocolate product fillings using magnetic resonance imaging, with the samples stored at 20°C, 23°C and 28°C. Here the importance of storage temperature was clear with a distinct migration of fats occurring at 28°C as early as within 25 days, while at 23°C, the migration was in equilibrium even after two months. The slowest fat transition was observed for storage temperatures of 20°C. The authors also report that the products are sensitive not only to the presence of foreign fats in the chocolate, but also to the change in structure caused by their presence. Consequently, eutectic mixtures are usually formed by dissolving cocoa butter as foreign lipids migrate into the chocolate.

The results of this experiment therefore permit a conclusion that chocolate product storage temperature to 20°C is advisable with respect to hardness. Stortz et Maragoni [15] state that generally, finished chocolate products should be stored at 18°C to 20°C and under a relative humidity lower than 50%, without the access of light.

Conclusion

Advisable and not recommended storage conditions were assessed through each of the analysis as part of monitoring the effect of storage temperature and method of manufacture of chocolate confectionery on changes in the product quality. Clear results were achieved for the temperature mode of 30°C, with the sensory rating, measurement of colour and texture analysis confirming that this temperature is not appropriate, even in the short term, for storing the chocolate products analysed. Products were observed to worsen their sensory attributes and turn to abnormally bright colours. Their strength and hardness was also changing regardless of having been subjected to retempering. Storage temperatures of 20°C generally achieved good results in the measurement of both colour and texture, with however visible shortcomings being seen during sensory rating. Reflected here was also the impact of technology when the retempered products achieved better resistance to fat blooming. Temperature modes of 6°C and 12°C were comparable in all the analyses performed. For texture measurements of products stored at 6°C, the results were even more favourable. A comprehensive assessment is therefore possible that when stored at 6°C, the products retain their initial attributes even after ten weeks of the production date. As a result, the storage temperature to 12°C can be referred to as appropriate storage conditions for chocolate products.

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