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CHOCOLATES COM FRUTA DESIDRATADA E ESPECIARIAS: DESENVOLVIMENTO E CARACTERIZAÇÃO FÍSICA E SENSORIAL

CHOCOLATES WITH DRIED FRUIT AND SPICES: DEVELOPMENT AND PHYSICAL AND SENSORY CHARACTERIZATION

CHOCOLATES COM FRUTAS SECAS Y ESPECIAS: DESARROLLO Y CARACTERIZACIÓN FÍSICA Y SENSORIAL

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RESUMO

Introdução: O chocolate é um snack de grande conveniência e constitui um produto muito apreciado por todos os extratos da população. Investigações nos últimos anos têm demonstrado que o chocolate, principalmente o negro, pode ser benéfico para a saúde e a fortificação pode adicionar ao chocolate alguns benefícios para a saúde.
Objetivo: Pretendeu-se criar formulações para bombons enriquecidos com fruta e especiarias, que fossem atrativos para o consumidor.
Métodos: Foram testadas diversas combinações de ingredientes e analisados os produtos obtidos em cada experiência. Após a otimização das formulações, foram utilizadas as melhores receitas para produzir chocolates que foram avaliados por um painel sensorial não treinado, simulando o consumidor em geral. Foram realizados testes descritivos e de preferência, e avaliadas as intenções de compra. Além disso, as melhores receitas foram caracterizadas em relação a algumas propriedades físicas, como a cor, a textura e a reologia, por serem altamente influentes na aceitação do produto.
Resultados: Os resultados mostraram duas formulações ótimas: Chocolate de Leite com Maçã Verde e Canela, e Chocolate Negro com Maçã Verde e Hortelã. A amostra de chocolate negro apresentou uma cor mais escura (2,84±2,83, 7,54±0,12 e 4,78±0,88, respetivamente para L*, a* e b*), foi mais dura (72,04±19,42 N) e apresentou menor pegajosidade (-1,62±0,67 N) e adesividade (-20,69±5,22 N.s). As medições reológicas mostraram que a amostra de chocolate negro apresentou uma maior variação de viscosidade (25–88 mN.s/m²) quando aquecida a temperaturas entre os 50 e os 95 °C. A análise sensorial mostrou que o chocolate de leite obteve uma melhor aceitação geral e pontuações mais elevadas para a aparência visual, crocância e doçura. Em contrapartida, o chocolate negro era mais uniforme, mais duro, mais escuro, com um aroma a chocolate mais intenso e maior acidez. Embora o chocolate de leite tenha sido o preferido por 75 % dos jurados, estes manifestaram intenções de compra positivas para ambos os tipos de chocolate.
Conclusão: O estudo permitiu obter duas formulações que têm potencial para serem comercializadas com sucesso no mercado.

Palavras-chave: chocolate; maçã; canela; menta; análise sensorial; cor; textura; reologia

ABSTRACT

Introduction: Chocolate is a highly convenient snack and is a product that is highly appreciated by all segments of the population. Research in recent years has shown that chocolate, especially dark, can be beneficial to health and that fortification can add some health benefits to chocolate.
Objective: The aim was to create formulations for chocolates enriched with fruit and spices that would be attractive to the consumer.
Methods: Various combinations of ingredients were tested, and the products obtained from each experiment were analysed. After optimisation of the formulations, the best recipes were used to produce chocolates that were evaluated by an untrained sensory panel, simulating the general consumer. Descriptive tests and preference tests were performed, and purchase intentions were assessed. Also, the best recipes were characterized relatively to some physical properties, namely colour, texture and rheology, for being highly influential in the accpance of the product.
Results: Results showed two optimal formulations: Milk Chocolate with Green Apple & Cinnamon, and Dark Chocolate with Green Apple & Mint. The dark chocolate sample presented a darker colour (2.84±2.83, 7.54±0.12 and 4.78±0.88, respectively for L*, a* and b*), was harder (72.04±19.42 N) and with lower stickiness (-1.62±0.67 N) and adhesiveness (-20.69±5.22 N.s). Rheology measurements showed that the darker chocolate sample had a higher variation of viscosity (25–88 mN.s/m^2) when heated at temperatures between 50 and 95 °C. Sensory profile analysis showed that the milk chocolate had better global appreciation, and scored higher for visual appearance, crunchiness, and sweetness. Conversely, the dark chocolate was more uniform, harder, darker, with a more intense chocolate aroma and higher acidity. Although the milk chocolate was preferred by 75 % of the judges, they expressed positive purchasing intentions towards both types of chocolate.
Conclusion: This study allowed obtaining two formulations that have the potential to be successfully commercialised on the market.

Keywords: chocolate; apple; cinnamon; mint; sensorial analysis; colour; texture; rheology

RESUMEN

Introducción: El chocolate es un snack muy conveniente y es un producto muy apreciado por todos los segmentos de la población. Las investigaciones de los últimos años han demostrado que el chocolate, especialmente el chocolate negro, puede ser beneficioso para la salud y el enriquecimiento puede añadir algunos beneficios para la salud al chocolate.
Objetivo: El objetivo era crear formulaciones de dulces enriquecidos con frutas y especias, que fueran atractivos para el consumidor.
Métodos: Se probaron diversas combinaciones de ingredientes y se analizaron los productos obtenidos en cada experimento. Tras optimizar las formulaciones, las mejores recetas se utilizaron para elaborar chocolates que fueron evaluados por un panel sensorial no entrenado, simulando al consumidor general. Se realizaron pruebas descriptivas y de preferencia, y se evaluaron las intenciones de compra. Asimismo, las mejores recetas se caracterizaron en función de algunas propiedades físicas, como el color, la textura y la reología, por su gran influencia en la aceptación del producto.
Resultados: Los resultados mostraron dos formulaciones óptimas: chocolate con leche, manzana verde y canela, y chocolate negro, manzana verde y menta. La muestra de chocolate negro presentó un color más oscuro (2,84 ± 2,83, 7,54 ± 0,12 y 4,78 ± 0,88, respectivamente para L*, a* y b*), una mayor dureza (72,04 ± 19,42 N) y menor pegajosidad (-1,62 ± 0,67 N) y adhesividad (-20,69 ± 5,22 N·s). Las mediciones reológicas indicaron que la muestra de chocolate negro presentó una mayor variación de viscosidad (25–88 mN·s/m²) al calentarse a temperaturas entre 50 y 95 °C. El análisis sensorial reveló que el chocolate con leche obtuvo una mejor valoración general y una puntuación más alta en apariencia visual, textura crujiente y dulzor. Por el contrario, el chocolate negro era más uniforme, más duro, más oscuro, con un aroma a chocolate más intenso y mayor acidez. Si bien el chocolate con leche fue el preferido por el 75 % de los jueces, estos manifestaron una intención de compra positiva para ambos tipos de chocolate.
Conclusión: Este estudio permitió obtener dos formulaciones que tienen potencial para comercializarse exitosamente en el mercado.

Palabras clave: chocolate; manzana; canela; menta; análisis sensorial; color; textura; reologia

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INTRODUCTION

Chocolate is seen as a convenient snack and delightful treat, and its consumption has the potential to switch from a health risk to a positive functional food, depending on a number of factors, especially if it is dark chocolate. It can function as a delivery matrix for health-enhancing components, such as herbal extracts (Rajabi and Sedaghati, 2024). The development of products that are appreciated by consumers, while having some positive influences on health, assumes an important role in helping people consume foods that are not seen as enemies of a balanced diet. Incorporation of fruits, herbs and spices into food products increases their potential functional properties since they carry the beneficial component found in those sources.

Dark chocolate is made from cocoa liquor obtained from roasted cocoa beans, sugar and cocoa butter, but without the addition of milk. According to the European Union's Directive 2000/36/EC dark chocolate is defined as a product derived from cocoa that contains sugars and that has at least 35 % total dry cocoa solids, including a minimum of 18 % cocoa butter and 14 % dry non-fat cocoa solids (Rajabi and Sedaghati, 2024). The EU Directive 2000/36/EC stipulates the definition and composition of milk chocolate, which is a food product obtained from cocoa products, sugar and milk or milk products. Milk chocolate must have at least 25 % total dry cocoa solids; 14 % or more dry milk solids; 2.5 % at a minimum of dry non-fat cocoa solids; 3.5 % minimum of milk fat and 25 % at least of total fat (cocoa butter plus milk fat) (Glicerina *et al.*, 2016).

Dark chocolate has a dark brown colour, bitter taste and a characteristic chocolate smell. When consumed moderately, chocolate, especially dark chocolate due to its high cocoa content, has numerous benefits besides nutritional value, such as antioxidant or anti-inflammatory effects. Recent trends and research have focused on the utilisation of chocolate fortified with valuable substances of botanical origin, which act as therapeutic agents against some non-communicable diseases and contribute to longevity. These enhanced health properties are due to a variety of ingredients that have been used to fortify chocolate, including phenolic compounds, phytosterols, probiotics and prebiotics, fish oil, or spices such as cinnamon (Rajabi and Sedaghati, 2024).

The quantity of total phenolic compounds present in cocoa powder can be up to 50 mg per gram. Based on current evidence, it has been suggested that eating one portion of 20 g of dark chocolate every three days helps decrease the serum concentrations of C-reactive protein, thus reducing inflammation.

The amount of flavonoids present in a serving of chocolate is considerably higher when compared, for example, with a serving of red wine, apple, or tea. Flavonoids are known for their cardioprotective effect through immunoregulatory properties, by a positive role on the endothelium, and owing to antioxidant and antiplatelet activities (Behzadi *et al.*, 2024).

The enrichment of chocolate with fruits, spices and herbs constitutes a way to further enhance its benefits. Apple powder is a nutrient-rich product obtained from ground apples that have been dried through different processes, from hot air drying to atomisation. Apples are rich in polyphenols and polysaccharides, which have been reported as having a wide range of biological properties. The powder obtained from young apples demonstrated a brain-protective effect in an *in vivo* mice model (Fang *et al.*, 2012). It has also been reported that apple polyphenols have a protective effect against intestinal damage by a modulator effect on gut microbiota (Zhang *et al.*, 2022).

Cinnamon is a spice obtained from the inner bark of trees from the genus *Cinnamomum*. It is used mostly as an aromatic condiment and flavouring additive. Cinnamon contains a particularly active component, cinnamaldehyde, which might be responsible for some of the possible health benefits attributed to this spice. Some health benefits include accelerating metabolism and thus lowering the incidence of obesity, lowering blood sugar, and consequently reducing diabetes, as well as reducing cholesterol and improving cardiovascular health. Cinnamon also has an antioxidant effect due to its contents in polyphenols (Spence, 2024).

Mint is an umbrella name for several plants. It is a genus of plants in the mint family, *Lamiaceae*. This aromatic herb has a sweet menthol flavour and aroma and can be used fresh or dried for culinary preparations, tea, beverages, sauces, and many more. Mint leaves have phenolic compounds and have been reported to have antimicrobial, anti-inflammatory and anti-cancer properties (Shanmuganathan *et al.*, 2023; Soleimani *et al.*, 2022).

Despite the incontestable enhanced health benefits of enriched chocolate, there are some technological and quality challenges associated with the incorporation of different substances into the chocolate matrix. This is particularly relevant when it comes to the rheological characteristics of chocolate, which are pivotal quality attributes of physical nature, as well as the sensory attributes which determine consumer acceptance. The process of incorporating health-enhancing components into chocolate can have adverse effects on its desirable characteristics. Therefore, the whole process of development of new chocolate-based products must be accompanied by a sensorial evaluation. Food product design must be centred on the consumer and is undoubtedly influenced by the sensory preferences of future customers. These preferences include a multiplicity of senses: visual appeal, aroma, auditory cues, taste and tactile sensations (Li *et al.*, 2024).

The objective of this work was to develop new chocolate products incorporating apple powder, cinnamon and mint as a way to improve the nutritional and biological value of the chocolates while also guaranteeing their quality and consumer acceptance. For that, the products were formulated and tested by a sensorial panel to evaluate their acceptance. Also important physical properties were anayzed, namely colour, texture and rheology.

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1. EXPERIMENTAL

1.1 Preparation of the chocolates and formulation

For the development of the proposed new candy products, chocolate enriched with health-enhancing ingredients, different tests were carried out, testing different formulations with variable quantities of each ingredient. For each test, the resulting product was evaluated until the final recipes were achieved, corresponding to products with desirable organoleptic properties.

All ingredients were purchased in a local supermarket, and the chocolates were prepared in only one day for each test. For the tests, dark and milk chocolates from the brand *Nestlé* were used (70 % and 30 % cocoa, respectively), and the dehydrated apple chips were from the brand *Fruut*, in variations of green apple and red apple.

To prepare the chocolates, in all recipes tested, the chocolate was first melted at a temperature of 40 to 70 °C in a thermal bath, and then pieces of dehydrated apple and spices (mint and cinnamon) were added to the chocolates. After homogenising these ingredients, the chocolates were placed in silicone moulds and set to solidify. During the first tests, they were left to solidify in the refrigerator, which led to the formation of white spots that damaged their visual appearance. Therefore, in the following essay, the chocolates were left to solidify at room temperature.

In the first experiment, four recipes were made, all of them including red apple chips roughly triturated but varying in the type of chocolate and the spice used: two formulations for dark chocolate (one cinnamon and the other with mint) and two other formulations for milk chocolate (cinnamon and mint variations) (Table 1). The goal of this preliminary essay was to choose just two of the recipes (one for the milk chocolate and one for the dark chocolate).

After selecting the best among the two milk chocolates and the two dark chocolates prepared in the first experiment, a second experiment was conducted. For this, four more recipes were tested, increasing the quantities of spices. Therefore, the objective would be to choose the best proportion of the flavour-intensifying agent in the recipe for each of the chocolates. However, in this test, green apples were used, which are more acidic. As for the processing of the chocolates, the procedure was basically that described in the first essay, but the spices were added before removing the chocolate from the thermal bath so that their aromas could be extracted more easily, thus enhancing the aroma and flavour of the chocolates. The formulations are also presented in Table 1.

Table 1 – Formulations of the enriched chocolates

Essay	Formulation	Quantity (g)					
		Dark chocolate	Milk chocolate	Red Apple	Green Apple	Cinnamon	Mint
I	I-A (MCAC) Milk Chocolate with Apple & Cinnamon	—	48.87	3.85	—	0.45	—
	I-B (MCAM) Milk Chocolate with Apple & Mint		48.78	4.32	—	—	0.50
	I-C (DCAC) Dark Chocolate with Apple & Cinnamon	51.51	—	3.86	—	0.55	—
	I-D (DCAM) Dark Chocolate with Apple & Mint	50.31	—	3.65	—	—	0.55
II	II-A (MCAC1) Milk Chocolate with Apple & Cinnamon1	—	48.62	—	3.85	0.45	—
	II-B (MCAC2) Milk Chocolate with Apple & Cinnamon2		48.59	—	4.09	0.78	—
	II-C (DCAM1) Dark Chocolate with Apple & Mint1	50.60	—	—	3.65	—	0.55
	II-D (DCAM2) Dark Chocolate with Apple & Mint2	50.42	—	—	3.86	—	0.88
III	III-A (MCGAC) Milk Choc. with Green Apple & Cinnamon	—	48.28	—	3.87	0.52	—
	III-B (MCRAC) Milk Choc. with Red Apple & Cinnamon	—	49.35	3.86	—	0.52	—
	III-C (DCGAM) Dark Choc. with Green Apple & Mint	50.48	—	—	3.87	—	0.88
	III-D (DCRAM) Dark Choc. with Red Apple & Mint	50.50	—	3.89	—	—	0.89

For the 3rd test, based on the recipes chosen in the 2nd test, four recipes were prepared, in this case using both types of apple (Table 1). So, in the end, the objective would be to choose the recipe with the type of apple that is best combined with each type of chocolate. In this last test, the chocolates were solidified at room temperature to avoid the white spots that were appearing in the dark chocolates. From these four recipes, a basic sensorial screening would result in selecting only two of them, one for dark and another for milk chocolate, each with the type of apple that most seemed to suit the recipe, and these two formulations were those that would be used for the final sensorial analysis with the sensory panel. Hence, those two formulations were used on one final preparation, for the sensorial panel to test.

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Figure 1 shows the preparation of the samples and the chocolates produced in each of the experiments.

Figure 1 – Preparation of the samples and chocolates produced in each of the essays, aiming at the optimization of the formulations

1.2 Sensory evaluations

All sensorial tests were made on the day after the chocolates were produced.

For the preliminary tests (essays I and II), the sensory evaluations were made following basic observational procedures, and a reduced number of judges, only eight, evaluated the samples. For the third experiment, the products were submitted to a full sensory evaluation using an untrained panel composed of 16 judges aged from 18 to 69 years. Most of the members of the sensorial panel were women (n = 11, 69 %), and the lowest percentage were men (n = 5, 31 %).

The samples were coded with a random number before being presented to the judges, who did not know what type of chocolate they were testing or the formulation. The samples were evaluated by the panel members following the principles of sensorial analysis (Figure 2).

The sensory profile tests were made to each of the two finally selected samples independently, requesting to evaluate a number of product attributes using a scale from 1 to 5, where 1 was the lowest and 5 was the highest score of intensity for each attribute. The product characteristics evaluated were: visual aspect (from 1 = very bad to 5 = very good), colour (from 1 = very clear to 5 = very dark), uniformity of the apple pieces (from 1 = nothing uniform to 5 = very uniform), texture (from 1 = very soft to 5 = very hard), crunchiness of the whole chocolate (from 1 = nothing crunchy to 5 = very crunchy), crunchiness of the apple pieces (from 1 = nothing crunchy to 5 = very crunchy), aroma to chocolate (from 1 = nothing intense to 5 = very intense), aroma to spice (from 1 = nothing intense to 5 = very intense), sweetness (from 1 = very bitter to 5 = very sweet), acidity from 1 = nothing intense to 5 = very intense), global appreciation (from 1 = not like at all to 5 = like very much).

After that, the judges were questioned about purchasing intentions, with the following answering options: a) I would certainly buy this product; b) I would probably buy this product; c) I have doubts whether I would buy this product; d) I probably wouldn't buy this product; e) I certainly wouldn't buy this product.

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The other sensorial test performed was the preference test, in which the judges had to indicate the sample they preferred from the two types of chocolate analysed.
Appendix 1 shows the forms for the sensorial analysis used, sensory profile test and preference test.

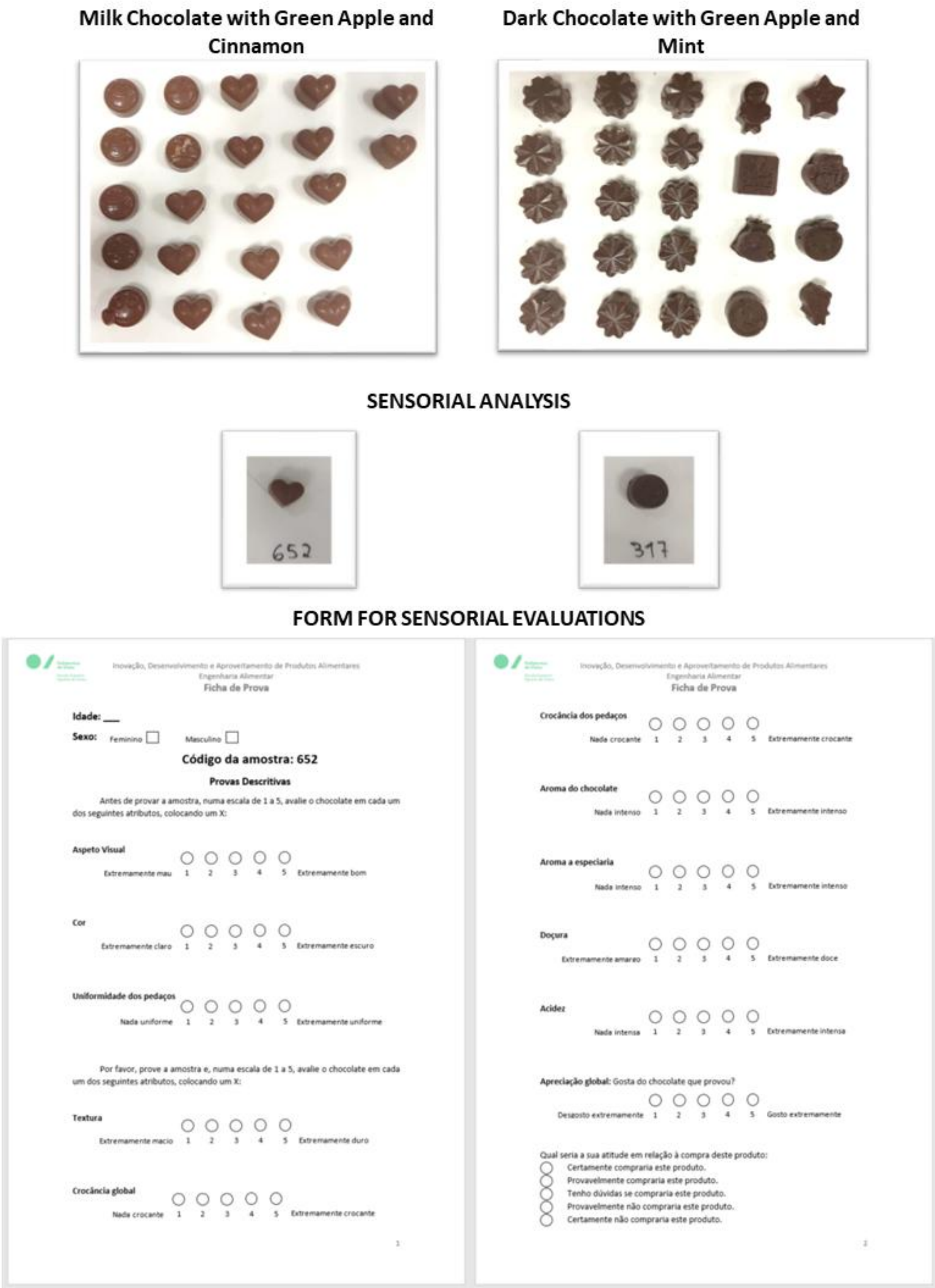

Figure 2 – Final chocolate formulations for sensorial evaluation (forms for sensorial evaluation are given in detail in Appendix A.1 and A.2)

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1.3 Analysis of physical properties

For the development of the proposed new candy products, chocolate enriched with health-enhancing ingredients, different tests were carried out, testing different formulations with variable quantities of

To perform the physical characterization only the two best formulations were used: Milk Chocolate with Green Apple & Cinnamon (MCGAC) and the Dark Chocolate with Green Apple & Mint (DCGAM).

For the analysis of physical properties, the chocolates were produced in moulds that allowed obtaining rectangular shapes for uniform dimensions. The chocolate pieces were parallelepipeds with 2,5x3,0 cm wide and 0,7 cm thick.

To measure moisture content was used a Halogen Moisture Analyser (model HG53, from Mettler Toledo: Columbus, Ohio, USA) with operation parameters set at 120 °C and rate 3 (medium). For each of the chocolate types the samples were previously grinded and 4 replications of the analysis were made. Then the mean value and standard deviation were calculated.

For evaluation of colour, was used a Colorimeter CR-400 (Konica Minolta, Inc.: Chiyoda, Tokyo, Japan), calibrated with a white standard tile and using a CIE standard illuminant D65. This equipment evaluates the three colour coordinates in the Cartesian CIELab space. The L* coordinate quantifies the lightness variation, ranging from 0 (black) to 100 (white). The opposed colour coordinates are a* and b*, which range from –60 to +60. The coordinate a* represents green colour for negative values and red for positive values, while b* represents blue and yellow for negative and positive values, respectively (Gómez-Polo *et al.*, 2016; Guiné *et al.*, 2019; Lopes *et al.*, 2016). These Cartesian coordinates were then used to calculate the polar or cylindrical coordinates: H° representing the hue angle, C the Chroma, and V the value, as defined by equations (1) and (2) (Guiné & Barroca, 2012):

$$\begin{cases} H^\circ = \text{arctg}\,(b^*/a^*), \text{ for } a^*>0\ ;\ b^*>0 \\ H^\circ = 180^\circ + \text{arctg}\,(b^*/a^*), \text{ for } a^*<0\ ;\ b^*>0 \\ H^\circ = 270^\circ + \text{arctg}\,(b^*/a^*), \text{ for } a^*<0\ ;\ b^*<0 \\ H^\circ = 360^\circ + \text{arctg}\,(b^*/a^*), \text{ for } a^*>0\ ;\ b^*<0 \end{cases} \quad (1)$$

$$C = \sqrt{(a^*)^2 + (b^*)^2} \quad (2)$$

$$\text{Value} = L^* / 10 \quad (3)$$

The value of Chroma represents the colour purity, intensity or saturation, while the Hue angle represents the colour itself, varying around a 360° circle. Value is similar to L*, varying from black (V = 0) to white with (Value = 10).

For the colour analysis, eight chocolate samples of each of the two final formulations were used, and then mean values and standard deviation were calculated.

For evaluation of texture, the chocolate samples were left in the stove for 2 hours at a constant temperature of 25 °C for uniform consistency when analysing texture. The samples were removed from the stove and immediately placed on the texturometer plate for analysis. For textural analysis was used a texturometer TA.XT.Plus (Stable Micro Systems: Godalming, Surrey, UK) equipped with a 500 N load cell. Four repetitions were made for each final product, i.e., eight chocolate squares of each of the two chocolate variations. The test used was cutting the sample using a Blade Set HDP/BS (Warner- Bratzler) probe. The pre-test and test speeds were 1.0 mm/s and the post-test speed was 10.0 mm/s. For this test the cutting distance was 30 mm, ensuring the integral cut of the sample, and the trigger force was 0.15 N. The obtained curve of force *versus* distance allowed calculating two textural properties: firmness (force at first peak), stickiness (force at lowest negative peak) and adhesiveness (area of the negative part of the curve (Figure 3).

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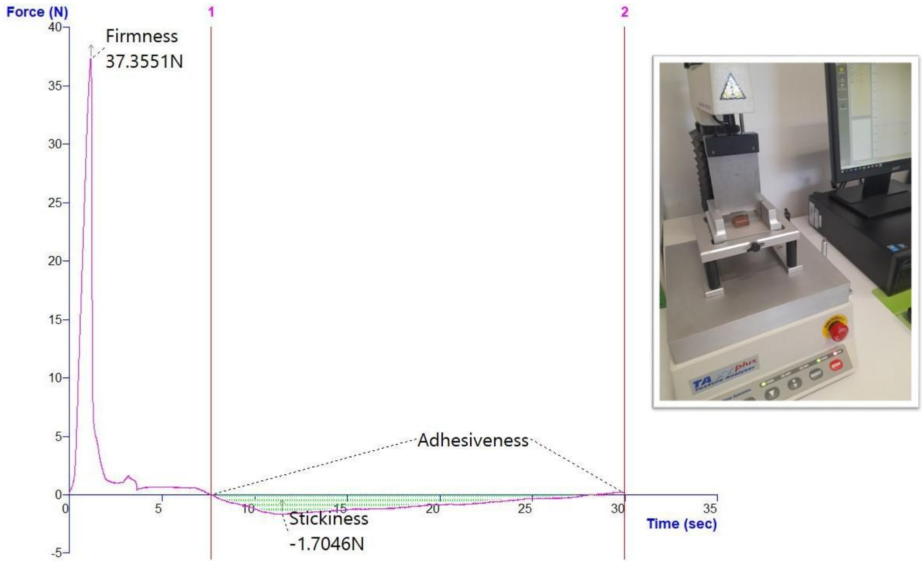

Figure 3 – Evaluation of texture

For analysis of viscosity the samples, a Rapid Viscosymeter Analyser – RVA 4500 was used (Perkin Elmer: Waltham, Massachusetts, USA). By definition, the RVA is a heating and cooling viscometer that measures the viscosity of a sample over a given period of time while it is stirred (Balet *et al.*, 2019). This equipment allows analysing viscosity of samples on a continuous base with a temperature-varying program, thus registering the effect of temperature on the viscosity of the samples. For the analyses, 10 g of each sample previously grinded were added to equal volume of water, and the tests were performed according to the plan listed in Table 2, adapted from Spada et al. (2020). Figure 4 shows one graph obtained with the RVA for a chocolate sample.

Table 2 – Program used to perform the viscometry analyses with RVA

Time (HH:mm:ss)	Function type	Value[1]
00:00:00	Temp	50
00:00:00	Speed	960
00:00:10	Speed	160
00:01:00	Temp	50
00:08:00	Temp	95
00:14:00	Temp	95
00:20:30	Temp	50
00:22:00	Temp	50
00:22:30	END	

[1] The values are in different units according to function: temperature is in °C and speed is in rpm.

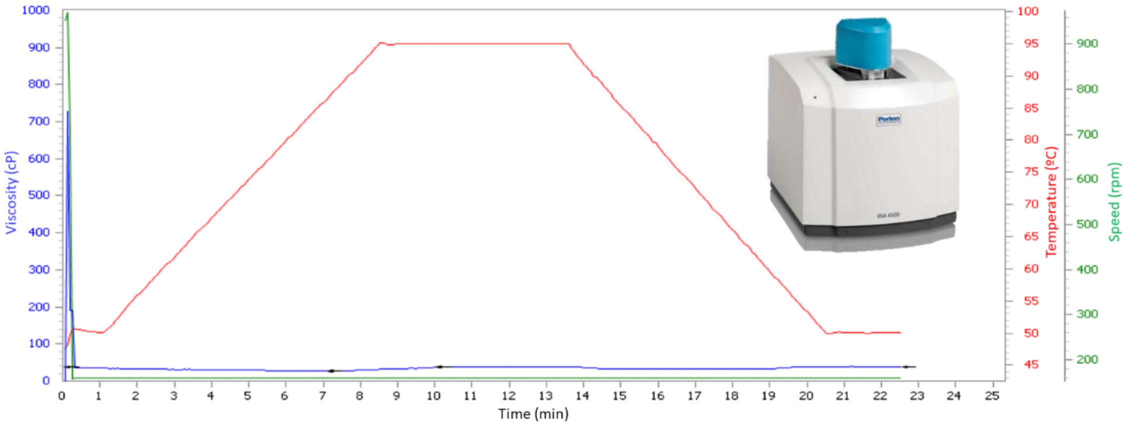

Figure 4 – Viscometry analysis with RVA

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2. RESULTS

2.1 Evaluation of the chocolates in preliminary tests

The chocolates produced in the different trials until the desired formulation was obtained were evaluated, and the main observations are presented in Table 3. Regarding the four formulations produced in the Essay I, it was observed that cinnamon matched well with milk chocolate while mint best fit the dark chocolate combination. Furthermore, it was concluded that in the next test, it would be necessary to add the cinnamon and mint when the chocolate was still in the thermal bath so that the aromas of these spices would be more easily released with the higher temperature to spread all over the chocolate. It was further concluded that the amount of spice would have to be slightly increased to be more perceptible, particularly for mint. Based on these evaluations, the Apple & Cinnamon Milk Chocolate and the Apple & Mint Dark Chocolate recipes were selected to be improved in the following tests. As for the visual aspect, there were some whitish spots on the dark chocolates, possibly due to the fact that they were placed in the refrigerator to solidify.
In what concerns the evaluation of the samples in Essay II (Table 3), in both original recipes, i.e., without increasing the amount of spice mint or cinnamon), a difference could be noted in relation to the previous essay concerning the increase in the intensity of the aromas of the spices. This confirms that the early addition of the spices, while the chocolate was still melting in the thermal bath, proved to be positive in terms of the diffusion of these components throughout the chocolate. However, while this increase was positive for the mint, the cinnamon resulted in a too-strong flavour that was not appreciated. Furthermore, in general, by replacing the red apple with the green apple, it was confirmed that the flavour of the chocolates became more intensified and more acidic in a pleasant way. As such, based on the obtained results for the four formulations, the milk chocolate 1 (original recipe from the previous essay) and dark chocolate 2 (recipe with an increased amount of mint) were chosen for the 3rd test. In visual terms, the dark chocolates again showed whitish spots, which visually impaired the appearance of the chocolates. In this sense, in the last essay, the chocolates would not be placed in the refrigerator to solidify; they would solidify at room temperature.
In the formulations of Essay III, the proportions of the ingredients were similar between the two milk chocolates, just varying the green or red apple, and were also similar between the two dark chocolates, again just varying the type of apple. After carrying out these experiments with both types of apple, it was observed that using the green apple brought more harmony to the different aromas present in the chocolate and greater acidity, especially in the milk chocolate, and these features enhanced the positive evaluation of the chocolates (Table 3). On the other hand, using the red apple turned the chocolates too sweet and more nauseating. Visually, with the solidification of the chocolates at room temperature, there was a significant improvement in the visual appearance, reducing the white spots that appeared in previous tests. Based on these results, it was concluded that the best formulations were the Milk Chocolate with Green Apple & Cinnamon and the Dark Chocolate with Green Apple & Mint, and therefore, these two were chosen as final products to be evaluated by the judges on the following sensorial analysis. For the preparation of these chocolates, the quantities shown in Table 1 were increased four times, but all relative proportions were maintained so as to prepare enough chocolate for all tasters.

Table 3 – Sensory perceptions about the chocolates produced until reaching the desired formulation

Essay	Formulation	Observations
I	I-A (MCAC) Milk Chocolate with Apple & Cinnamon	Chocolate with a balanced composition, pleasant to the taste
	I-B (MCAM) Milk Chocolate with Apple & Mint	In this chocolate the mint flavour was not perceptive
	I-C (DCAC) Dark Chocolate with Apple & Cinnamon	Chocolate with too much cinnamon, that was not beneficial for the whole flavour composition when with dark chocolate
	I-D (DCAM) Dark Chocolate with Apple & Mint	The mint flavour was not very well perceived within the chocolate sample, but nevertheless a good match between the mint and the dark chocolate was observed
II	II-A (MCAC1) Milk Chocolate with Apple & Cinnamon1	The combination of ingredients in this chocolate was balanced; the cinnamon aroma was very well perceived but in a pleasant way; the utilisation of green apple turned the chocolate slightly acidic, but pleasant; the crunchiness of the whole chocolate was increased
	II-B (MCAC2) Milk Chocolate with Apple & Cinnamon2	Formulation with unbalanced harmony between the ingredients, especially the chocolate with the cinnamon; too much cinnamon flavour and aroma; the increased acidity was not so beneficial in this case; the crunchiness also increased but just slightly
	II-C (DCAM1) Dark Chocolate with Apple & Mint1	Chocolate too hard; the mint flavour was improved; the acidity of the green apple was more perceptible
	II-D (DCAM2) Dark Chocolate with Apple & Mint2	Chocolate with a good balance between the chocolate and mint flavour (taste and aroma); the mint was more perceptible turning the combination more pleasant; the chocolate was not so crunchy
III	III-A (MCGAC) Milk Choc. with Green Apple & Cinnamon	Perfect equilibrium of flavours; the acidity of the green apple was positive to the mixture; very crunchy chocolate; formulation much appreciated
	III-B (MCRAC) Milk Choc. with Red Apple & Cinnamon	Due to the utilisation of the red apple the chocolate became too sweet, especially in the context of a milk chocolate; combination not appreciated
	III-C (DCGAM) Dark Choc. with Green Apple & Mint	Perfect flavours equilibrium; very smooth with a soft moisty texture; freshness sensation; valued acidity resulting from the green apple
	III-D (DCRAM) Dark Choc. with Red Apple & Mint	Moisty texture; good intensity of the mint aroma; the red apple by being more sweet did not stand out in the set

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2.2 Sensorial analysis of the final chocolate samples

Each Each one of the two chocolate samples had a code, which was used to identify the sample in the corresponding sensory test score sheet. The following attributes were analysed, all on a 5-point scale: visual appearance, colour, uniformity of the apple pieces, texture, crunchiness of the whole chocolate, crunchiness of the apple pieces, chocolate aroma, spices aroma, sweetness, acidity, and global appreciation. Table 4 presents the scores given by each of the 16 judges for the attributes evaluated for both samples. The results 3 show that the number of maximum scores attributed to both samples was similar, with 24 scores of 5 for sample 652 (Milk Chocolate with Green Apple & Cinnamon) and 23 scores of 5 for sample 317 (Dark Chocolate with Green Apple & Mint). Regarding the minimum score of 1, sample 652 (Milk chocolate-cinnamon) got just a few, six, while sample 317 (Dark chocolate-mint) got even less, only four. In terms of visual aspect Table 4), eight judges found the milk chocolate/cinnamon sample good, and five found it very good (scores 4 and 5, respectively), while seven judges found the dark chocolate/mint sample good and three very good (scores 4 and 5, respectively). Hence, the judges liked the milk chocolate more.

Regarding colour, for the milk chocolate sample, only one judge gave the highest score (5 = very dark), while for the dark chocolate sample, three judges considered it very dark. Also, there were many more judges giving a score of 4 = dark to the dark chocolate sample than for the milk chocolate sample (six and ten judges, respectively. Concerning the uniformity of the apple pieces, the judges considered more uniform the dark chocolate sample (seven judges gave a maximum score – extremely uniform) than the milk chocolate sample (five judges gave a maximum score for uniformity).

Regarding texture, the results were very similar for the two samples, with ten judges considering the milk chocolate hard and three considering it very hard, while for the dark chocolate, eleven judges scored it as hard and two very hard. With respect to the crunchiness of the whole chocolate sample, the milk chocolate was considered more crunchy (eight judges gave a score of 4 and four judges gave a score of 5), while the dark chocolate was less crunchy (six and three judges gave scores 4 and 5, respectively). In regards to the crunchiness of the apple pieces, again, the milk chocolate was evaluated as having more crunchy apple chips than the milk chocolate (four judges considered the milk chocolate very crunchy, and ten judges considered it crunchy, as compared to two and seven judges, respectively, for the dark chocolate).

Table 4 – Scores attributed by the judges to the product attributes evaluated in the descriptive test (scale from 1 – least intense to 5 – most intense)

Sensorial attributes	Number of the Judge															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sample 652[(1)]																
Visual appearance	3	4	5	3	5	4	5	4	4	4	4	5	3	4	4	5
Colour	3	3	4	3	4	2	4	2	4	4	4	3	3	3	3	5
Uniformity of apple pieces	4	4	3	3	4	3	3	2	3	3	3	5	3	4	4	-
Texture	2	3	3	3	2	4	3	4	2	3	3	3	3	3	4	3
Crunchiness of whole sample	3	4	4	5	4	5	4	4	4	4	3	4	3	3	5	5
Crunchiness of the apple pieces	4	4	4	5	4	4	4	4	4	5	4	4	3	3	5	5
Chocolate aroma	4	2	2	5	4	3	3	3	4	3	3	4	2	3	5	4
Spices aroma	4	3	2	5	4	4	3	1	4	4	2	4	2	4	2	3
Sweetness	4	2	5	3	5	4	3	4	3	5	4	3	3	3	3	2
Acidity	3	4	1	2	1	3	2	1	1	3	3	2	2	2	3	1
Global appreciation	5	4	4	4	4	4	4	3	-	3	3	4	3	3	5	5
Sample 317[(2)]																
Visual appearance	3	5	4	3	4	3	4	4	5	3	4	3	4	3	4	5
Colour	4	4	4	3	4	4	5	4	5	3	4	5	4	4	4	3
Uniformity of apple pieces	4	4	3	3	4	4	3	3	5	4	3	3	3	4	3	4
Texture	4	4	4	3	4	3	4	4	4	5	4	5	4	4	4	3
Crunchiness of whole sample	4	2	3	5	4	3	4	3	3	3	4	5	4	2	4	5
Crunchiness of the apple pieces	3	2	3	5	4	3	4	4	4	3	4	5	4	2	3	4
Chocolate aroma	5	3	4	5	4	4	3	4	4	4	4	5	2	2	4	2
Spices aroma	3	1	3	5	5	2	3	4	4	1	3	3	3	4	3	3
Sweetness	2	3	3	3	2	3	1	3	3	3	4	2	2	3	3	3
Acidity	4	2	3	2	3	5	3	4	1	4	2	2	3	3	2	2
Global appreciation	5	4	5	4	2	-	4	2	-	4	4	2	2	3	4	5

(1) Sample 652 was the blind code for milk chocolate with green apple and cinnamon.
(2) Sample 317 was the blind code for dark chocolate with green apple and mint.

Table 4 also shows the results for aroma. In this regard, the chocolate aroma was found to be stronger in the dark chocolate (three judges gave a score of 5 and eight judges gave a score of 4), while for the milk chocolate, a lower number of judges gave high scores (two judges scored 5 and five judges scored 4). With respect to the spice aroma, the cinnamon used in the milk chocolate was more intense (one judge scoring 5 and seven scoring 4) than the mint used in the dark chocolate (two judges scoring 5 and three scoring 4), even though this last was used in higher dosage.

In what concerns sweetness, the milk chocolate was evaluated as being sweeter than the dark chocolate (three judges scored the milk chocolate as sweet and only one scored the dark chocolate as sweet). None of the judges considered any of the samples as very sweet. Concerning the acidity, although this derives from the addition of the green apple, its effect on the chocolate composition is different. In fact, the acidity was rated higher in the dark chocolate (one judge scored 5 and three judges scored 4)

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than in the milk chocolate (zero judges scored 5 and only one judge scored 4). Finally, the results for global appreciation (Table 4) showed that the results were very similar for both types of chocolate (zero judges scoring 5 = like very much, and three scoring 4 = like, making these results equal for both samples).
The values of the scores given by all the judges were used to calculate an average score for each attribute being these mean values represented in the graph in Figure 5 for both samples. The results show that the milk chocolate was preferred for visual appearance (mean score = 4.13), for crunchiness of the whole sample and of the apple pieces (mean values of 4.00 and 4.13, respectively), for sweetness (mean = 3.50), and for global appreciation (mean = 3.87). The dark chocolate sample was considered darker (mean = 4.00), more uniform (mean = 3.56), harder (mean = 3.94), with a more intense aroma to chocolate (mean = 3.69), and with higher acidity (mean = 2.81).

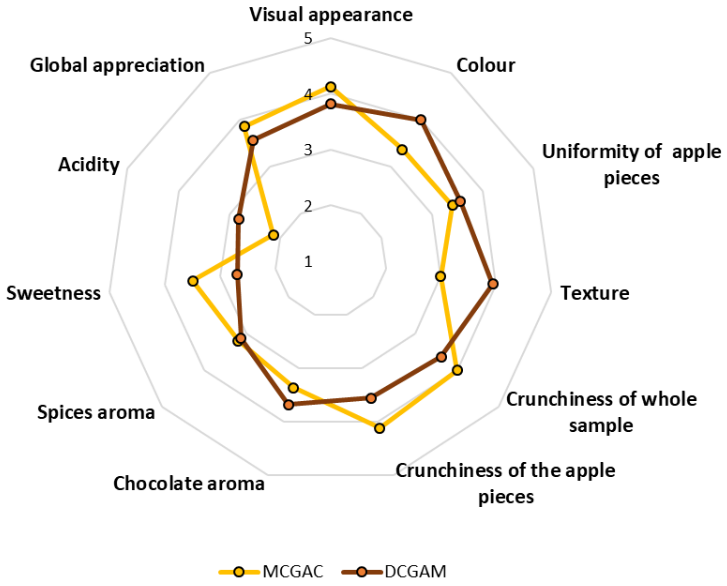

Figure 5 – Average scores obtained for the sensorial analysis (MCGAC = Milk Chocolate with Green Apple & Cinnamon; DCGAM = Dark Chocolate with Green Apple & Mint)

The preference test consisted of asking which one of the two samples the judges preferred. The results showed that 75 % (n = 12 judges) preferred the Milk Chocolate with Green Apple & Cinnamon, and 25 % (n = 4) preferred the Dark Chocolate with Green Apple & Mint. Hence, the milk chocolate was the choice for most of those who tasted both types of chocolate.
After evaluating the two chocolate samples, the judges were asked to indicate their purchasing intentions towards each of them, and the results are shown in Figure 6. The results showed that 56 % of the judges who tasted the Milk Chocolate with Green Apple & Cinnamon would probably buy and 25 % would certainly buy it. As for the Dark Chocolate with Green Apple & Mint, 44 % would buy this product, and 31 % would certainly buy it.

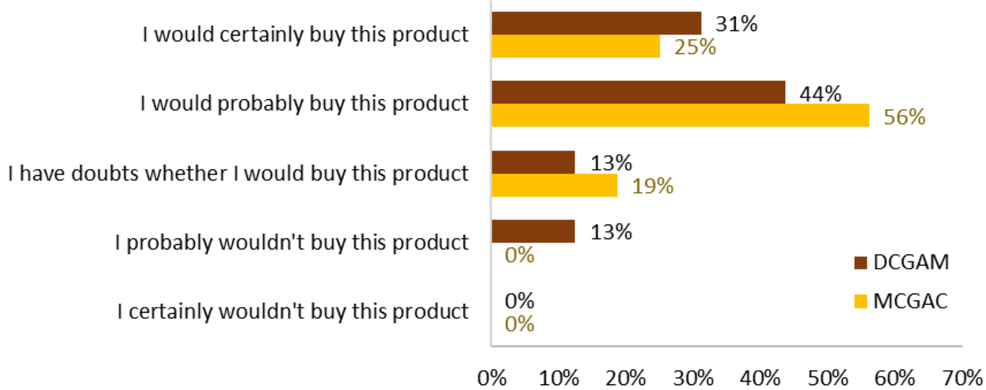

Figure 6 – Purchasing intentions (MCGAC = Milk Chocolate with Green Apple & Cinnamon; DCGAM = Dark Chocolate with Green Apple & Mint)

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2.3 Physical properties

The mean values of moisture content were 0.723 ± 0.045 % for the Milk Chocolate with Green Apple & Cinnamon, and 0.580 ± 0.175 % for the Dark Chocolate with Green Apple & Mint. Both these values are very low indicating that both chocolate samples prepared were very stable and moisture free.

Table 5 shows the colour coordinates (Cartesian coordinates L*a*b* and cylindrical coordinates Chroma and Hue°) as well as the textural properties of the chocolate samples. The coordinate L* (lightness) was lower (22.84 ± 2.83) for the dark chocolate sample, DCGAM, corresponding to a value closer to zero (black), while the milk chocolate sample, MCGAC, had a higher value (36.70 ± 1.20), i.e., closer to 100 (white).

Table 5 – Colour and texture properties of the chocolates

Physical properties	Milk Chocolate with Green Apple & Cinnamon (MCGAC)[1]	Dark Chocolate with Green Apple & Mint (DCGAM)[1]
	Cartesian colour coordinates	
L*	36.70 ± 1.20[a]	22.84 ± 2.83[b]
a*	12.86 ± 0.26[a]	7.54 ± 0.12[b]
b*	11.48 ± 0.84[a]	4.78 ± 0.88[b]
	Cylindrical colour coordinates	
Value	3.67 ± 0.12[a]	2.28 ± 0.28[b]
Chroma	17.24 ± 0.74[a]	8.96 ± 0.43[b]
Hue (°)	41.70 ± 1.58[a]	32.15 ± 5.02[b]
	Texture properties	
Firmness (N)	53.55 ± 11.78[a]	72.04 ± 19.42[b]
Stickiness (N)	−2.46 ± 1.17[a]	-1.62 ± 0.67[b]
Adhesiveness (N.s)	−21.27 ± 4.18[a]	-20.69 ± 5.22[b]

[1]Values in the same line with different supperscript letters are significantly different (T-test for independent samples, $p < 0.05$).

Regarding the opposed colour coordinate a* (Table 5), both values are positive indicating a red colouration (as opposed to green for negative values), with higher value for the milk chocolate sample than for the dark chocolate sample (12.86 ± 0.26 and 7.54 ± 0.12, respectively). With respect to the other opposed colour coordinate, b*, again both values are positive indicating a yellow colour predominance over blue (for negative values), with the higher value being again for the milk chocolate sample (11.48 ± 0.84). The Chroma was higher for the milk chocolate sample, indicating a higher purity of the colour, and the hue angle was also higher for the milk chocolate sample, indicating a different tone of brown.

In what concerns the textural properties of the samples (Table 5), the dark chocolate sample, DCGAM, had higher hardness (72.04 ± 19.42 N) and lower stickiness and adhesiveness, i.e., corresponding to lower absolute values (-1.62 ± 0.67 N and -20.69 ± 5.22 N.s). These results indicate that the dark chocolate sample was harder and more brittle than the milk chocolate which was softer and more creamy.

Figure 7 shows the maximum and minimum values of the viscosity of the chocolate samples, as they were submitted to variable temperatures in the range from 50 °C to 95 °C (temperature cycle as shown in Table 2). Since chocolate dos not have a Newtonian behaviour, the values obtained correspond to apparent viscosity. Both samples showed very similar values of apparent viscosity, but the dark chocolate sample presented just a slightly higher range, varying from minimum of 25 to a maximum of 88 $mN.s/m^2$, while the range for the milk chocolate sample was slightly lower (27 to 83 $mN.s/m^2$).

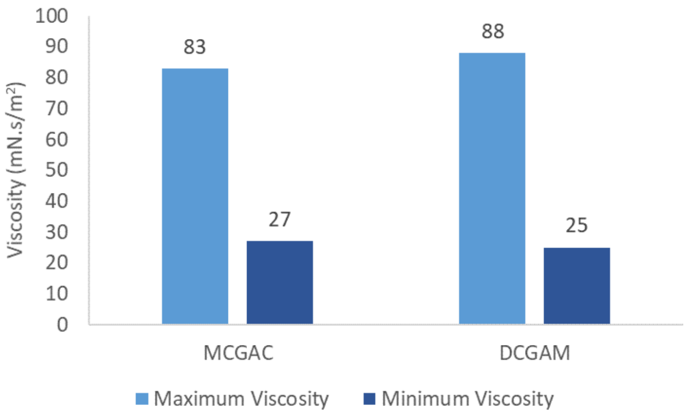

Figure 7 – Minimum and maximum values of viscosity of the chocolate samples (MCGAC = Milk Chocolate with Green Apple & Cinnamon; DCGAM = Dark Chocolate with Green Apple & Mint)

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3. DISCUSSION

Eating chocolate can evoke positive and negative emotions at the same time, creating desire and conflicting emotions. On one hand, its consumption can be interpreted as a delight, but on the other hand, it can be perceived as a threat. Desires can have a positive impact on human behaviour, but the desire to eat chocolate, which can arise even when there is no hunger, can lead to unbalanced consumption. Also, because chocolate may disrupt appetite regulation, there is a risk of not consuming enough of other essential and nutritive-rich foods. Therefore, chocolate consumption has to be balanced in order to benefit from the positive impacts it can have (Kaan and van Kleef, 2024). A study by Sun et al. (2010) examined a possible link between chocolate consumption and mortality (all-cause and cause-specific). The study included nearly 85 thousand postmenopausal women who were followed for a period of 20 to 30 years until 2018. The women at baseline were free from cardiovascular diseases and cancer. They observed that moderate consumption of chocolate of 1 to 3 servings per week contributed to a diminished incidence of mortality attributed to all causes, specifically cardiovascular disease and dementia. On the other hand, no relation was found between chocolate consumption and cancer.

Chocolate has some components in its composition that can have beneficial as well as harmful effects on the human body. For example, sugars have a negative impact on the body. They increase blood glycaemia and may lead to diabetes when consumed in excess. Type 2 diabetes incidence was seen to be higher in unhealthful food environments (Feyissa *et al.*, 2024). However, the chocolate industry has accompanied the need for developing healthier formulations as a way to cope with healthful consumption. A review by Selvasekaran & Chidambaram (2021) highlights the advances in chocolate formulations to obtain low-fat/fat-free and low-sugar/sugar-free chocolates as a way to respond to the consumers' demand for healthier foods. Nowadays, the variety of reduced fat and reduced sugar chocolate products offered to the consumer is increased, and these differ from each other in various qualities including taste, flavour, texture, and appearance.

Besides some less healthy substances in chocolate, it also contains beneficial components, such as stearic acid, phenolic compounds and flavonoids in particular (Sun *et al.*, 2010). Stearic acid, despite being a saturated fat, does not appear to increase cholesterol and seems to be associated with a decrease in the risk of heart disease, cardiovascular disease and cancer (Senyilmaz-Tiebe *et al.*, 2018). A review by Behzadi et al. (2024) on the consumption of cocoa and dark chocolate and their relation with oxidative stress and inflammation highlights that their contents of polyphenols and flavonoids have the potential to reduce oxidative stress and inflammation, thus being beneficial for many chronic diseases. However, the positive role of cocoa as an antioxidant and anti-inflammatory needs to be further established.

According to Dias (2025) chocolate is a very versatile ingredient in food preparations, and is a part of the cultural and gastronomic background of Portugal, where it has been reported since the 17th century in a high number of document, including a privileged source, which was the first cookbook printed in Portugal. The historical relevance of chocolate for the Portuguese is directly linked with the era of the discoveries, where Portuguese ships brought cocoa from Brazilian plantations.

Consumer acceptance of new food products is pivotal when these products are launched on the market. For this reason, food companies need to include sensory evaluations and consumer studies in their product development programs. New foods have a considerable probability of failure at the commercialisation stage. Therefore, to improve the chances of success, companies need to implement a consumer-oriented approach to product development that emphasises the significance of an optimal match between consumers' needs and/or desires and the new food product. This can be achieved by food professionals through the generation and use of a wide variety of consumer data. These include sensorial evaluations and consumer studies about preferences and buying intentions (Horvat *et al.*, 2019). In this way, the utilisation of these tools to assess the consumer attitudes and perceptions about the new chocolate products developed fall into these recommendations and is a factor possibly leading to success. The present research used sensorial analysis to evaluate the chocolate formulations under study, by means of an untrained panel, simulating the actual consumer. Also semi-trained or trained panels can be used to assess the sensorial properties. This practice is frequent in testing several types of foods, and particularly chocolate-based products (Ku and Liu, 2024; Marchioretto *et al.*, 2024; Souza *et al.*, 2024; Tosif *et al.*, 2025).

Physical properties such as colour and texture are pivotal for product acceptance at first glance. Colour impacts people's moods, stimulates their minds and influences how they feel about the products (Lin and Au, 2025). According to Singh (Singh, 2006) up to 90 % of people's decisions are based solely on colour. Colour also plays a key role in the context of healthy food purchasing and consuming, based, for example, in the traffic light system to design nutritional labels indicating food healthiness (Lin and Au, 2025). In the case of chocolate. Colour is also a pivotal physical property, greatly impacting consumer acceptance and preference. According to Briones et al. (2006) texture and colour are related in what comes to the surface of chocolates, The surface structure of chocolate, such as roughness or gloss, impacts the way light behaves when hitting the surface, changing reflectiveness and colour visualization. This seems to play a decisive role in visual quality appearance. Blooming or the migration of fat from the inside of chocolate to the surface produces colour changes and the development of non-uniform colour patterns, that are detrimental to the consumer perception (Briones and Aguilera, 2005).

Texture significantly influences product acceptance by impelling consumer perceptions of quality, value, and emotional connection. The textural properties are intrinsically connected with sensory experiences that can enhance or reduce a product's appeal, thus being crucial when designing new food products. Texture corresponds to the sensorial and functional manifestation of the food's properties on the structural and mechanical levels, and is detected by humans through several senses, like touch, audition and vision (Jaworska and Hoffmann, 2008). According to Jeltema et al. (2015) individuals show preferences towards mouth behaviour, corresponding to the ways they handle food in their mouths. On the other hand, this mouth behaviour has a great impact on food choice, satisfaction, and the desire to buy the product after a first contact. Mouth Behaviour is, according to

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these authors (Jeltema *et al.*, 2015) one of the major drivers of food selection product choice, while texture itself is a secondary factor, being important only as a support to the primary driver, which is mouth behaviour. Other authors, on the other hand, identify texture as a major trend in product development due to its great impact in food choice and in product rejection as well (Baylan and Ozilgen, 2025; Jeltema *et al.*, 2015, 2017; Meullenet, 2004).

Rheology and texture of chocolate are important properties frequently evaluated in foods products such as chocolate. Yang et al. (2025) evaluated structure of chocolate by scanning electron microscopy (SEM) and rheology by oscillatory sheer deformation using a rheometer, and reported the viscoelastic behaviour of chocolate samples containing different proportions of oleogel. They observed that, when chocolate products are under large stresses, they easily reach the yield strain point, starting from there the viscoelastic-plastic phase. Melted chocolate is a multiphase system where cocoa butter (possibly also mixed with other fats) constitutes a continuous phase in which are dispersed some particles of solid cocoa and perhaps sugars and milk powder as well. The rheology of such a concentrated suspension is highly complex and is of the highest importance for subsequent processing like moulding or coating (Rohm *et al.*, 2018). Monteiro et al. (2024)presented a fast and economic method to measure chocolate viscosity, using a rheometer and two different techniques. They fund that, while one of the proposed models correlated inversely with the Casson model for plastic viscosity, the other correlated positively. In conclusion they were able to find two expedite and cheap models to determine chocolate viscosity, particularly useful for industrials. Laličić-Petronijević et al. (2015) evaluated the rheological properties of different chocolate samples containing probiotics and they found that dark chocolate presented lower values of all determined rheological parameters, including the plastic viscosity and the apparent viscosity, when compared to milk chocolate. This behaviour was explained by a high-fat content that coats the solid particles in the dark chocolate and makes it easy to start a flow (yield stress), as well as to continue the flow (plastic viscosity) of chocolate mass. A similar work was published by Laličić-Petronijević et al. (2017) whose primarily main was to investigate the effects of probiotics on the sensory and rheological properties of different chocolates. Their results indicated that the use of probiotics did not have a significant impact on the rheological properties of the chocolates. Ardakani et al. (2014) evaluated the rheology of milk chocolate at different temperatures by using parallel-plate and capillary flow. They reported that for temperatures higher than 30 °C, chocolate behaves as a visco-elasto-plastic liquid, described by a Herschel–Bulkley viscoplastic model with a little of thixotropy. Also De Graef et al. (2011) report that liquid chocolate exhibits a non-Newtonian flow behaviour that is conventionally characterized by a yield stress and plastic viscosity. The rheological behaviour of chocolate is also highly relevant for the mouth feeling of texture, since the chocolate must melt gradually and smoothly when in the mouth (Bahari and Akoh, 2018; Wells, 2009).

CONCLUSION

After several tests, the final formulations for two types of chocolate were established, in line with what we idealised our products to be, i.e., fortified with spice and fruit for their contribution in terms of nutrition and biologically active substances beneficial to health. Both formulations included dehydrated green apple, but one was for milk chocolate, to which cinnamon was added, and the other was for dark chocolate, to which mint was added.

It was found that milk chocolate showed a better organoleptic combination with cinnamon, allowing the flavour of this spice to be enhanced, thus creating harmony through the combination with the intense acidity characteristic of the green apple. As for the dark chocolate, its organoleptic characteristics were highlighted by the freshness of the mint, originating a darker and harder chocolate, with a moderate sweetness and crunchy texture. The judges who evaluated the samples showed a clear preference for the milk chocolate with cinnamon, although they also liked the dark chocolate with mint, as the purchasing intentions revealed. The results showed that 56 % would probably buy the Milk Chocolate with Green Apple & Cinnamon, and 25 % would certainly buy it. As for the Dark Chocolate with Green Apple & Mint, 44 % would probably buy it, and 31 % would certainly buy this product. Evaluation of the physical properties indicated that the Dark Chocolate with Green Apple & Mint was harder, and presented lower stickiness and adhesiveness. With respect to colour, this sample had a darker colouration, resulting from lower values of L*, a* and b*. Also the results from rheological analysis showed that the Dark Chocolate with Green Apple & Mint presented just a slightly higher range of viscosity than the Milk Chocolate with Green Apple & Cinnamon.

In conclusion, this work allowed obtaining two formulations that have the potential to be successful on the chocolate market.

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AUTHORS' CONTRIBUTION

Conceptualization, R.G.; data curation, R.G.; formal analysis, R.G.; funding acquisition, R.G.; investigation, R.G., A.F. and S.F.; methodology, R.G.; project administration, R.G.; resources, R.G.; software, R.G.; supervision, R.G.; validation, R.G.; visualization, R.G.; writing – original draft, R.G. and S.F.; writing – review & editing, R.G.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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APPENDIX A

Appendix A.1 - Form for sensorial profile analysis

Age: : _______ years

Gender:

☐ Female ☐ Male

Code of the sample:

☐ 652 ☐ 317

Before tasting the sample, please rate the chocolate on each of the following attributes, on a scale from 1 to 5:

Visual aspect:

	1	2	3	4	5	
Extremely bad						Extremely good

Colour:

	1	2	3	4	5	
Extremely clear						Extremely dark

Uniformity of the pieces:

	1	2	3	4	5	
Nothing uniform						Extremely uniform

Please taste the sample, and rate the chocolate on each of the following attributes, on a scale from 1 to 5:

Texture:

	1	2	3	4	5	
Extremely soft						Extremely hard

Crispiness of the sample:

	1	2	3	4	5	
Nothing crispy						Extremely crispy

Crispiness of the apple pieces:

	1	2	3	4	5	
Nothing crispy						Extremely crispy

Aroma to chocolate:

	1	2	3	4	5	
Nothing intense						Extremely intense

Spicy aroma:

	1	2	3	4	5	
Nothing intense						Extremely intense

Sweetness:

	1	2	3	4	5	
Extremely bitter						Extremely sweet

Acidity:

	1	2	3	4	5	
Nothing intense						Extremely intense

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Global appreciation:

	1	2	3	4	5	
Extremely dislike						Extremely like

What would be your intentions towards buying this product?

☐ I would certainly buy this product
☐ I would probably buy this product
☐ I have doubts as to whether I would buy this product
☐ Probably I would not buy this product
☐

Appendix A.2 - Form for test of preference

Age: : _______ years

Gender:

☐ Female ☐ Male

After tasting the two samples presented to you, which of them do you prefer?

☐ Sample 652
☐ Sample 317