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# PRODUCTION OF CHOCOLATE ENRICHED WITH CAROB POWDER

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## Abstract

**Description of the subject:** Chocolate is one of the world's most popular confectionery products. Today, the food industry is increasingly seeking to formulate and produce healthier products. The development of these products requires modifications to ingredients and recipe formulation.

**Objective**: The aim of our work is to develop a chocolate enriched with carob powder. Carob was chosen and used as a substitute for cocoa due to the absence of certain stimulating substances such as caffeine and theobromine and for its richness in dietary fibre. The work has a double interest: on the one hand, it is a contribution to the development of a functional chocolate, and on the other, it enhances the value of the carob tree, which is of considerable economic importance.

**Methods :** Preliminary trials of dark chocolate formulation with different concentrations of carob flour were carried out and five concentrations were finally selected (5, 10, 15, 20 and 25‰). The chemical composition of carob powder, the physicochemical analysis and the sensory quality of chocolates enriched with carob powder was studied.

**Results :** Carob flour was found to be low in fat and protein, moderately high in sugars and a source of soluble and insoluble fiber. The results of the physicochemical analyses show that pH ranges from 5.35 to 5.70. Concerning humidity, the data show that these chocolates appear to be wetter and exceed the norm. For viscosity and refining the results show that a rate above 10‰ of enrichment decreases refining and makes it difficult to spread the chocolate layer, and above 15‰ viscosity reading becomes impossible.

**Conclusion :** Tasters found the 5‰ and 10‰ chocolates to be the best, with a significant preference for the 5‰ chocolate. The 5‰ carob chocolate is significantly perceived as the darkest chocolate, with the firmest texture and the most frank and pleasant smell while the 25‰ carob chocolate was perceived as the lightest chocolate, with the least firm (disintegrated) texture and the least frank.

**Keywords** : Carob, Dark chocolate, Grading, Refining, Viscosity.

# FABRICATION DE CHOCOLAT ENRICHI EN POUDRE DE CAROUBE

## Résumé

**Description du sujet :** Le chocolat est l'un des produits de confiserie les plus consommés au monde. Aujourd'hui, l'industrie alimentaire cherche de plus en plus à élaborer des produits plus sains. Le développement de ces produits nécessite des modifications des ingrédients et de la formulation des recettes.

**Objectif :** Le but de notre travail est de développer un chocolat enrichi en poudre de caroube. La caroube a été choisie et utilisée comme substitut du cacao en raison de l'absence de certaines substances excitantes telles que la caféine et la théobromine et pour sa richesse en fibres alimentaires. Le travail a un double intérêt : d'une part, il s'agit d'une contribution à l'élaboration d'un chocolat à caractère fonctionnel, et d'autre part, il valorise le caroubier, dont l'importance économique est considérable.

**Méthodes :** Des essais préliminaires de formulation de chocolat noir avec différentes concentrations de farine de caroube ont été réalisés et cinq concentrations ont finalement été retenues (5, 10, 15, 20 et 25‰). La composition chimique de la poudre de caroube, l'analyse physico-chimique et la qualité sensorielle des chocolats enrichis en poudre de caroube ont été étudiées.

**Résultats :** La farine de caroube s'est avérée pauvre en matières grasses et en protéines, modérément riche en sucres et source de fibres solubles et insolubles. Les résultats des analyses physico-chimiques montrent que le pH varie de 5,35 à 5,70. Concernant l'humidité, les données montrent que ces chocolats semblent plus humides et dépassent la norme. Pour la viscosité et l'affinage les résultats montrent qu'un taux supérieur à 10‰ d'enrichissement diminue l'affinage et rend difficile l'étalement de la couche de chocolat, et au-dessus de 15‰ la lecture de la viscosité devient impossible.

**Conclusion :** Les dégustateurs ont trouvé que les chocolats 5‰ et 10‰ étaient les meilleurs, avec une nette préférence pour le chocolat 5‰. Le chocolat enrichi à 5‰ est significativement perçu comme le chocolat le plus noir, avec la texture la plus ferme et l'odeur la plus franche et agréable tandis que le chocolat enrichi à 25‰ était perçu comme le chocolat le plus léger, avec la texture la moins ferme (désintégrée) et la moins franche.

**Mots clés :** Caroube, Chocolat noir, Classement, Raffinage, Viscosité.

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## INTRODUCTION

Chocolate is one of the world's most popular confectionery products. It is a sweet food made from cocoa. Chocolate is a mixture, in varying proportions, of cocoa mass, cocoa butter and sugar, to which spices such as vanilla or vegetable fats may be added. The proportions of each of these constituents vary according to the type of chocolate (dark, white and milk) [1]. In today's world, the food industry is increasingly seeking to formulate and produce healthier products. The development of these products requires modifications to ingredients and recipe formulation. According to Yousif and Alghzawi [2], carob contains no caffeine or theobromine, which are anti-nutritional compounds found in cocoa. Its light, caramel-like chocolate taste is considered a nutritional advantage, qualifying carob as a good substitute for cocoa in certain foodstuffs. Carob (*Ceratonia siliqua* L.) is an arborescent species, belonging to the legume family, widely cultivated in the Mediterranean. It is considered an important component of vegetation for economic and environmental reasons [3]. The fruit of the carob tree is composed of 80-90% pulp and 10-20% seeds by weight [4]. Gum is the major constituent of the seed endosperm, and is used in the food industry as a stabilizer, thickener and emulsifier in a wide range of food products [5]. While the pulp is very rich in sugars, dietary fibers such as cellulose, hemicelluloses and lignin, and minerals, it is also considered a potential reservoir of bioactive molecules. It is rich in phenolic compounds, the most important of which are proanthocyanidins, flavonoids and ellagitannins [6]. The aim of our work is to develop a chocolate enriched with carob powder. Carob was chosen and used as a substitute for cocoa because of its low protein and fat content, and the absence of certain exciting substances such as caffeine and theobromine. The work has a twofold interest: on the one hand, it is a contribution to the development of a functional chocolate, and on the other, it enhances the value of the carob tree, which is of considerable economic importance.

## MATERIEL AND METHODES

### *1. Sampling and preparation of biological material*

The plant material, consisting of ripe CARUMA C30 carob pods, was collected from Tlemcen in August 2021. The pods are washed, drained, cut into small pieces and the seeds removed. The carob pieces are dried at room temperature. Drying is stopped when the dry matter content reaches 90%. The pulp was ground using a coffee grinder [7], then sieved using a 200 µm mesh diameter sieve, roasted to develop the aromas, cooled and then stored in a dark, dry place until use.

### *2. Analysis of the chemical composition of carob powder*

The total sugar content was determined according to the method of Dubois et al. [8]. The protein content is determined by the Kjeldhal method using the conversion factor of 6.25 [9]. The extraction of the fat was carried out by organic solvent (Hexane) with a Soxhlet type apparatus, according to the method of ISO 659 [10]. The ash content is determined by the destruction of any organic matter under the effect of the high temperature (550°C for 3 to 5 hours) and the obtaining a white or grayish-white powder [11]. The determination of the Na, K, P, Ca, Zn, Fe, Mn, Cu, Cd, Pb and Mg ions was carried out by atomic absorption spectrophotometry (AAS) [12]. The determination of total fiber is carried out according to Weende's method [13]. Concerning NDF, ADF and ADL were estimated according to the protocol of Van Soest and Wine [14]. The determination of pectin is carried out according to Multon [15]. It is based on the principle of transformation of pectin into calcium pectate. The overall energy value is calculated from the relationship below. $E = (9 \times L) + (4 \times C) + (4 \times P)$. With, ***E:*** global energy value in kcal, ***L:*** total lipid content in g per 100g of sample, ***C:*** total carbohydrate content in g per 100g of sample, ***P:*** total protein content in g per 100g of sample and 9, 4 and 4: the Atwater coefficients of lipids, carbohydrates and proteins [16].

### *3. Formulation trial of a standard dark chocolate recipe and chocolate enriched with carob powder*

The job involves making two types of chocolate: cocoa-based dark chocolate (control) and dark chocolate enriched with carob powder. For dark chocolate, used as a standard or control, several preliminary tests with different percentages of ingredients were carried out, and the final composition was fixed at: cocoa mass, cocoa powder and cocoa butter (49.70%), white sugar (49.70%), lecithin (0.50%) and vanillin (0.10%). Table 1 shows the composition. Concerning the "chocolate enriched with carob powder" type, preliminary trials with different concentrations of carob flour were carried out and five concentrations were finally selected (5, 10, 15, 20 and 25‰) to thus elaborate five formulations of carob-enriched dark chocolate. Table 1 gives the composition of each preparation.

Table 1: Composition of the different formulations of chocolates enriched with carob powder

| Ingredients (g per 1000g of product) | Dark chocolate with cocoa (Standard) | Dark chocolate enriched with carob powder | | | | |
|---|---|---|---|---|---|---|
| | | 5‰ | 10‰ | 15‰ | 20‰ | 25‰ |
| Cocoa mass + cocoa butter + cocoa powder | 49.70 | 47.20 | 44.70 | 42.2 | 39.7 | 37.2 |
| Carob flour | / | 5 | 10 | 15 | 20 | 25 |
| Sugar | 49.70 | 47.20 | 44.70 | 42.2 | 39.7 | 37.2 |
| Vanillin | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Lecithin | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |

### *4. Chocolate preparation*

The chocolate is prepared by mixing the dry ingredients with melted cocoa butter (in a Marie bath at 60°C). The mixture is blended with a mixer until homogeneous, then poured into clean, dry silicone molds and stored in a cool place (4° to 6°C). After cooling for 1h30 min, the chocolate becomes solid at room temperature, so it can be removed from the molds and kept cold.

### 5. *Physico-chemical analysis of chocolates*

Some physicochemical parameters were analyzed, such as humidity [9] and pH [17]. Viscosity was determined using a viscometer or rheometer, which works by rotating a rod immersed in the material to be analyzed (melted chocolate at 40°C) and measuring the resistance of this substance at a selected speed. The result is given by direct reading of the viscosity on the device (reflected in m Pascal/s) [18]. The refining test was applied in accordance with ISO [19]). This test expresses the homogeneity of the chocolate ingredients, in particular the sugar, which must be well dissolved in the chocolate, otherwise the chocolate spread on the plate will be shorter and will show more or less wide lines. To achieve this, 2 or 3 drops of melted chocolate at a temperature of between 40 and 50°C are placed on the micrometer plate, and the chocolate is spread over the micrometer area using a metal spreader. The extent of the chocolate spread on the micrometer plate is then bound.

### *6. Sensory analysis of chocolate*

The chocolate was analyzed using a ranking test. The subject's task (40 tasters) was to be presented with different types of coded, elaborate chocolates and asked to rank them in order of intensity of color (dark and light), smell (good and bad), texture (weakly or strongly smooth and shiny) and taste (good and bad). Each subject is given the products to taste and asked to answer a questionnaire for each type of chocolate separately.

### *7. Statistical study*

Statistical analysis of the results was carried out using STATISTICA 5.5 software, with significance taken at probability $p \leq 0.05$. We performed a one-factor analysis of variance. All data represent the mean of the three trials ± standard deviation. We applied the pairwise multiple comparison test of rank sums to determine which sample pairs differ from each other [20].

## RESULTATS

### *1. Analysis of the chemical composition of carob powder*

The chemical composition of carob powder and its energy value are given in table 2. Carob flour was found to be low in fat (0.48%) and protein (6.46 g E BSA/100 g), moderately high in sugars (43.81 g GE/100g FM) and a source of soluble and insoluble fiber. Its overall energy value is estimated at 205.4 kcal /100g. From the results of table 2, the ash content is estimated at 3.059%. It can be seen that the various minerals found in the carob powder and which are in the dominant quantity are calcium, followed by potassium, phosphorus, sodium and magnesium. Iron, zinc and manganese are found in trace form.

Table 2: Chemical composition of carob powder and energy value

| Compounds | Quantity |
|---|---|
| Proteins (g BSA E/100g FM) | 6.46±0.25 |
| Total sugars (g GE/100g FM) | 43.81±0.21 |
| Fat (g/100g FM) | 0.48±0.01 |
| Overall energy value (Kcal/100g FM) | 205.4±0.16 |
| Ash (g/100g) | 3.059±0.064 |
| Manganese(Mn) (µg/g) | 3.83±0.30 |
| Iron (Fe) (µg/g) | 6.34±0.50 |
| Cadmium(Cd) (µg/g) | Nd |
| Lead (pb) (µg/g) | Nd |

Suite Table 2: Chemical composition of carob powder and energy value

| Compounds | Quantity |
|---|---|
| Calcium(Ca) (µg/g) | 1803±16 |
| Copper(Cu) (µg/g) | Nd |
| Magnesium(Mg) (µg/g) | 250±2.65 |
| Sodium(Na) (µg/g) | 376±6.65 |
| Zinc(Zn) (µg/g) | 2.78 ± 0.14 |
| Phosphorus(P) (µg/g) | 833± 1.77 |
| Potassium(K) (µg/g) | 1102±1.11 |
| Crude Cellulose (% FM) | 11.72±0.67 |
| Neutral Detergent Fiber (NDF (%FM) | 35.71±1.33 |
| Acidic Detergent Fiber (ADF) (%FM) | 25.32±0.57 |
| Acidic Detergent Lignin (ADL) (%FM) | 13.38±0.07 |
| Pectins (% FM) | 10.17±1.11 |

BSA E: Bovine Serum Albumin Equivalent, GE: Glucose Equivalent, FM: Fresh Matter.

### *2. Physicochemical analysis of chocolates*

The physicochemical characteristics of the chocolates analyzed are shown in the table 3. According to the results presented in Table 3, the pH does not differ significantly ($p>0.05$) from one chocolate to another; it varies from 5.35 to 5.70. These results are in line with the standard required by *Codex alimentarus* (pH≤7). The results illustrated in Table 3, show overall that moisture varies significantly ($p\leq0.05$) between the chocolates analyzed, except for the 15, 20 and 25‰ chocolates. Dark chocolate (control) appears to be the least moist and complies with the standard set by the company (≤0.75%) unlike chocolates enriched with carob powder.

Analysis of our data shows that 5 and 10‰ chocolates appear to be significantly ($p\leq0.05$) the wettest. In the chocolate manufacturing process, water does not enter into the formulation of the product its presence results from the residual content in the raw material and by its capture in the surrounding atmosphere. The results of viscosity show that there is no significant difference ($p>0.05$) in refining between dark chocolate (control) and dark chocolates enriched with carob powder up to 10‰, the spread is estimated at 25 µm, it complies with the *Codex alimentarus* standard (≤30µm). A level higher than 10‰ reduces refining and makes it difficult to spread the chocolate layer.

Table 3: Effect of carob flour enrichment on the physicochemical characteristics of the dark chocolates produced.

| Chocolates | pH | Humidity (%) | Viscosity (m steps/s) | Refining (µm) |
|---|---|---|---|---|
| Control (DC) | 5,44±0,11$^{ab}$ | 0,06±0,01$^{e}$ | 27,03±0,50$^{d}$ | 25±0,00$^{a}$ |
| DC to 5‰ of carob | 5,62±0,06$^{ab}$ | 0,18±0,01$^{b}$ | 33,23±0,67$^{c}$ | 25±0,00$^{a}$ |
| DC to 10‰ of carob | 5,42±0,12$^{ab}$ | 0,24±0,0$^{a}$ | 44,87±1,59$^{b}$ | 25±0,00$^{a}$ |
| DC to 15‰ of carob | 5,35±0,18$^{ab}$ | 0,12±0,02$^{cd}$ | 73,13±2,00$^{a}$ | Nd |
| DC to 20‰ of carob | 5,70±0,09$^{a}$ | 0,15±0,0$^{c}$ | Nd | Nd |
| DC to 25‰ of carob | 5,50±0,09$^{ab}$ | 0,14±0,02$^{c}$ | Nd | Nd |

*DC: Dark chocolate, Nd: Not determined; Values bearing the same letter in each column show no significant difference (p>0.05).; Results are listed in descending order: a>b>c>d>e.*

### *3. Sensory analysis*

Classifying chocolates according to certain parameters (taste, texture, flavor, etc.) is a descriptive method. It is used to qualify the differences between products by establishing a "sensory profile" for each one. To process the data from the ranking tests, we first calculated all the differences betweenthe sums of the ranks of the products taken 2 by 2. Then, in a second step, we read the critical value at the intersection of the column (products) and row (subjects) on the corresponding Newell and mac Farlane table at risk $\alpha \leq 5\%$. Any calculated difference between products equalto or greater than this critical value means that the corresponding products can be considered different.

Multiple comparison of the chocolate pairs: (DC at 5‰ - DC at 10‰) and (DC at 10‰ -DC at15‰) and (DC at 15‰ - DC at 20‰) shows that the calculated value for each pair is below the critical value (Table 4). It is concluded that the difference in perceived taste betweenthe sample pairs is not significant ($p>0.05$). The value calculated for the 5‰ and 15‰ enrichedchocolates is higher than the critical value. It is concluded that the difference in perceived taste between the two samples is significant and the two chocolates are classified in two different groups. Tasters find the 5‰ and 10‰ chocolates the best with a significant preference for the 5‰ chocolate.

The results in Table 4 show that the values calculated from pairwise multiple comparisons for chocolate enriched to 25‰ and chocolates of the other enrichment percentages are above the critical value. The difference in perceived taste is significant. Tasters find that chocolate with 25‰ is perceived as the least good ($p$<0.05).

This chocolate is therefore classified in a different group from the others, i.e. group (D). The chocolates are classified as follows: DC at 5‰ (group A), DC at 10‰ (group AB), DC at 15‰ (group BC),DC at 20‰ (group C), DC at 25‰ (group D)

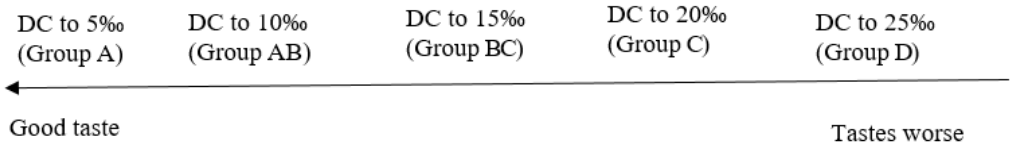



Table 4: Pairwise multiple comparisons of rank sums for taste appreciation of the enrichedchocolates tested

| Samples | Workforce (n) | Sum of rows | Rank differences between possible pairs | Critical value for $p \leq 0.05$ and Number= 40 Number of products=5 | Groups |
|---|---|---|---|---|---|
| DC to 5‰ of carob**(1)** | 40 | 177 | (1)-(2) = 32<br>(1)-(3) = 53*<br>(1)-(4) = 77*<br>(1)-(5) = 128* | 39 | A |
| DC to 10‰ of carob **(2)** | 40 | 145 | (2)-(3) = 21<br>(2)-(4) = 45*<br>(2)-(5) = 96* | 39 | AB |
| DC to 15‰ of carob**(3)** | 40 | 124 | (3)-(4) = 24<br>(3)-(5) = 75* | 39 | BC |
| DC with 20‰ carob**(4)** | 40 | 100 | (4)-(5) = 51* | 39 | C |
| DC with 25‰ carob**(5)** | 40 | 49 | | 39 | D |

DC: Dark Chocolate, *: Significant at threshold $p \leq 0.05$

The results in Tables 5, 6 and 7 show that the values calculated, from multiple pairwise comparisons, for dark chocolates enriched with carob powder, are above the critical value for all enrichment percentages. The tasters found that the color, texture and smell of the chocolates differed significantly ($p \leq 0.05$) according to the enrichment percentages. The chocolates testedare therefore classified in different groups (A, B, C, D and E). Tasters found that chocolate with5‰ of carob was perceived significantly ($p \leq 0.05$) as the darkest chocolate, with the firmest texture and the cleanest, most pleasant smell, while chocolate with 25‰ of carob was perceived as the lightest chocolate, with the least firm (disintegrated) texture and the least clean, least pleasant smell. These chocolates were therefore classified into two extreme groups (A and E, respectively). Chocolates with 15‰ and 20‰ carob were perceived as significantly different ($p \leq 0.05$) from each other and from groups A and E. The rankings of the different groups according to the tasters' assessment for each parameter analyzed are illustrated as follows:

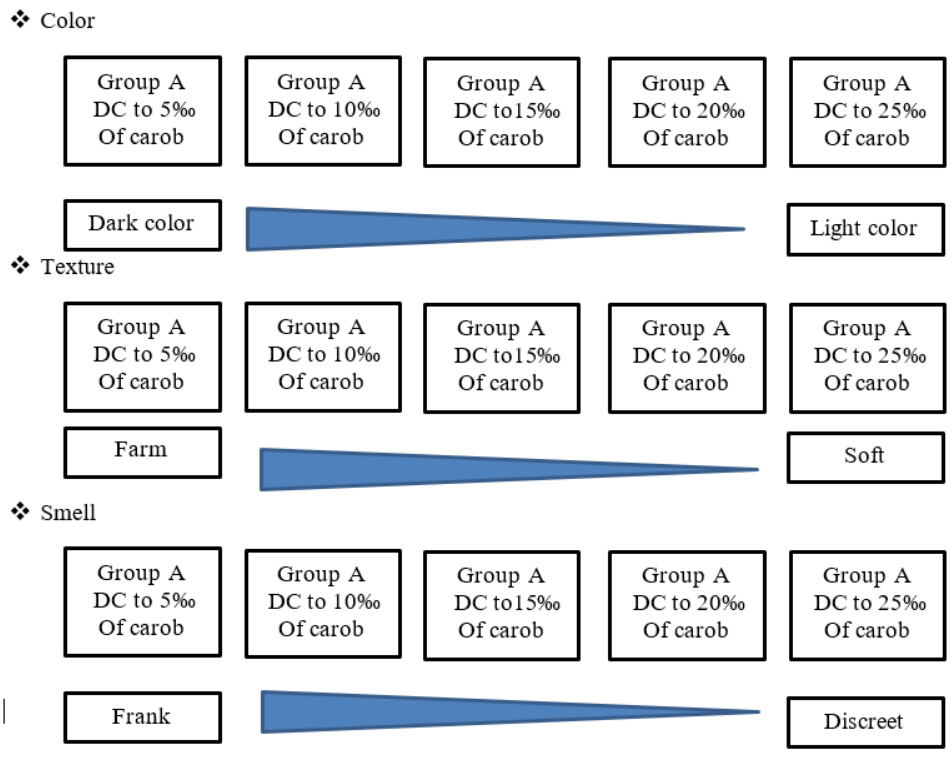


Table 5: Pairwise multiple comparisons of rank sums for color intensity of the enrichedchocolates tested.

| Samples | Work force(n) | Sum of Ranks | Rank differences between Possible pairs | Critical value for $p \leq 0.05$ and Number= 40 Number of products=5 | Groups |
|---|---|---|---|---|---|
| DC to 5‰ of carob **(1)** | 40 | 40 | (2)-(1) = 40*<br>(3)-(1) = 80*<br>(4)-(1) = 120*<br>(5)-(1) = 160* | 39 | A |
| DC to 10‰ of carob**(2)** | 40 | 80 | (3)-(2) = 40*<br>(4)-(2) = 80*<br>(5)-(2) = 120* | 39 | B |
| DC to 15‰ of carob**(3)** | 40 | 120 | (4)-(3) = 40*<br>(5)-(3) = 80* | 39 | C |
| DC with 20‰ carob**(4)** | 40 | 160 | (5)-(4) = 40* | 39 | D |
| DC with 25‰ carob**(5)** | 40 | 200 | | 39 | E |

DC: Dark Chocolate, * : Significant at threshold $p \leq 0.05$

Table 6: Pairwise multiple comparisons of rank sums for the texture of the enriched chocolatestested.

| Samples | Work force (n) | Sum of rows | Rank differences between possible pairs | Critical value for $p \leq 0.05$and Number= 40 Number of products=5 | Groups |
|---|---|---|---|---|---|
| DC to 5‰ of carob **(1)** | 40 | 200 | (1)-(2) = 40*<br>(1)-(3) = 80*<br>(1)-(4) = 120*<br>(1)-(5) = 160* | 39 | A |
| DC to 10‰ of carob**(2)** | 40 | 160 | (2)-(3) = 40*<br>(2)-(4) = 80*<br>(2)-(5) = 120* | 39 | B |
| DC to 15‰ of carob**(3)** | 40 | 120 | (3)-(4) = 40*<br>(3)-(5) = 80* | 39 | C |
| DC with 20‰ carob**(4)** | 40 | 80 | (4)-(5) = 40* | 39 | D |
| DC with 25‰ carob**(5)** | 40 | 40 | | 39 | E |

DC: Dark Chocolate, * : Significant at threshold $p \leq 0.05$

Table 7: Pairwise multiple comparisons of rank sums for odor appreciation of the enrichedchocolates tested.

| Samples | Workforce (n) | Sum of rows | Rank differences between possible pairs | Critical value for $p \leq 0.05$ and Number= 40 Number of products=5 | Groups |
|---|---|---|---|---|---|
| DC to 5‰ of carob**(1)** | 40 | 200 | (1)-(2) = 40*<br>(1)-(3) = 80*<br>(1)-(4) = 120*<br>(1)-(5) = 160* | 39 | A |
| DC to 10‰ of carob**(2)** | 40 | 160 | (2)-(3) = 40*<br>(2)-(4) = 80*<br>(2)-(5) = 120* | 39 | B |
| DC to 15‰ of carob**(3)** | 40 | 120 | (3)-(4) = 40*<br>(3)-(5) = 80* | 39 | C |
| DC with 20‰ carob**(4)** | 40 | 80 | (4)-(5) = 40* | 39 | D |
| DC with 25‰ carob**(5)** | 40 | 40 | | 39 | E |

DC: Dark Chocolate, *: Significant at threshold $p \leq 0.05$

## DISCUSSION

The protein contents of the carob powder is in agreement with the contents given by Gaouar [21] for carob pulp (6.38%-6.56%). The results obtained for total sugars are in agreement with those of other authors. Boublenza et *al.* [22] determined the sugar content of ten varieties of spontaneous and cultivated carob, located in different regions of northern Algeria. According to the results obtained, total sugars ranged from 43.22% to 50.28%, with the varieties harvestedin Boumerdes being the least sweet. El Batal et *al.* [23] found values between 31.5 and 50.1%MF for Moroccan carob varieties. In contrast, Haddarah et *al.* [24] recorded highly elevated values for Lebanese varieties (72.2% and 89.46%).

Dietary lipids play an important role in the organoleptic properties of foods. They contribute to food texture, palatability and pleasant taste. Nutritionists recommend a daily intake of 30-35% to cover our physiological needs. Lipids are molecules that provide energy and enable the transport of fat-soluble vitamins. The fat content of carob powder is low. This content is close to that found by Avallone *et al.* [25] (0.4%) for pulp carob but slightly lower than that given by El-Batal *et al.* [23] (0.5- 0.8%). Multiple parameters influence the fat content such as particle size, humidity, the nature of the solvent and the extraction method used [21].

The overall energy value of carob powder is estimated at 205.4 kcal /100g. This value is lower than that found by Ozcan et *al.* [26] (248.38±7.64Kcal/ 100g). This difference in results can be explained by the variability of quantification methods, the degree of ripening of the fruit, the sweetness of the fruit, the humidity of the sample, etc.

The ash content represents the total quantity of mineral matter present in a product. The ash content is almost similar to those found by Özcan et *al.* [26] and Khlifa et *al.* [27]. The latter detected contents of 3.33% and 3, respectively. It can be seen that the various minerals found in the carob powder and which are in the dominant quantity are calcium, followed by potassium, phosphorus, sodium and magnesium. Iron, zinc and manganese are found in trace form. Our result agrees with that of Khlifa et *al.* [27]. These latter report a predominance of calcium and potassium, an absence of copper and detect iron, manganese and zinc as trace form in carobpulp.

The amount of each component of the dietary fiber determined as insoluble fiber (crude cellulose, NDF, ADF and ADL) and soluble fiber (pectin). NDF measures most ofthe structural components of plant cells, cellulose, hemicellulose, lignin, silica, tannins and cutins, but not pectin.

This measurement is thus considered a reliable estimate of the total fiber present in a food. Theorycally, NDF composition is similar to the insoluble dietary fiber composition [28]. With 10% soluble fiber and 36% insoluble fiber, carob flour can help regulate transit and promote intestinal motricity. Insoluble fibers play a mechanical role in the speed of intestinal transit. They help regulate digestion, with positive effects on constipation. In addition, solublefibers, thanks to their power of water retention, can also have a beneficial effect on diarrhea [29].

pH is a parameter that determines the suitability of food for preservation, and is one of the main obstacles that microbial flora must overcome in order to proliferate. A pH of between 3 and 6 is highly favorable to the development of yeasts and molds.The relationship between water content and equilibrium relative humidity is an essentialfactor in manufacturing processes. Water is a useful element in the formulation of food products, but if left unchecked, it becomes a hindrance to preservation [30]. According to codex STAN 87-198, chocolate with a water content of less than 1.5% does not present a risk in terms of microbiological quality.

Viscosity and refining were analyzed for the semi-finished product (control chocolate andchocolate enriched with carob powder). Refining involves rolling the dough obtained after kneading between steel cylinders, so as to reduce the particle size to less than 25 microns. Thisoperation transforms the initial dough into a fine, hygroscopic powder that can trap ambient odors. This parameter expresses the homogeneity of the chocolate ingredients, in particular thesugar, which must be well dissolved in the chocolate, otherwise the chocolate spread on the plate is shorter and shows more or less wide lines [19]. Viscosity expresses a fluid's resistance to movement when subjected to uniform, turbulence-free flow. The higher a fluid's viscosity, the more its ability to flow decreases. The results in Table III show that viscosity differs significantly from one chocolate to another; it islowest for the control dark chocolate (27.03m pas/s). The processing of our data shows that viscosity increases proportionally with increasing chocolate carob powder content up to an enrichment of 15‰, beyond this rate the reading of the result becomes impossible (threshold>100 m pas/s). Chocolate enriched with carob powder appears more solid than control chocolate. This can be attributed to the difference in the composition of the chocolates: enriched chocolate contains carob powder, whose texture is different from that of cocoa. As itscontent increases, the texture becomes more viscous and consequently firmer to solidify.

## CONCLUSION

The aim of the project is to develop a chocolate enriched with carob powder. The work isof twofold interest: on the one hand, it is a contribution to the development of a functional chocolate, and on the other, it enhances the value of the carob tree, which is of considerable economic importance. Determination of a number of physico-chemical parameters has shown that the pH levels of the enriched chocolates comply with the standard required by *Codex alimentarus.* Dark chocolate (control) appears to be the least moist. There is no significant difference in refinement between dark chocolate (control) and dark chocolates enriched with carob powder up to 10‰.A level higher than 10‰ decreases refining and makes it difficult to spread the chocolate layer. Concerning viscosity, it increases proportionally with the increase of the chocolate content in carob powder up to an enrichment of 15‰, beyond this rate the reading of the result becomes impossible (threshold>100 m pas/s). The sensory quality of chocolates enriched with carob powder was also studied. Concerning taste, tasters find 5‰ and 10‰ chocolates the best with a significant preference for 5‰ chocolate. Tasters find that the 5‰ carob chocolate is significantly perceived as the darkest chocolate, with the firmest texture and the most frank and pleasant smell while the 25‰ carobchocolate was perceived as the lightest chocolate, with the least firm (disintegrated) texture andthe least frank and pleasant smell.

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