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SOME RHEOLOGICAL AND ORGANOLEPTIC PROPERTIES OF THE BISCUIT DOUGH WITH CACAO AND CAROB FLOUR

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Abstract: *The purpose of this paper is to investigate some rheological properties (viscosity and swelling) and organoleptic characteristics of the biscuit dough consisting of the natural or alkalized cacao and carob. Natural or alkalized cacao and medium thermally treated carob increase the dough viscosity, and, in the case of both types of cacao, this effect is more significant than in the case of carob, which is caused by weaker extraction of water-soluble components from carob powder. In the case of natural or dark carob, the dough viscosity decreases with an increase in their contents because no additional dough structuring takes place with these additives.*
Dough swelling and porosity also depend on the additive's nature. Alkalized and natural cacao increase swelling, porosity, and friability of dough. A similar, but weaker effect was registered for the medium-treated carob, while natural and dark carob decrease these organoleptic characteristics of dough and lower the consumer quality of confectionery.
The medium-treated carob powder can be recommended as a cacao substitute for decaffeinated bakery items of other confectionery with special dietary requirements.

Keywords: *confectionery dough, decaffeinating additives, viscosity, swelling, porosity, friability*

1. Introduction

As the food industry faces increasing competition, new technologies, materials, and products should be implemented into everyday practice to meet the consumers' demand and ensure sustainable development of this branch. Firstly, good organoleptic properties and food production safety must be guaranteed to maintain their high commercial and marketing value. Secondly, new agricultural and food processing technologies, which involve some less expensive and more available non-traditional raw materials and additives, sometimes may result in the deterioration of taste, aroma, texture, and other organoleptic characteristics of the food. Besides, some changes in the technological flowchart or equipment settings may be required, as the additives lead to some changes in physico-chemical characteristics of dough. Traditional food raw materials become scarcer and more expensive, so the use of flavor and taste enhancers, colorants, antioxidants, preservatives, surfactants, emulsifiers, and other food supplements becomes a widely spread practice [1-3].
Cacao is a popular ingredient in many confectionary and food items. It can be used as a natural or alkalized product. Since this component is quite deficient and expensive and may be a subject of restriction because of medical or dietary reasons, many investigations are directed to the search for possible cacao substitutes. Carob is one of the

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components that can be used for this purpose instead of cacao [4-6]. Carob is a ground powder made of unripe Carob tree (*Ceratonia siliqua*) pods. This powder looks similarly to cacao but contains less caffeine, more sugars and antioxidants. It tastes like a mixture of cacao and sugar. Thermally untreated and ground carob powder is a beige substance with some nutty smack. A medium thermo-treated carob is obtained after a 5-6 min long keeping at 200 ^{0}C, and after a 10-12 min long treatment at the same temperature, a dark (deeply treated) carob can be prepared. These products are darker than the untreated material and have a bitter smack. Among others, they can be used as low-caffeine substitutes for cacao.

Any new component of the dough causes some changes in its properties, such as rheological characteristics, texture, elasticity, stability, and so on. It should be noted that dough viscosity, elasticity, and stability are important technological parameters because dough transportation, storage, and other operations should be performed within a rather narrow range of their values [3, 7-9]. Therefore, they must be controlled and, if needed, corrected in the case they went beyond the technologically permissible limits because of new components added to the dough. Besides, organoleptic properties of the final products like noodles, bakery, confectionery, cookies, and others may also change.

That is why it is important to investigate the dependence of the above characteristics on the qualitative and quantitative composition of the dough with these ingredients. Based on the results of such a study, it is possible to keep the dough quality within technological requirements and to determine the appropriate concentration ranges of the additional components.

2. Materials and methods

The following dough admixtures were used in this work:

- alkalized cacao powder;
- natural cacao powder;
- beige powder of carob (no thermal processing);
- medium-dark powder of carob (after medium thermal processing);
- dark powder of carob (after deep thermal processing).

All dough samples were prepared from the commercially available wheat flour, sugar, eggs, powders of cacao, and carob obtained from a local “METRO” store. Then the dough characteristics were investigated for its various compositions (see Table 1).

Effective viscosity of dough was measured using a rotational viscometer “Rheotest-2” by VEB “MLW” (Germany) with the set of cylinders “S and S_3” following the relevant instructions [10]. The viscosity (η, Pa·s) was calculated as

$$\eta = \frac{z \times a}{D_r} \times 100, \qquad (1)$$

where z – measuring cylinder’s constant, a – shifting angle, deg, D_r – shifting velocity, s^{-1}.

Table 1.

Composition of the dough samples.

Sample	Egg white, g	Sugar, g	Flour, g	Admixture (cacao or carob), g
1	100	50	50	0
2			45	5
3			40	10
4			35	15
5			30	20

Fig.1. Experimental set for determination of dough swelling. A lower part of the columns' content is the swollen dough, and the top is the liquid phase.

Dough components extraction intensity was measured photometrically against distilled water within the wavelength range of 250-350 nm using a liquid phase obtained after the extraction from cacao and carob powders. 1 g of powder was mixed with 10 mL of water, stirred and left for 24 h to complete the extraction. Then the mixture was centrifuged at 8000 rpm, and the absorbance of centrifugate was measured on a "LOMO SF-26" spectrophotometer.

Dough swelling was measured using an original set of measuring columns. Each column was 12 mm in diameter and 300 mm long. A 3 g sample of the dough mixture was poured into the column, the initial volume of the mixture was measured, and then a required amount of water at 20 ^{0}C or 60 ^{0}C was added. Finally, the dough composition was kneaded and left for 24 or 48 h. Then a dough volume was measured and compared with its initial value (Fig. 1).

The content of fatty components was measured using the Abbe WAY-2S refractometer by the following procedure. A 2±0.001 g sample of the dough mixture was placed in a glass cuvette, where 2 mL of petroleum ether was added. The cuvette was closed, stirred intensively, and left for 24 h for complete extraction. Then the liquid phase was taken from the cuvette, its refraction index was measured and compared with the index of pure ether. The weight content of fats in the dough components (X, g/g) was calculated by formula (2).

$$X = [(V \cdot \rho_{et}^{20})/(m \cdot 1000)] \cdot [(n_s - n_{ex})/(n_{ex} - n_f)], \quad (2)$$

where V – a volume of ether taken for extraction, mL, ρ^{20}_{et} – density of ether at 20 ^{0}C. g/mL, m – weight of the dough mixture, g, n_s – refraction index of pure ether, n_{ex} – refraction index of extract, n_f – refraction index of the dough fat.

The biscuits' texture and porosity were compared by measuring their height. It was determined in the standardized 200 g baked samples 12 cm in diameter. A special measuring needle was stuck into the center area of a sample and so its height was measured.

3. Results and discussion

The effective dough viscosity is an integral parameter depending on various processes taking place in its disperse phase. On the other hand, it is very important for some technological stages. That is why it should be thoroughly controlled, and the influence of various dough ingredients on its viscosity must be clear and predictable.

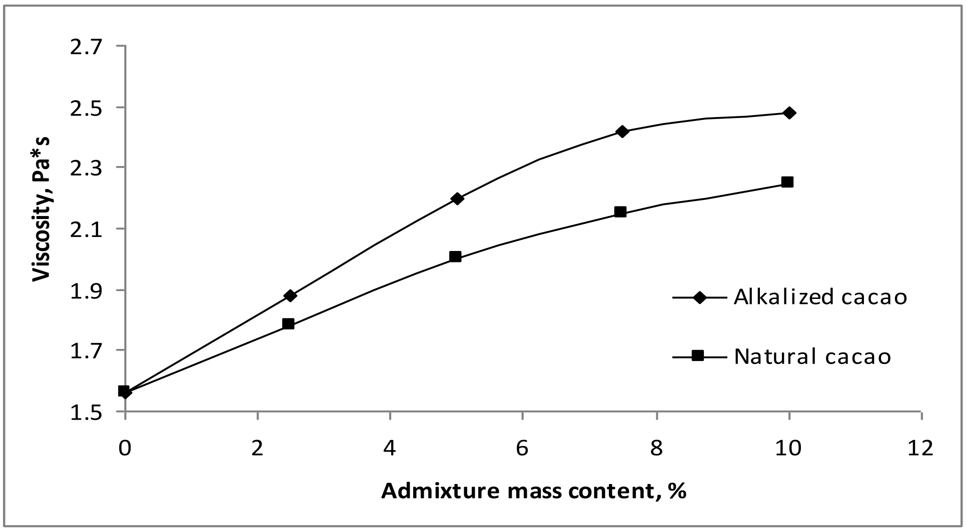

Fig. 2. Effective viscosity of the dough with alkalized (♦) and natural (■) cacao.

It was found that an increase in the natural and alkalized cacao content leads to a rise in the dough viscosity. This effect is caused by adding of high-molecular components present in both cacao powders that get adsorbed on the flour particles and form large aggregated flakes. They improve the disperse system's stability and increase its viscosity.

The alkalized cacao affects the dough viscosity more strongly than the natural product (see Fig. 2). This is caused by a higher solubility of some phenols and fats present in cacao after its alkalizing. As seen in Fig. 3, the absorbance of the extraction from alkalized cacao is greater than that of the natural cacao. However, the absorbance curves' pattern for alkalized and natural cacao is the same, which means that the alkaline processing of cacao does not change the chemical nature of its soluble components but increases their solubility.

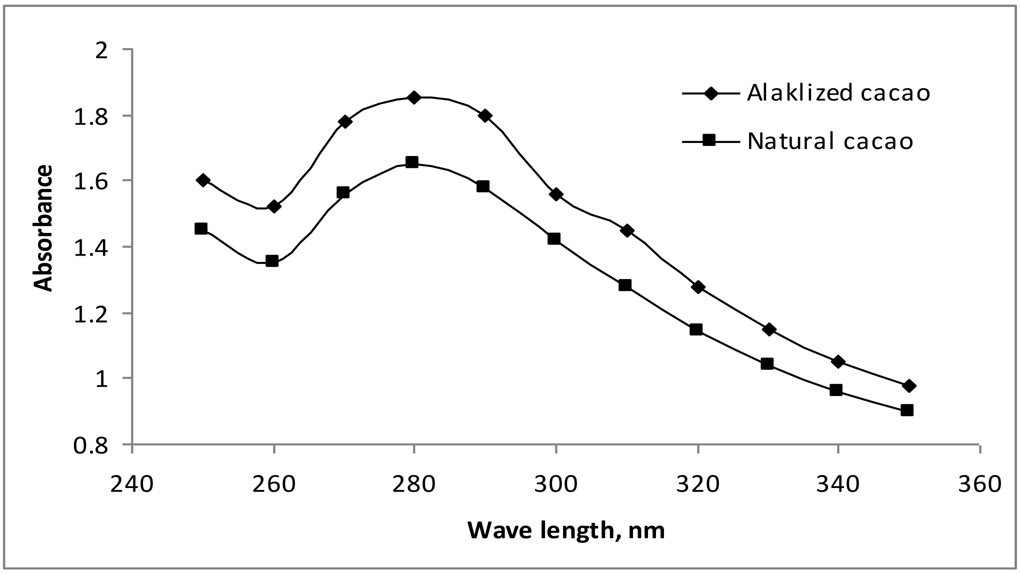

Fig. 3. Absorbance of the extraction from alkalized (♦) and natural (■) cacao.

Carob provides a weaker effect on the rheological characteristics of dough (compare Fig. 2 and Fig. 4).

Only medium-treated carob increases the effective viscosity of the dough in a similar way to cacao, but in this case, this influence is weaker. Untreated and dark carob powders affect viscosity in the opposite way. It means that, unlike cacao, carob is practically unable to cause additional structuring of the dough. This effect takes place due to a lower degree of extraction of water-soluble carob components compared to cacao. As seen from the comparison between Fig. 3 and Fig. 5, the absorbance of all carob-dough extractions remains lower than that of the cacao-dough along the entire wavelength range. Even a line corresponding to the highest absorbance of the extraction from medium-processed carob dough lies below the lines corresponding to the extracts from natural and alkalized cacao dough. This is a proof of better extraction of optically active components from the cacao-containing dough. A weaker extraction from the carob dough can be explained based on their lower content in the source carob powder (compared to cacao). Light thermal processing of carob results in an increased content of mobile forms of optically active compounds and increases a corresponding absorbance. That is why the absorbance curve for the medium-processed carob dough extraction lies higher than that of the unprocessed carob dough extraction. However, deeper thermal processing leads to partial oxidation and decomposition of optically active components, causing a decrease in the degree of their extraction. That is why the absorbance from dark carob extract is the lowest (Fig. 5).

Similar results were obtained in [11] for another type of wheat dough, consisting of milk kefir, some rice, and raw untreated carob flour. It was shown that the viscosity and stability of dough decrease with an increase in carob content by up to 40 %. This trend was observed for the ‘static’ and ‘dynamic’ viscosity.

In general, this effect corresponds with that of some other additives. As reported in [12], a 5-15 % admixture of apricot and pumpkin seed caused a rise in the wheat dough viscosity, similarly to the effect of natural and alkalized cacao found in our investigation.

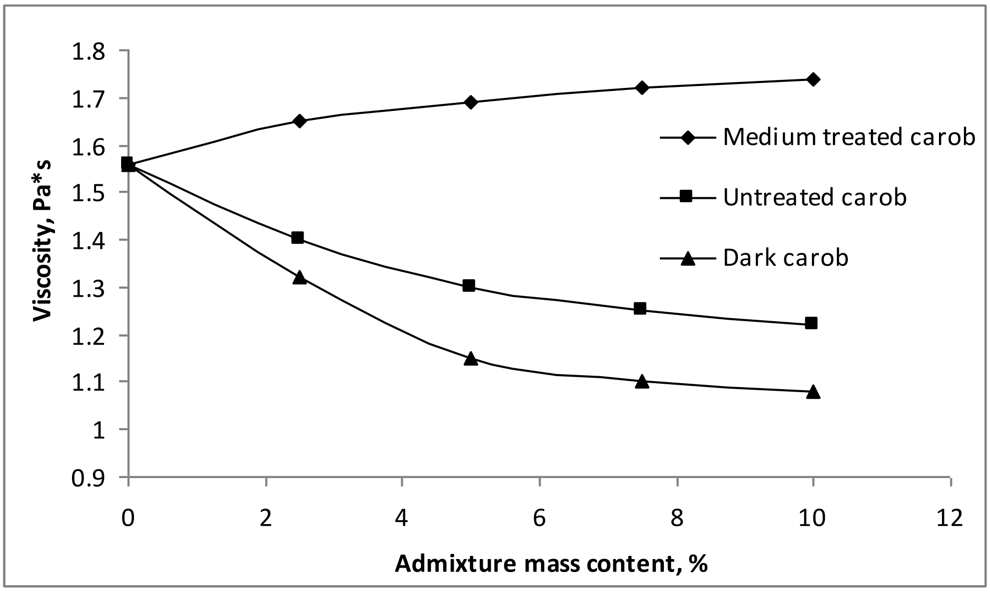

Fig. 4. Effective viscosity of the dough with untreated (■), medium-treated (♦), and dark (▲) carob powder.

An influence of the additives' components extracted from cacao or carob on the dough viscosity that acts through strengthening/weakening of its structure can be proven by comparison with the constant viscosity increase in a liquid yogurt-like medium containing some carob [13]. Unlike dough, a liquid medium like yogurt does not form any inner structure. Therefore, any extra solid component, like carob, will only increase the viscosity just because of extra solid particles added to the system. In the case of dough, this effect can be overridden (and, in the case of some types of carob flour, it actually is) by weakening the inner dough structure by the components released from the carob.

It is well-known that dough absorbs water while ripening and swells. As the volume of the dispersed phase particles increases because of swelling, the dough's structural stability also changes. Firstly, the dough volume rises, but then further swelling affects the dough's stability and deteriorates its structuring, causing some recession in the dough volume. All these processes also depend on the qualitative and quantitative composition of dough.

As seen from the dough stability experiments (Fig. 6 and 7), all samples showed the same swelling dynamics, but the degree of swelling significantly depended on the dough composition. The volume of all samples increases during the first 24 h, but then it decreases, and at 60 ^{0}C, all these changes are faster than at 20 ^{0}C. The alkalized cacao dough shows the most significant volume changes, followed by the natural cacao dough, and all carob samples showed much weaker changes. The comparison between Fig. 5 and 6 proves that the swelling of the medium-processed carob dough is a bit greater than that of the unprocessed and dark carob samples.

It can be explained in the following way. Intact grains of the source carob and cacao materials do not absorb water well and stay mostly immobile, not moving to the dispersion medium. Light thermal processing of carob or cacao alkalization damages their external shell, makes more cracks on the grain's surface, and increases its specific surface area, which results in easier water absorption and weakens their fixation, facilitating better transfer of the loose grains to the dispersion medium. Further thermal processing of carob leads to a deeper decomposition of carob organic components and hydrophobization of the grain's surface. These processes complicate water absorption, and the following dough swelling.

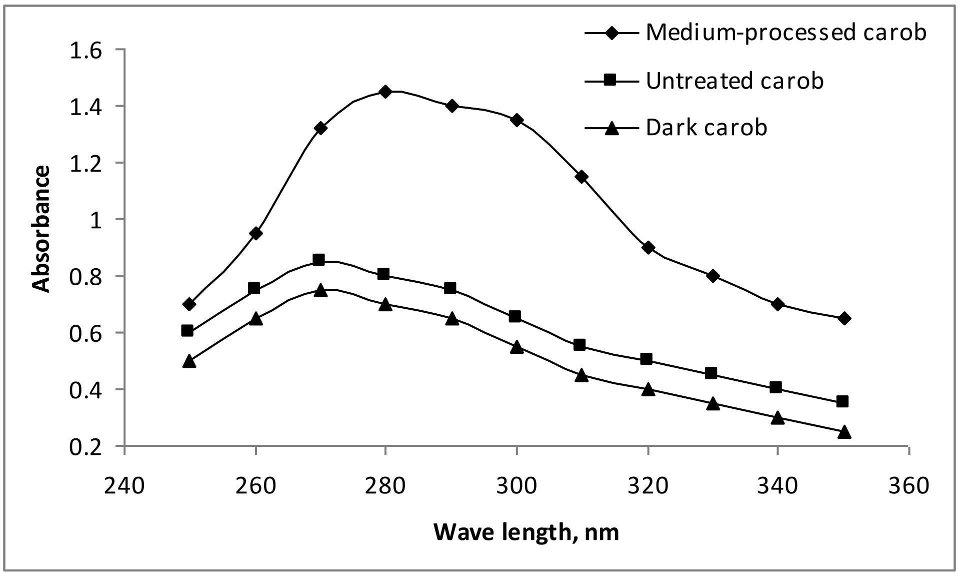

Fig. 5. Absorbance of the extraction from natural (■), medium-processed (♦), and dark (▲) carob.

Besides, the swelling also depends on the natural fat content. Since fatty compounds act like colloidal stabilizers through their adsorption on the surface of colloidal particles and increasing the thickness of their external shell, which impedes aggregation and coagulation of the particles, higher fats content facilitates better swelling and aggregation stability of dough.

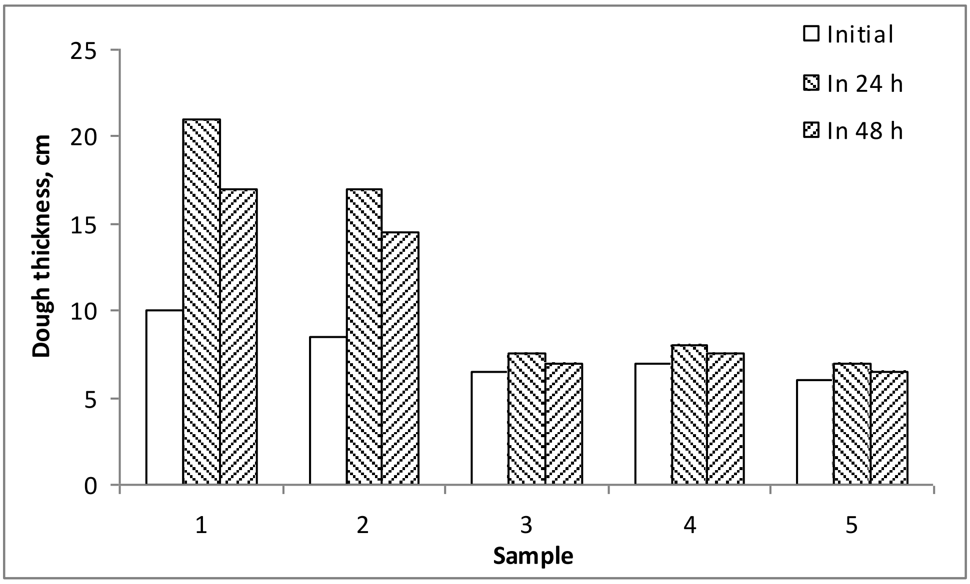

Fig.6. The 48 h changes in the dough thickness for the samples containing alkalized cacao (sample 1), natural cacao (2), beige untreated carob (3), medium-thermotreated carob (4), and dark carob (5) for 20 ^{0}C.

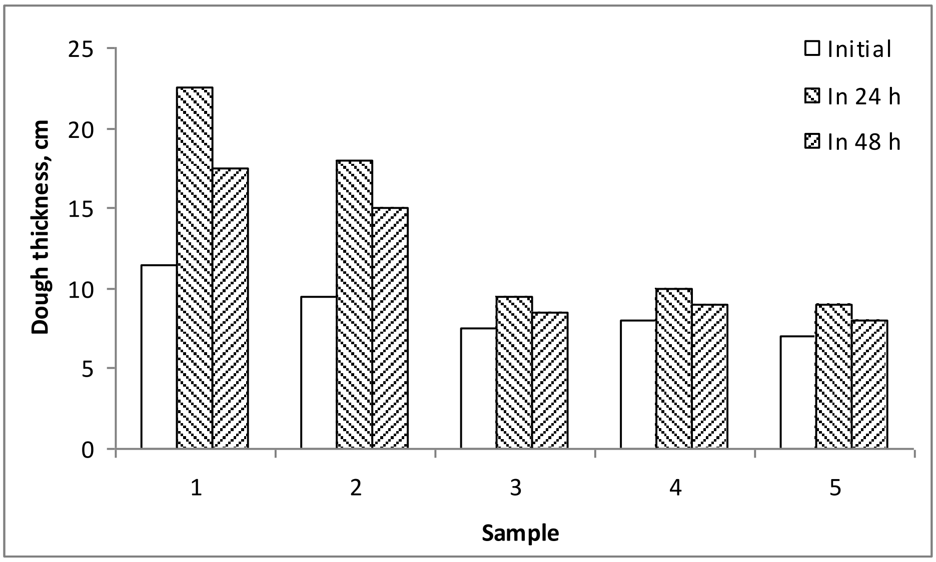

Fig.7. The 48 h changes in the dough thickness for the samples containing alkalized cacao (sample 1), natural cacao (2), beige untreated carob (3), medium-thermotreated carob (4), and dark carob (5) for 60 ^{0}C.

All colloidal systems, including dough, experience aging or thixotropy when some amount of water is released, which causes some compacting of the system [14]. Obviously, thixotropy is one of the reasons for the gradual decrease in the volume of all samples after 48 h.

The fat content of different types of dough is shown in Table 2. It is seen that the most stable and the best swelling alkalized cacao dough indeed contains the most fatty components, while this content is the lowest in the least stable dark carob dough.

Table 2.

Mobile fats content in different dough samples

Sample	Fats content, wt %
Alkalized cacao	14.7
Natural cacao	12.4
Raw beige carob	0.4
Medium processed carob	0.6
Dark carob	0.3

Good swelling of the alkalized and natural cacao dough ensures high porosity, friability, and proper organoleptic characteristics of the confectionery. Since the carob dough swelling is weaker, its organoleptic characteristics are worsening. This effect is less influential for the medium-processed carob powder and more influential for natural and dark carob. The porosity of different types of baked confectionery can be compared directly by measuring their height in the central area (Table 3).

Data from Table 3 prove that alkalized and natural cacao actually increase the porosity and friability of the bakery. Alkalized cacao is more effective than the natural product, but they both improve this organoleptic characteristic of the confectionery within the entire investigated range of the additives contents. A similar but weaker effect was registered for the medium-processed carob, but its influence seems to stop between 7.5 and 10 wt % of the additive when no further rise in dough friability was detected.

Table 3.
Height in the central area of the standardized baked confectionery

Additive	Additive content, wt %	Confectionery height, cm
Alkalized cacao	0	4.2
	2.5	4.6
	5.0	4.8
	7.5	5.1
	10	5.4
Natural cacao	0	4.2
	2.5	4.5
	5.0	4.6
	7.5	4.8
	10	5.0
Natural beige carob	0	4.2
	2.5	4.1
	5.0	3.9
	7.5	3.8
	10	3.8
Medium-treated carob	0	4.2
	2.5	4.3
	5.0	4.4
	7.5	4.5
	10	4.5
Dark carob	0	4.2
	2.5	4.0
	5.0	3.8
	7.5	3.7
	10	3.7

As found in [12], apricot and pumpkin seed provide an effect similar to that of the medium processed carob: organoleptic properties of wheat dough do not change much until the additive's content remains below 5 %, while further increase in this content leads to some deterioration of the dough sensorial properties.
Both types of cacao powder involved in our investigation do not affect the dough porosity and friability at least up to the content of 10 % (see Table 3).
In the case of natural and dark carob dough, the friability decreases with the rise in additive's content, which makes the dough organoleptic properties worse. Therefore, these two components are less suitable as decaffeinating cacao substitutes, while the medium-treated carob can be used for this purpose without significant limitations. It does not change dough color and flavor neither it deteriorates its porosity. Natural and dark carob maintains the color and flavor but worsens the friability of confectionery. The same trend is reported in [11] for the dough with higher contents of carob flour. Even though its sensorial properties worsen, overall organoleptic acceptability in the context of sweetness and aroma remains satisfactory.

4. Conclusion

Carob powder can be used in confectionery after various degrees of thermal processing or as a raw product to substitute cacao to follow some dietary requirements, such as caffeine-free schemes. However, it should be taken into consideration that it affects the rheological and organoleptic properties of dough and the final confectionery.

Similarly to cacao, a medium thermal processed carob increases the dough viscosity, but at a lower degree, while natural and dark carob decreases it. This result should be taken into account for the proper adjusting of dough transportation and storage equipment and machines. All changes in the dough viscosity are caused by additional strengthening/weakening of the inner dough structure because of its stabilization/destabilization by the additives' components extracted from the corresponding flour added to the recipe.

The swelling of all carob dough types is much weaker than that of the cacao-containing dough. Among the carob dough, the one containing a medium-processed carob swells better than the two other carob dough types.

The porosity and friability of carob dough are also worse than that of the cacao types, and the characteristics of the dough containing some medium-treated carob powder are also better than those of the natural and dark carob-containing dough.

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