



Substitution of Critical Ingredients of Cookie Products to Increase Nutritional Value[†]

Giorgos Myrasis^{1,2}, Silvia Aja¹ and Claudia Monika Haros^{1,*}

¹ Instituto de Agroquímica y Tecnología de alimentos, Consejo Superior de Investigaciones Científicas (IATA-CSIC), 46980 Valencia, Spain

² School of Food and Nutritional Sciences, Agricultural University of Athens, 118 55 Athens, Greece

* Correspondence: cmharos@iata-csic.es

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Abstract: In accordance with the current technological advances in the bakery industry, to increase the nutritional value of cookies without affecting their technological and sensorial parameters, critical ingredients of cookie products (flour, sugar, butter) were substituted with whole quinoa flour and by-products of chia (oil and fibre). To optimize the formulation of the cookie (% substitution of critical ingredients) and the baking conditions, factorial design and the response surface methodology were applied. The optimal formulation presented significantly higher amounts of protein content with an improved amino acid profile and ash and fibre contents, while caloric values decreased compared to the control sample. Concerning baking conditions, 170–180 °C and 11 min were found to be the most appropriate conditions for the control formulation. The same conditions were then applied to the optimized formula. As cereal products are one of the sources of acrylamide and as many studies have indicated its carcinogen potential, its concentration in the cookie products was investigated. The International Agency of Research on Cancer classified acrylamide as a probable human carcinogen (Group 2A). The results indicated that the acrylamide levels were lower than the limit concentrations of the regulation (EU) 2017/2158 (350 µg/kg). The results showed that all cookies have acceptable technological and sensorial quality, and the new cookies have highly nutritious properties and health benefits.

Keywords: chia by-products; cookie; nutritional value; quinoa flour; acrylamide



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1. Introduction

Nowadays, the relationship between nutrition and health has become a trend in constant evolution because consumers are aware of the importance of their diet, so they consume foods that are low in fat, salt, and/or calories and high in nutritional value.

Baked products are an important part of one's diet, and today, a great variety of such products can be found by adding innovative ingredients to improve their nutritional characteristics [1]. In particular, cookies are frequently eaten by all segments of the population [2].

Quinoa (*Chenopodium quinoa*) and chia (*Salvia hispanica* L.) are ingredients that stand out for their high nutritional value, containing essential fatty acids (omega-3 and omega-6), high mineral and vitamin content [3], high amounts of fibre [1], and high biological-value proteins and essential amino acids [4]. Therefore, adding these ingredients to the formulation of cookies will nutritionally improve their properties.

As cereal products are a source of acrylamide, and as many studies have indicated its carcinogen potential, its concentration in the cookie products was investigated. The International Agency of Research on Cancer has classified acrylamide as a probable human carcinogen (Group 2A).

This study aimed to investigate the utility of chia and quinoa products as ingredients to produce cookies with high nutritional value and to evaluate their technological and sensorial quality.

2. Materials and Methods

2.1. Materials

The raw materials were commercial flour, whole royal quinoa flour (*Chenopodium quinoa* Willd), and fibre chia fraction (*Salvia hispanica* L.) from BENEXIA Company (Santiago, Chile). Commercial butter, sunflower oil, chia oil, and nonfat dry milk were purchased from local market (Valencia, Spain).

2.2. Cookie Production

The cookie control dough formula was made according to the Approved American Association of Cereal Chemists (AACC) method 10-52 [5]. The cookie formulations with quinoa, chia fibre, and/or chia/sunflower oil were obtained by replacement flour, sugar, and butter, respectively, at three levels (0, 50, and 100% substitution following a factorial design 3³ (Table 1).

Table 1. Ingredients substituted.

1. Critical Ingredients	2. Substitute
3. Vegetable fat or butter	4. Sunflower/Chia Oil
5. Wheat Flour	6. Whole Quinoa flour
7. Sugar	8. Chia fibre *

* Included Stevia.

2.3. Baking Conditions

The conditions for making the cookies were optimized (170–180 °C and 11 min) and were used to elaborate the control, optimized, and 100% substituted formulations.

2.4. Proximate Composition of the Cookies

Analyses of the cookies were completed to determine the total dietary fibre (TDF) and starch according to the approved AOAC Methods 991.43 and 996.11, respectively [6]. Protein determination was performed with the Dumas combustion method and a nitrogen conversion factor of 6.25 (ISO/TS 16634-2) [7], whereas the lipids and ash contents were determined according to the AACC Methods 30-10 and 08-03 [8], respectively.

2.5. Preliminary Sensory Evaluation

The preliminary sensory evaluation was carried out by 20 untrained testers who consume cookies in their everyday life. The parameters that were evaluated were: aspect, texture, taste, and overall acceptability on a 9-point hedonic scale (9) “Especially like”; (8) “Very much like”; (7) “Moderately like”; (6) “Somewhat like”; (5) “Neither like nor dislike”; (4) “Slightly dislike”; (3) “Moderately dislike”; (2) “Very much dislike”; and (1) “Especially dislike” [9].

2.6. Determination of Acrylamide

The UNE-EN 16618:2015 method was implemented to determine acrylamide concentration in the cookie samples (Eurofins Ecosur Laboratory, Murcia, Spain).

2.7. Statistical Analysis

To establish significant differences between samples ($p < 0.05$), one-way ANOVA and Fisher’s least significant differences (LSD) were applied.

3. Results

The optimal formulation, taking into account technological and nutritional parameters, was observed at around 60% substitution of wheat flour for whole quinoa flour, around 80% substitution of butter for chia-sunflower oil mix, and around 50% substitution of sugar for chia fibre fraction with stevia.

To corroborate that the optimal cookie formulation had a better nutritional value than the control, a comparison between samples was completed. The substitution with whole quinoa flour or chia fibre increased the mineral content; the substituted sample at 100% had the highest values, followed by the optimized sample and the control sample. The results are shown in Figure 1. Protein values and total dietary fibre values showed the same pattern as for ashes. The results obtained were due to quinoa having a high content of total minerals (ash). The caloric values of the three samples are represented in Figure 2, where the control formulation has the highest value, followed by the optimized sample, and the 100% substituted formulation showed the lowest value. These results were explained by the fact that the control sample has a significant quantity of simple carbohydrates and is poor in dietary fibre.

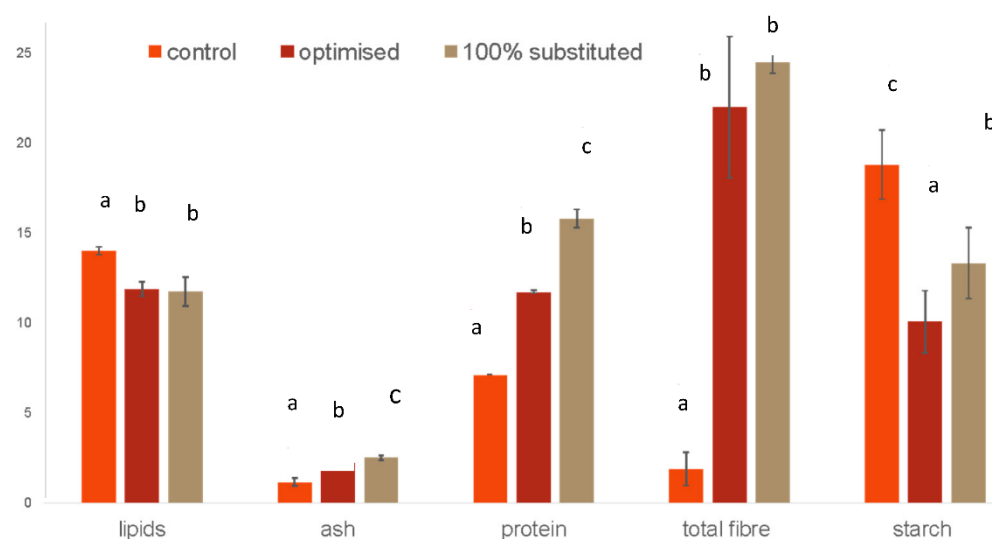


Figure 1. Proximate composition of cookies. Data are expressed as g/100 g in dry matter, mean \pm standard deviation ($n = 3$). Values in bars followed by the same letter are not significantly different at 95% confidence level ($p < 0.05$).

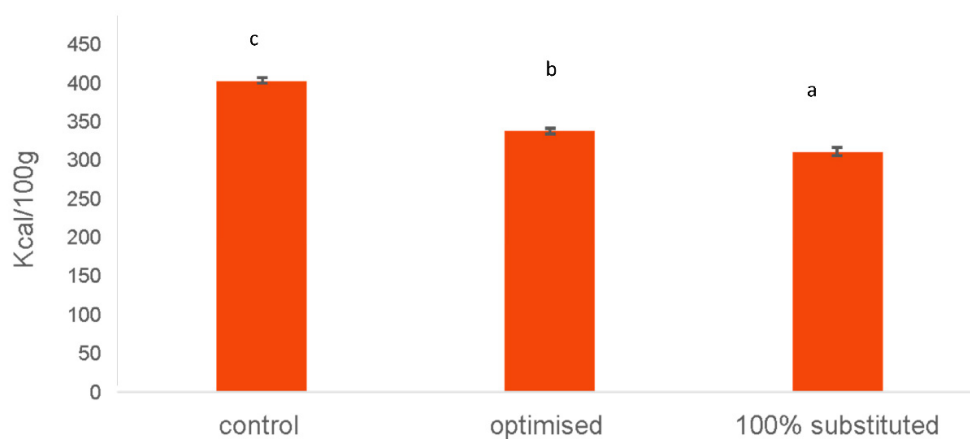


Figure 2. Caloric values of cookies. Data are expressed as mean \pm standard deviation ($n = 3$). Values in bars followed by the same letter are not significantly different at 95% confidence level ($p < 0.05$).

According to the preliminary sensory evaluation, all the studied parameters showed the same pattern: the high value corresponds to the control, followed by the optimized sample and the lowest values for the 100% substituted cookie (Figure 3). However, the samples are acceptable by consumers, with overall acceptability for the optimal formulation between 7 and 8 on the hedonic scale.

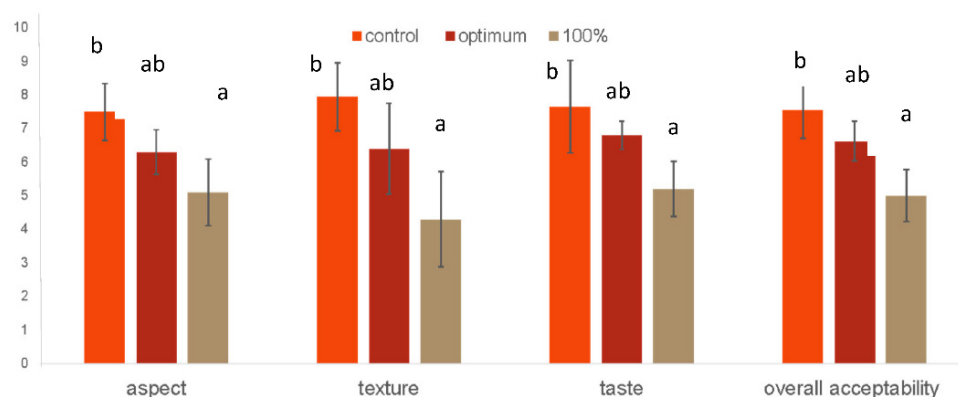


Figure 3. Preliminary sensory analysis on hedonic scale of nine points. Data are expressed as mean \pm standard deviation ($n = 3$). Values in bars followed by the same letter are not significantly different at 95% confidence level ($p < 0.05$).

The International Agency of Research on Cancer [10] has classified acrylamide as a possible human carcinogen (Group 2A). In Figure 4, we can observe the values obtained for acrylamide in the three studied formulations. The results indicate that the highest acrylamide levels were found in the control samples, followed by the 100% substituted cookies, with the lowest value in the optimized sample. All the formulations presented lower values than the recommended limit of the EU Regulation 2017/2158, lower than 350 $\mu\text{g}/\text{kg}$ for biscuits and wafers [11].

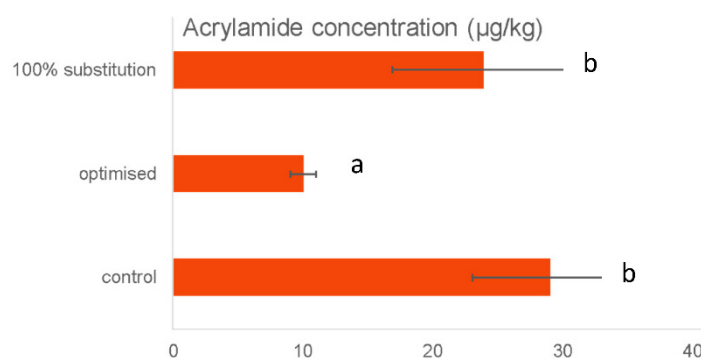


Figure 4. Acrylamide content in cookies. Data are expressed as mean \pm standard deviation ($n = 3$). Values in bars followed by the same letter are not significantly different at 95% confidence level ($p < 0.05$).

4. Conclusions

The optimized sample is highly nutritious and has a similar technological quality to the control sample with lower harmful components, such as acrylamide, than the control. Therefore, the optimized cookie, with the replacement of critical ingredients, is a nutritional and healthy alternative to common cookies for a better diet.

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C.M.H.; supervision, C.M.H.; project administration, C.M.H.; funding acquisition, C.M.H. All authors have read and agreed to the published version of the manuscript.

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