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Improvement of the nutritional value of biscuits by the addition of Spirulina powder and consumer acceptance

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Abstract

The research was conducted in order to evaluate the quality characteristics and consumer acceptance of Spirulina powder-enriched biscuits for the improvement of their nutritional value. The control group was produced only with wheat flour, while in experimental groups a portion of wheat flour was replaced with an equal proportion of Spirulina powder (3, 6, and 9%, respectively). To assess the quality of biscuits the following parameters were determined: moisture, ash and fat content, acidity, saturation capacity, total phenolic content (TPC), peroxide value (PV), *p*-anisidine value (*p*-AV), as well as sensory evaluation and micro structural characteristics. Results showed that fortified biscuits were characterized by higher total phenols values, higher mineral content and reduced oxidative changes. The biscuits baked with the addition of Sirulina powder were significantly harder and darker than the control, but they were still acceptable by consumers. Biscuits fortified with 3% Spirulina powder were highly valued for their appearance, flavour, taste, overall quality, and less for color. In control sample was determined the greatest degree of oxidation measured as PV and *p*-AV, but the degree decreased with the percentage of added spirulina. Incorporation of Spirulina powder improves the nutritional value and quality attributes of biscuits, and also it could retard lipid oxidation during storage.

Keywords: biscuits, Spirulina powder, total phenolic content, peroxide value, sensory evaluation

1. Introduction

The food market, including bakery production, requires a constant adaptation of the product offer to the needs and expectations of consumers. The diversity of consumer preferences is one of the main challenges for the biscuit market. Small but full of resources, the biscuit is distinguished among the bakery specialities by having the highest consumption rate. Quality, appearance and ingredients are the main criteria taken into account by consumers when choosing to buy a certain range of biscuits [1, 2].

There are certain trends in the biscuit market, both in terms of consumption and preferences: the demand for products with increased nutritional values and the focus on healthier products. Innovation is an asset for entering new markets, but also a prompt response to the demands of consumers looking for more refined products [3].

Arthrosphira platensis (Spirulina) a blue-green micro-algae, can be a natural source of bioactive compounds that could be used as a functional ingredient of food, for instance biscuits. A significant number of publications indicate that Spirulina has a stimulating effect on human immune system and also antioxidant and antibacterial properties. Likewise, it prevents the growth of cancerous cells and provides protection against some viruses [4-7].

The algae is a good source of dietary fiber, protein, polyunsaturated fatty acids, antioxidants, vitamins, and minerals. Also, it is an important source of group B vitamins for vegetarians and vegans, whose main nutritional concern is to get adequate levels of vitamins, which can be found primarily in animal products. None of the raw materials can provide as many nutrition elements as *A. platensis* [8-10].

Cracked biscuits are prepared from flour with medium or low gluten, because a high gluten content leads to hard biscuits.

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To reduce the high gluten protein content of a flour, it can be used wheat, potato or corn starch, which reduces the elasticity and increases the plasticity of the dough. Due to its complex composition, the biscuits dough is more difficult to prepare compared to the dough intended for bread preparation, because additional additives reduce the moisture capacity of the flour and gluten elasticity [11].

The dough for sugary biscuits involves an initial mixing of powdered sugar with fats, until it reaches an aliphous consistency without any roughness. The cream is mixed with sugars, eggs and essences homogenised in advance, and finally the flour is added. After homogenization, the leavening agents are added and the kneading continues for 20-30 minutes. The increasing of the mixture temperature to an optimal value, favors the fluidization of certain components, the ability to hydrate the flour and reduce kneading time. Although in dough with higher humidity the development of the gluten network is faster, it is not recommended to use a very wet dough, because it occurs a negative influences on the texture and shape of biscuits. After kneading the dough is left at rest, when the dough is matured, by repairing gluten threads damaged at kneading. This leads to the improvement of the rheological characteristics of the dough [12, 13].

Inappropriate storage or low humidity, leads to defective biscuits such as absence of volume and porosity, ruptures, and surface blisters. Also, if the thickness of the dough layers is too high, the dough layers in the lower part are heated, chemical decomposition is very fast and they break apart completely during the resting phase. The formed gases will be largely eliminated at rolling and the final products will have low porosity and volume. The cooling of biscuits should be done as soon as possible, to strength the structure of the product, making it more resistant [14, 15].

Bakery products fortification can help address micronutrient and malnutrition issues. Micronutrients play an important role in achieving and maintaining optimal health across all life stages. Vitamins are essential nutrients for many body functions and are particularly important during growth as well as for certain vulnerable groups, such as pregnant women, young children, and the elderly. The nutritional fortification of biscuits could provide an alternative fortified snack to help alleviate malnutrition in adults and children [16].

Biscuits with Spirulina powder could provide a solution for those people who do not want to give up certain eating habits. They could be an alternative to what is already available on the market and will be in line with the current trend favoring natural foods.

The aim of the study was to evaluate the influence of different levels of Spirulina powder on the physicochemical and quality characteristic of shortbread biscuits and their consumer acceptability. To assess the quality of biscuits the following parameters were determined: moisture, ash and fat content, acidity, saturation capacity, total phenolic content (TPC), peroxide value (PV), *p*-anisidine value (*p*-AV), as well as sensory and microscopic examination.

2. Materials and methods

2.1 Samples

Biscuits were prepared according to the formulations presented in Table 1. The control group was produced only with wheat flour (R1), while in experimental groups (R2, R3, and R4) a portion of wheat flour was replaced with an equal proportion of Spirulina powder (3, 6, and 9%, respectively). Biscuit blends were prepared by adding flour, powder sugar, butter, sour cream and mechanically beaten for 5 min. Wheat flour was substituted with Spirulina algae powder at 3, 6 and 9% (w/w) ratios. The biscuits were backed in an electric oven at 180 ºC for 15 min. After cooling for one hour, biscuit blends were packed in polyethylene bags. The samples were used to evaluate organoleptic properties and physicochemical parameters.

Table 1. Formulation of the biscuits

Samples	Wheat flour (%)	Spirulina powder (%)	Powder sugar (g)	Butter (g)	Sour cream (g)	Sodium bicarbonate (g)
R1	100	0	150	200	10	1.0
R2	97	3	150	200	10	1.0
R3	94	6	150	200	10	1.0
R4	91	9	150	200	10	1.0

2.2 Physicochemical and sensory examination

The chemical composition of the products was determined according to the methods described by Masoodi et al. [17] and Pop F. [18]. Acidity is based on the extraction of the biscuits acids and their titration with sodium hydroxide 0.1 N, using phenolphthaleine, as an indicator. The results were expressed as degree of acidity. Determination of moisture content is based on drying of a sample with known initial mass to a constant mass. The content of mineral substances is based on the calcination of a known mass of product up to constant weight.

Total phenolic content (TPC) was determined using the Folin-Ciocalteu reagent according to the method described by Singleton and Orthofer [19]. A volume of 0.5 mL of Folin-Ciocalteu reagent previously diluted with distilled water (1:10) was mixed with 2.5 g of ground biscuits dissolved in 7.5 mL of ethanol. The solution was allowed to stand for 5 min at 25 °C before adding 1.7 mL of sodium carbonate solution (20%). Then, 10 mL of distilled water were added to the mixture, and the absorbance was measured at λ=735 nm after 20 min of incubation with agitation at room temperature. Results were expressed as mg of gallic acid per kg sample.

Total fat was extracted by Soxhlet method and peroxide value and *p*-anisidine value were determined to quantify primary and secondary oxidation products.

Peroxide value (PV) was determined using a UV-VIS T60U spectrophotometer (Bibby Scientific, London, UK). A test portion was dissolved in a mixture of chloroform/methanol (2:1, v/v), then iron(II) chloride and ammonium thiocyanate were added. The peroxides in the sample oxidize the iron(II) ions to iron(III). Ammonium thiocyanate forms with iron(III) a red complex. The absorbance of each sample was read at 500 nm against blank. To quantify the peroxides in the sample, a calibration curve was constructed using iron(III) chloride. The PV has been expressed as meq O_2/kg [19].

P-anisidine value (*p*-AV) was determined spectrophotometrically using a UV-VIS T60U spectrophotometer (Bibby Scientific, London, UK) by measuring absorbance at 350 nm and to characterize the secondary oxidation products.

Panels of 15 judges, who are familiar with the quality characteristics of biscuits, were recruited to perform the sensory evaluation of spirulina enriched-biscuits using a 5-point hedonic scale. Attributes, which are indicative of major quality differences were selected, i.e. color, flavour, taste, appearance, and firmness.

Microscopic examination was performed with an Optika-B290 microscope equipped with tablet (Optika, Italy), with the following technical characteristics: binocular, 360° rotating and 30° inclined; interpupillary distance from 48 to 75 mm; built-in 3.1 MP camera; double layer rackless mechanical sliding stage; vernier scale on the two axes, accuracy: 0.1 mm; Abbe N.A. 1.25 condenser, with objective-coded iris diaphragm, focusable and centerable; objectives: N-PLAN 4x/0.10, N-PLAN 10x/0.25, N-PLAN 40x/0.65, N-PLAN 100x/1.25.

All analytical determinations were performed at least in triplicate. Values of different parameters were expressed as the mean ± standard deviation (X ± SD). Significant differences between mean were determined by using “Student” (“t”) distribution.

3. Results and Discussion

In the present study, the influence of different levels of Spirulina powder on sensory and physicochemical characteristic of fortified biscuits was evaluated. Chemical analysis results for biscuits formulations are presented in Tables 2.

Moisture and fat content were not significantly influenced by added microalgae powder. Control biscuits (R1) and biscuits with 3% Spirulina powder (R2) presented a higher moisture content, while biscuits with 9% Spirulina powder (R4) presented the lowest value. This may be due to high fiber, protein, and hydrophilic colloids presented in Spirulina, which have the ability to bind the available water and contributes to reduce moisture content.

The value of acidity increased with the percentage of spirulina in biscuits formulations. Also, the addition of spirulina has led to an substantial increase in the content of minerals, biscuits with 9% Spirulina powder presented the highest value.

Table 2. Proximate analysis of biscuits

Parameters	R1	R2	R3	R4
Moisture (%)	$4.60^{a} \pm 0.01$	$4.50^{a} \pm 0.03$	$3.90^{ab} \pm 0.02$	$3.70^{b} \pm 0.04$
Ash (%)	$0.52^{a} \pm 0.03$	$0.70^{ab} \pm 0.01$	$0.82^{b} \pm 0.05$	$1.12^{bc} \pm 0.02$
Fat (%)	$26.8^{a} \pm 0.02$	$27.4^{a} \pm 0.01$	$26.9^{a} \pm 0.03$	$27.9^{ab} \pm 0.04$
Acidity (mL NaOH 0.1N/100g)	$0.86^{a} \pm 0.04$	$0.99^{ab} \pm 0.05$	$1.13^{b} \pm 0.02$	$1.24^{bc} \pm 0.01$
Saturation capacity (%)	$11.5^{a} \pm 0.02$	$12.9^{a} \pm 0.05$	$13.6^{ab} \pm 0.01$	$14.8^{b} \pm 0.03$
Dought elasticity (%)	$36.2^{a} \pm 0.03$	$34.1^{ab} \pm 0.02$	$32.4^{b} \pm 0.04$	$29.7^{c} \pm 0.01$
Total phenolic content (mg/kg gallic acid)	$152.6^{a} \pm 0.02$	$244.4^{b} \pm 0.04$	$364.2^{c} \pm 0.03$	$482.7^{e} \pm 0.05$

Values are means of triplicates ± standard deviation. Values with the same superscript in a line are not significantly different ($p > 0.05$).

Total phenolic content (TPC) of evaluated biscuits is shown in Table 2. There was a significant effect of concentration of the added algae powder on TPC values. It was observed that biscuits with Spirulina had more phenolic compounds than the control, and their contents increased with the level of algae addition, from 3 to 9%. Similar trend in TPC values of cooked pasta enriched with Spirulina biomass was found by Rodríguez De Marco et al. [9]. The incorporation of *A. platensis*, due to higher TPC values of fortified biscuits in comparison with control group, could for extance to retard lipid oxidation.

Lesiak M. et al. [3] studied the effect of the addition of Spirulina powder on physicochemical properties and consumer acceptability of shortbread biscuits during storage. The results showed that biscuits baked with the addition of Spirulina powder were significantly harder and darker than the control during the whole period of storage. The researchers observed that in each day of storage, biscuits with Spirulina had more phenolic compounds than the control, and their contents increased with the level of algae powder addition. Also, the addition of Spirulina powder reduced oxidative changes of shortbread biscuits during storage.

Amino acids composition of biscuit blends fortified with different levels of dried Spirulina algae were determined [20]. The study showed that biscuits blends fortified with different levels of dried Spirulina had the highest amount of indispensable amino acids than control biscuits.

The researchers also determined the minerals content of fortified biscuits, including sodium, potassium, calcium, phosphorus, magnesium and iron. They concluded that adding dried Spirulina algae to biscuit blends increased minerals content of all samples. It was noticed that there were significant difference between all biscuits blends and the control in all studied minerals except for phosphorus.

A significant decrease in PV an *p*-AV values was registered in Spirulina enriched-biscuits (Fig. 1). In control samples was determined the greatest degree of oxidation, and the degree decreased with the percentage of added spirulina. The results showed that Spirulina powder could retard lipid oxidation in enriched-biscuits.

Ramadan et al. [7] as well as El-Baky et al. [21] demonstrated that the fatty acid composition and high amounts of PUFA make the *A. platensis* lipids a special component for nutritional applications. Due to the fact that lipid oxidation is dependent on the level of unsaturation, a greater proportion of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) decreased the quality and storage stability of biscuits.

Rekha et al. [22] studied the incorporation of various levels of Spirulina powder in cooking pastas from non-durum wheat. The results indicated that enriched-cooking pastas had lower cooking loss, swelling index and texture values than the control. Overall sensory scores of all fortified pastas was low as compared to the control except in the case of 1% enriched-pasta which had a score comparable with the control.

For dough with Spirulina, color parameters were characterized by green tonality, which depended on the algae incorporation.. Green color decreased compared to the dough after baking, but was still dominant in fortified biscuits and increased with the amount of added Spirulina. The biscuits baked with the addition of algae were significantly harder than the control samples. It was also observed that hardness of biscuits increased with Spirulina content in the formulations. This may be due by its high carbohydrates and proteins contents and is in agreement with another study, which determined the effects of microalgae on biscuits texture [23].

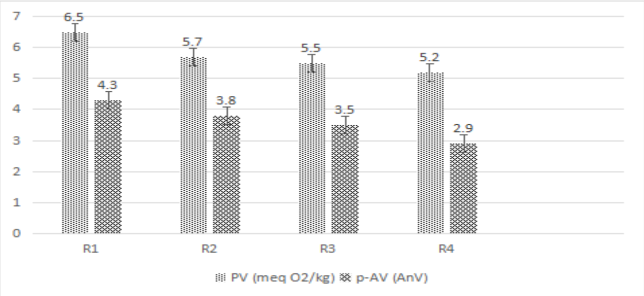

Figure 1. Values of PV and *p*-AV for biscuits formulations

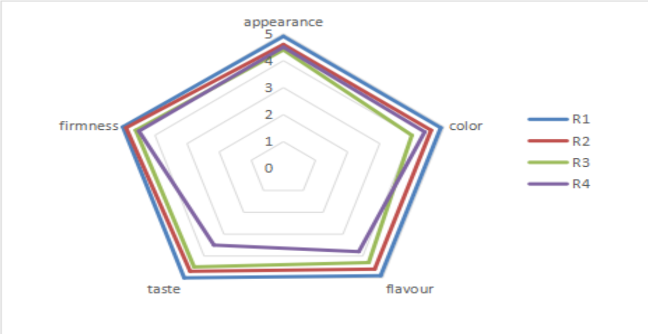

Figure 2. Sensory analysis of biscuits

Biscuits with 3% added Spirulina were top rated by the consumer's panel, scoring a statistically significantly higher value ($p < .05$) in the overall acceptability than groups with the addition of 6 and 9% Spirulina. These results are in accordance with Shahazizadeh et al. [20] who reported lower scores of hedonic tests for Iranian traditional cookies containing 8% algae.

Sharma and Dunkwal [24] prepared biscuits with 10% dried Spirulina algae in India. They found that mean score for overall acceptability of value added biscuit was 7.5 against the control sample, 7.9 on nine point hedonic ranking scale.

Accepted high percentage (10% dried Spirulina algae) in the Indian study and unaccepted even half of it (4% dried Spirulina algae) in the Egyptian study [25] could be attributed for panel members, food culture and habit. The eating habits of an individual are acquired depending on one's environment or family experiences.

According to microscopic analysis, the protein-starch network was not affected by the addition of *A. platensis* powder.

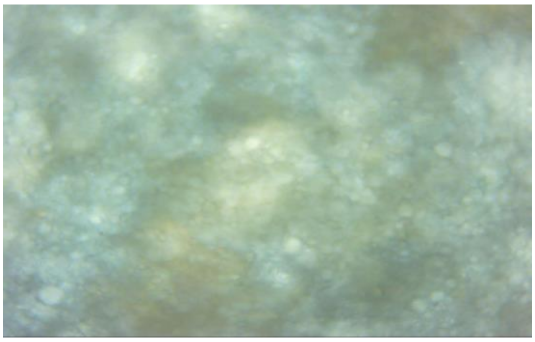

Figure 3. Microstructure of control biscuits

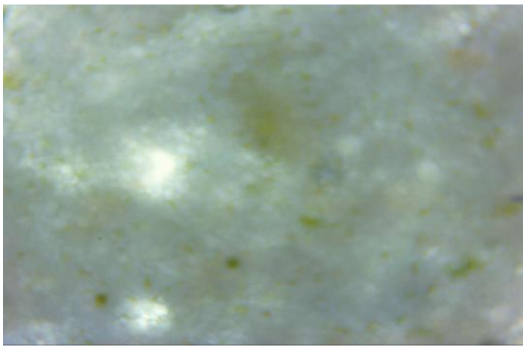

Figure 4. Microstructure of biscuits with 3% spirulina powder

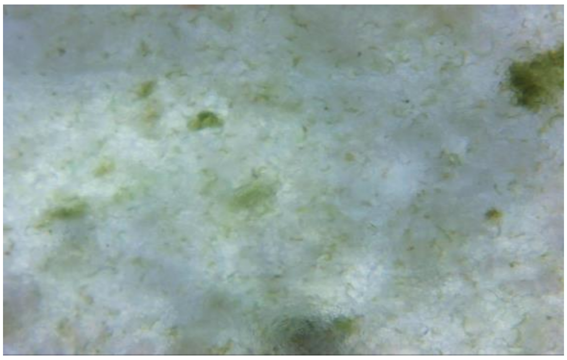

Figure 5. Microstructure of biscuits with 9% spirulina powder

4. Conclusion

Different levels of Spirulina powder were incorporated to prepare biscuits and their quality attributes were studied. When compared to control group, the fortified biscuits were characterized by higher total phenols values and mineral content, and reduced oxidative changes.

The incorporation of algae matter has led to a greater hardness of biscuits with the increase of Spirulina content in the formulations. A slight decrease in the green tonality was observed in the baked biscuits compared to dough, and the color increase with Spirulina content in the formulations. Biscuits with 3% Spirulina powder were highly valued for their appearance, flavour, taste, overall quality, and less for color.

It may be concluded that the incorporation of Spirulina powder improves the nutritional value and quality attributes of the biscuits, and also it could retard the lipid oxidation during storage.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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