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PASTRIES WITH FUNCTIONAL SPIRULINA PLATENSIS INGREDIENTS

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Abstract. The aim of the research is to develop new bakery products with increased functional value by adding ingredients from the biomass of *Spirulina platensis*. High quality wheat flour (P1), oatmeal (P2) and whole wheat flour (P3) sticks were formulated with the addition of 3% S2 preparation based on spirulina, thus increasing the bioavailability of the active components in microalgae. It was established that the addition of S2 preparation in sticks results in an increase in the total polyphenol content by 41.67% in the P2 samples of oatmeal sticks and by 56.17% in the P3 samples of whole wheat flour. The addition of S2 leads to a decrease in the content of reducing sugars by up to 2.56% in P1, by 2.50% in P2 and by 2.19% in P3 compared to the control. In sticks with the addition of S2, the fat content of cyanobacterial origin increases by almost 3.2% in sample P1, by 4.4% in P2 and by 6.0% in P3 compared to the control samples. The research results show that the use of the preparation based on *Spirulina platensis* contributes to increasing the nutritional value of flour products through the increased intake of amino acids, fatty acids of cyanobacterial origin, minerals, vitamins and bioactive substances, which are missing in conventional products, consumed daily. The S2 preparation based on microalgae, rich in pigments - chlorophylls, carotenes and phycocyanins with beneficial properties for health, could be used as a natural food dyes.

Keywords: *antioxidants, microalgae biomass, pigments, bakery products, bioactive substances, nutritional value, reducing sugars.*

Introduction

The market's tendency, nowadays, is to meet the requirements of the modern consumer for functional foods and nutraceuticals, important for the proper functioning of the body. Today, science emphasizes the relationship between human health and nutrition, thus encouraging the creation of foods with certain properties and structures, made from high quality raw materials, rich in antioxidants, vitamins, minerals, proteins, fibers, etc., naturally sourced and ecologically friendly [1]. Besides the traditional sources like fruits, vegetables, berries and plants, highly nutritive sources of food are the algae.

Microalgae biomass is considered a superior source of phytonutrients and antioxidants, not only due to its much higher productivity, compared to the conventional terrestrial sources, but also due to the cell's content of substances, estimated as follows: 8-14 % pigments, 12-30 % carbohydrates, 4-20 % lipids, 40-70 % proteins and vitamins A, C, B₁, B₂, B₁₂, E, K, D [2, 3].

Many scientific studies have shown that the bioactive substances synthesized by microalgae exhibit antioxidant properties, protect cells from the ultraviolet radiation, reduce the oxidative stress in the body and modulate the immune system [4, 5].

In order to increase the nutritional and functional value of the conventional foods, microalgae and phytonutrients from microalgae are used to fortify pasta, bakery products, snack foods, confectionery, sweets, beverages, dairy, etc. [1 - 7]. Various additives are obtained from microalgae, such as agar-agar, carrageenan with emulsifying and thickening properties, used in producing dairy, ice-cream and confectionery products. Another food additive obtained from microalgae is the alginate. It prevents delamination and it is used in the manufacturing of sauces, mayonnaise, etc. On top of that, microalgae and preparations derived from them can be used as natural dyes and vitamin precursors, harmless to the human body and can replace noxious, chemically synthesized, food additives and dyes [1, 8-10].

Spirulina species are multicellular, filamentous cyanobacteria and have been widely used as a nourishment source since the ancient times [11]. It is proven that spirulina contains 6.7 times more protein than tofu, 1.8 times more calcium than milk, 51 times more iron than spinach and 31 times more carotenoids than carrots [3 - 5]. It contains approximately 2000 functional components such as vitamins, pigments, minerals, amino acids, including essential amino acids and enzymes [5, 12].

Spirulina sp. is also used for its' antioxidant, immunostimulatory and cholesterol-lowering properties, while the sulfur polysaccharides contained in its' biomass have an antiviral function [13, 14]. Spirulina biomass extract exhibits antimicrobial activity. There are several benefits provided by the microalgae carotenoids to the animal organisms, including the activity of provitamin A. The therapeutic value of carotenoids cannot be ignored, as they are used in the prevention and treatment of chronic inflammatory diseases, cancer, treatment of cardiovascular, renal, pulmonary, hepatic, intestinal diseases, treatment of metabolic disorders and autoimmune diseases, etc. [13 - 15]. As for lutein and zeaxanthin, microalgae carotenoids vital for the eyesight, they prevent the deterioration of the retina and protect it against light and ultraviolet radiation [14, 16].

Many countries have safety standards for spirulina use. The food safety rules have been developed in Japan and the United States. Studies initiated in 1980, by the United Nations Industrial Development Organization (UNIDO), have proved the safety and the benefits of spirulina as human food [17].

Bakery products with microalgae

Bakery products have an important role in the food preferences of the modern consumer due to their taste, appearance, texture, ease of preparation and effect of satiety. Nevertheless, the content of proteins, vitamins, minerals, dietary fibers in bakery products is insignificant. Therefore, bakery products can serve as a support (matrix) for vital nutrients. The use of microalgae in bakery can provide with nutrients with a modified color and functional characteristics, such as an antioxidant activity [18].

Research conducted in the field of bakery products, fortified with macro and microelements from algae, has shown that the addition of 1 % of *Laminaria* in biscuits increases their nutritional value, enriching them with the vitamins of group B [19]. Brown algae (*Fucus*), some of the richest sources of iodine [20], were powdered and added to high quality flour cakes, in a ratio of 3.7 and 12 % of the flour mass [21, 22].

Salehifar et al. [23] investigated the impact of spirulina (0.5, 1.0 and 1.5 %), used in the production of the traditional Iranian biscuits, on the nutritional properties, color and texture. Another study shows that adding *Spirulina sp.* and *Chlorella sp.* to noodles, results in good nutritional, organoleptic (color, smell, taste) and structural properties [24].

As per bibliographic data [25], technologies of manufacturing frozen dough, with the addition of spirulina, have been developed. It turned out that adding spirulina to the frozen dough, increases the intake of dietary fibers, amino acids and *Ca, Mg, Fe, Zn, Cu, Se*, etc., minerals, and enhances the rheological properties of the dough.

Considering all the above, researching the opportunity of using the microalgae biomass as a source of phytonutrients and natural food dyes and developing new functional products, has become the new goal of the modern food industry [26].

Research methods and materials

The main ingredients for the sticks' production were the flours from the cereal group: high quality wheat flour „Băneasa”, Romania, oat flour from finely ground flakes „Haferflocken OATS”, Germany, whole wheat flour „Beatrice-Com” [27] and the *Spirulina pl. (Arthrospira platensis)* based *S2* preparation. The manufacturing recipes include other ingredients as well: caster sugar [28], table salt, vegetable oil [29], baking powder [30] and whole milk (1.5 % fat) [31].

The *S2* preparation was elaborated by the „Ficobiotehnologie” laboratory of the Institute of Microbiology and Biotechnology of Moldavian Academy of Science and consists of biomass extracts of cyanobacteria of *Spirulina platensis* CNM-CB-02. The cyanobacteria were inoculated in nutritious environments with a selected composition, which stimulates the production of pigments, free amino acids and oligopeptides [32]. The biomass was further separated from the cultural liquid, demineralized, frozen and thawed; then the biomass was subjected to extraction with harmless solvents (aqueous ethylic alcohol 30-85 %). The alcoholic extracts, with a content of lipophilic and hydrophilic biocomponents, were separated, purified and dried, as per the elaborated method [33, 34].

Determination of the pigment content in *S2*

The content of porphyrin pigments in the spirulina based *S2* preparation was determined through the Spectrophotometric method (*DR5000*), according to the method described in bibliography [35]. For this, 0.2 g of *S2* was dissolved in 10 mL of methyl alcohol, then centrifuged for 10 minutes at 2500 *rot·min⁻¹*. The procedure was repeated twice. The supernatants were recovered, transferred to volumetric flasks and the volumes were adjusted with solvent. Samples were obtained in three repetitions. The total chlorophyll concentration was estimated by the spectrophotometric method. The calibration curve was developed based on chlorophyllin solution in methanol in the concentration range of 5 - 100 $\mu\text{g}\cdot\text{mL}^{-1}$.

Extract samples were analyzed after appropriate dilution. The absorbents were recorded at a length of $\lambda=650\text{ nm}$.

Determination of quality and technological properties of the flours

To determine the quality and the technological properties of the protein and aproteic flours, sensory analysis methods and physicochemical methods were used [36]: the total compliant ash content, moisture, titratable acidity, the Hagberg falling number. Flour quality indicators and technological properties were tested: the organoleptic characteristics, granularity of the flour (particle size – with the *Motic DM* Digital microscope, with the 40X image enlargement option (S)). The functional properties were determined as well: the quantity of the gluten and the hydration capacity, according to standard international methods [36].

Preparation of sticks

The preparation technique of the dough for the sticks implies the direct work process, as per the classical method [37]. Known methods were used to determine the physicochemical indicators of the dough – alkalinity, moisture, the influence of the hydrocolloids on the physicochemical and rheological parameters of the dough [36].

Determination of the quality of the experimental stick samples

To determine the quality of the experimental samples, the following sensory and physicochemical methods were used [38, 39]. Moisture content, alkalinity, the fat content by refractometric method, reducing sugars concentration by *G. Bertrand* method, soaking index (wettability), total ash, including the insoluble in HCL solution (10 %), were determined following standard methods SR 91:2007 [40] and [41].

Determination of total content of polyphenols (TCP) in sticks

A total phenolic content assessment was carried out according to [42], with minor modifications, using the Folin Ciocalteu assessment. Samples of 0.3 g of ground sticks were dissolved in 15 mL of methanol: deionized water (6:4, v/v) and sonicated (ISOLAB Laborgeräte GmbH) for 30 min at maximum power (frequency 20 kHz and power 130 W) and a temperature below 30 °C. The extracts were centrifugated (10 min, 2500 rot·min⁻¹) and the supernatants were collected. The experiments were conducted in 3 repetitions. An aliquot (0,1 mL) of the aqueous methanolic phase was diluted with water to a total volume of 6.5 mL, followed by the addition of 0.5 mL of the Folin-Ciocalteu reagent. After 8 min of incubation at room temperature, 3 mL of sodium carbonate solution (10 %) was added to the reaction mixture. The mixture was incubated in a water bath at 40 °C. After 30 min, the soaking index of the preparation was measured with a DR5000 spectrophotometer at a wave length of 765 nm.

Results were expressed in gallic acid equivalents ($mg\ GAE \cdot g^{-1}$) through a calibration curve (gallic acid: 0 to 1000 mg/L, $R^2 = 0.9997$).

Statistical analysis of the experimental data was performed [43] through variance analysis (one way ANOVA), by comparison at a significance level of 95 % ($p \leq 0.05$). All tests were performed in triplicate and all results have been presented as average \pm standard deviation. All calculations were made using IBM SPSS Statistics 23 and Microsoft Excel 2010.

Results and discussion

The S2 preparation, elaborated by the „Ficobiotehnologie” laboratory of the Institute of Microbiology and Biotechnology of Moldavian Academy of Sciences, consists of biomass extracts of cyanobacteria of *Spirulina platensis*. According to the results of several years of studies, conducted at the „Ficobiotehnologie” laboratory of IMB of ASM, under the supervision of the academician Rudic Valeriu, the biomass obtained from cyanobacteria,

grown in nutritious environments with a selected composition, has a rich content of phytonutrients and biologically active substances (Table 1) [2].

Table 1

Biochemical composition of *Spirulina platensis* biomass (from dry mass) [2].

Components	%	Components	
Proteins	61 - 68	Ascorbic acid	$>1.17 \text{ mg} \cdot \text{g}^{-1}$
Free amino acids	4 - 6	α -tocopherol	$>0.1 \text{ mg} \cdot \text{g}^{-1}$
Lipids,	5 - 61	Cyanocobalamin	$>0.017 \mu\text{g} \cdot \text{g}^{-1}$
Gamma-linolenic acid	1 - 1.4		
Carbohydrates	10 - 17	Zn	0.2-0.4%
Chlorophylls	1 - 2	Fe	1.0-1.15%
Carotenes	1.2 - 4	I ₂	<0.2%
β -carotene	0.2 - 0.4		
Phycobiliproteins	12 - 14	Other minerals	
C-Phycocyanin	1.25 - 9	Na, K, Mg, Ca, P, Cu, Cr, B	
allophycocyanin	1.2 - 6		

The S2 preparation was obtained from the spirulina biomass (separated from the cultural liquid, demineralized, frozen and thawed) with aqueous ethylic alcohol.

The alcoholic extracts, with a content of lipophilic and hydrophilic biocomponents, were separated, purified and dried [2, 33]. S2 is an intense green powder with a pleasant smell. The preparation has a moisture value of $6.89 \pm 0.24 \%$ and a content of ash of $6.08 \pm 0.2 \%$. The content of chlorophylls in the S2 preparation, obtained from *Spirulina pl.* biomass, was determined as per the procedure described in bibliography [35]. Spectrophotometric analysis and calibration curve measurements for chlorophyllin show that S2 contains $6.41 \pm 0.3 \text{ mg} \cdot \text{g}^{-1}$ porphyrin pigments.

Three types of flour were used to make the sticks: high quality wheat flour „Băneasa” (Romania), oat flour from finely ground flakes „Haferflocken OATS” (Germania), whole wheat flour „Beatrice-Com” (Moldova) and the S2 spirulina-based preparation. The sensory analysis established that the flour used to obtain the stick samples comply with quality requirements [27]. Following the physicochemical determinations, it was established that the registered parameters for the used flours fall within the permissible limits, Table 2.

Table 2

The experimental results regarding the psychochemical analysis of the used flours

Raw material or auxiliary	Moisture, %	Acidity, degrees of acidity	Ash content, %	Falling numbers	Gluten content, %	Content of ferromagnetic impurities, $\text{mg} \cdot \text{kg}^{-1}$
High quality wheat flour	14.5 ± 0.3	2.2 ± 0.3	0.45 ± 0.1	300 ± 10.0	24.4 ± 0.3	Not found
Oat flour	9.6 ± 0.3	5.0 ± 0.3	1.03 ± 0.1	250 ± 10.0	Not contain	Not found
Whole wheat flour	10.3 ± 0.3	4.0 ± 0.3	1.29 ± 0.1	250 ± 10.0	$15.2\% \pm 0.3$	Not found

Note: Results are expressed as average \pm standard deviation ($n = 3$). Comparison at a significance level of 95 % ($p \leq 0.05$).

Following the determination of the acidity of the raw materials used, it was found that these values correspond to the types of the flour analyzed (Table 2).

The crude ash contains mineral substances obtained as a result of the complete combustion of the organic substances. This index should not exceed 0.55 % for the high quality wheat flour, 2.1 % for the oat flour and 2.0 % for the whole wheat flour [27].

The gluten content determined in high quality wheat flour is $24.4 \% \pm 0.3$, in whole wheat flour - $15.2 \% \pm 0.3$ and oatmeal does not contain gluten (Table 2).

Following the determination of the falling number of the analyzed materials, the obtained values correspond to the types of flour analyzed. The obtained values fall within the established limits; the falling number for the high quality wheat flour being of 300 s, and of 250 s for both the oat and the whole wheat flour [36].

The granularity of the flours has an impact on the following: hydration capacity, the rheological properties of the dough, the activity of the amylolytic enzymes and the quality of the finished product. According to the microscope images (Figure 1), the whole wheat flour has the largest particles, of $250 \mu\text{m}$. The high quality wheat flour has particles of $55 \mu\text{m}$ [27, 44].

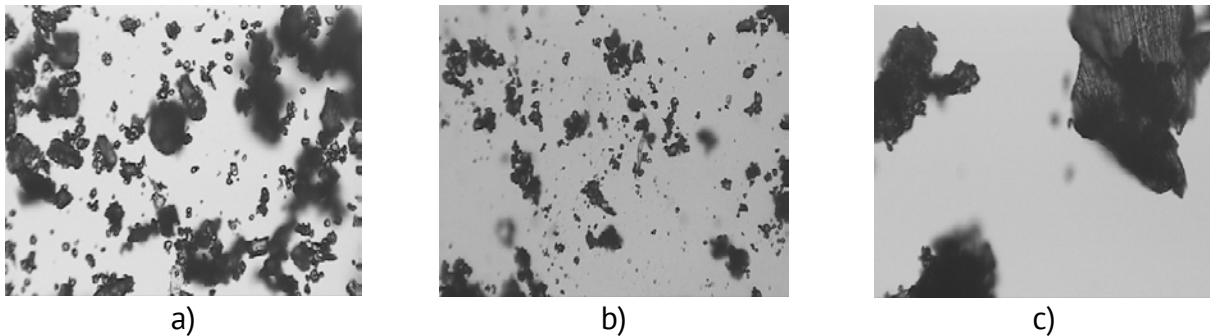


Figure 1. Particle size of the materials used: a) High quality wheat flour; b) Oat flour; c) Whole wheat flour.

The oat flour has the smallest particles, of $50 \mu\text{m}$. It also has the most uneven particles, as the flour was obtained from oat flakes ground in a grinder [27].

The hydrating capacity of high quality wheat flour is maximum, $63.0 \% \pm 0.3$, due to the high content of protein substances [36]. Oat flour has a hydrating capacity of $57.0 \% \pm 0.2$ and whole wheat flour - $54.0 \% \pm 0.2$. The dough preparation technique involves the direct process, where all the ingredients are kneaded for 10-15 minutes. The obtained 3 types of products have a different consistency of the dough, depending on the flour used. Due to the high content of gluten, the dough made from high quality wheat flour has soft consistency and sufficient elasticity. The dough obtained from oat flour and whole wheat flour has a low gluten content, thus is firmer, more crumbly and less elastic.

In order to evaluate the quality of the semi-finished products, their main characteristics were determined: the influence of hydrocolloids on the physicochemical and rheological parameters of the dough, the moisture of the dough. The baking powder increased the degree of alkalinity. The dough from oat flour with addition of S2 has the higher alkalinity degree ($2.3 \pm 0.1 \%$) due to the particularities of this type of flour; followed by the dough from whole wheat flour fortified with S2 ($2.2 \pm 0.2 \%$) and the dough from high quality wheat flour, with the lowest alkalinity ($1.5 \pm 0.2 \%$).

The hydration capacity of the flours is important for the dough structure; the finer the flour granules, the higher the water absorption. The moisture of the semi-finished

products was determined to be in the range of 29.9 - 35.2 %. Due to the falling number and the flour granularity, the dough from oat flour with the addition of S2 has the smallest moisture value (29.9 ± 0.2 %), followed by the dough from whole wheat flour with the addition of S2 (31.1 ± 0.1 %). The highest value belongs to the dough from high quality wheat flour with S2 (35.2 ± 0.1 %); it also has an increased protein content.

Testing the nutritional and functional character of the finished flour products – sticks with addition of S2

The assessment of the moisture of the finished products resulted in values that do not exceed the established norms, which is due to the same consecutiveness in the flours used [40, 45].

After the incorporation of the S2 preparation in the recipes, a non-essential increase of the moisture values was detected in all of the samples, if compared to the control samples (Table 3), as follows: with 0.29 % in P1, with 1.6 % in P2 and with 1.4 % in P3.

Due to the modification of the sticks' recipe by adding the baking powder as a loosening agent for the dough, the finished products have an alkaline environment. The alkalinity values of the finished products do not exceed the established norms (Table 3). These values are lower compared to the semi-finished products due to the baking process, where biochemical and microbiological processes reduce the alkalinity [46].

The fat content was determined accordingly [41]. The obtained data show that P2 has the highest fat value (due to the chemical composition of the oat flour [27]) and contains approximately 8.54 % lipids. The second in line is the product P1, which contains about 6.70 % lipids. P3 has the lowest value, with a lipid content of about 5.50 %. As it can be noticed, the incorporation of S2 in the recipes led to an essential increase in the fat content in all of the samples, compared to the control samples, as follows: an increase of 3.20 % in P1 compared to PM 1, an increase of 4.43 % in P2, and a 6.0 % increase in P3 compared to PM3 (Table 3).

Table 3

The experimental results regarding the analysis of the physicochemical factors of the finished products.

Physico-chemical indices	Obtained products					
	Sticks from wheat flour (PM1)	Sticks from wheat flour with spirulina (P1)	Sticks from oat flour (PM2)	Sticks from oat flour with spirulina (P2)	Sticks from whole wheat flour (PM3)	Sticks from whole wheat flour with spirulina (P3)
Moisture, %	6.78 ± 0.3	6.80 ± 0.1	6.10 ± 0.1	6.20 ± 0.2	6.41 ± 0.1	6.50 ± 0.3
Alkalinity, degrees		1.0 ± 0.1		2.0 ± 0.1		1.90 ± 0.09
Ash, %	0.07 ± 0.3	0.10 ± 0.2	0.55 ± 0.2	0.60 ± 0.3	0.75 ± 0.3	0.80 ± 0.1

Continuation Table 3

Fat, %	6.49 ± 0.24	6.70 ± 1.3	8.19 ± 0.4	8.54 ± 1.1	5.19 ± 0.14	5.50 ± 1.0
Reducing sugars, %	2.35 ± 0.8	2.29 ± 0.9	1.64 ± 0.9	1.60 ± 0.9	1.38 ± 0.9	1.35 ± 0.9
Soaking index, %	135 ± 5.0	140 ± 5.0	125 ± 5.0	130 ± 5.0	135 ± 5.0	135 ± 5.0

Note: Results are expressed as average ± standard deviation ($n = 3$). Comparison at a significance level of 95 % ($p \leq 0.05$).

According to the bibliographical data, spirulina is rich in lipids made of essential polyunsaturated acids, including the gamma-linolenic acid [5]; with the addition of S2, part of the lipids contained in spirulina is incorporated in the sticks, thus increasing their nutritional value.

The reducing sugars' content was determined accordingly [40, 41]. The sticks from high quality wheat flour with addition of S2 (Table 3) have the highest value; this is due to the chemical composition of the flour [46]. The sticks made of oat flour, P2, have the second highest value of 1.60 %; while the whole wheat sticks, P3, have a value of 1.35 %. Comparative analysis of the results against the control samples shows a decrease in the content of reducing sugars in sticks with addition of S2, as follows: by 2.56 % in P1, by 2.50 % in P2 and by 2.19 % in P3. Hence, by adding S2 to the sticks, the content of the reducing sugars was diminished while the intake of functional ingredients was increased.

The variation of the ash content in the analyzed samples is obvious, the values varying from sample to sample. With the incorporation of S2, the ash content values rise in all of the samples, P3 (whole wheat flour) having the highest value. The increase of the ash content in all the stick samples, to which S2 was added, is explained by the addition of minerals and fibers to the final products (Table 3).

The highest soaking index was identified in the high quality wheat sticks with addition of S2 (P1), which is because of the moisture in the finished products. The addition of the spirulina based S2 preparation increases the hydration capacity of the products, except P3, compared to the control samples, as follows: a 3.7 % in P1 compared to the control sample PM 1 and a 4.0 % increase in P2 (Table 3).

The analysis of the antioxidants concentrations in all of the stick samples, using the spectrophotometric Folin-Ciocalteu method, expressed in gallic acid equivalents ($mg\ GAE \cdot g^{-1}$), through a calibration curve [42], shows a significant increase in the total content of polyphenols (TPC) in the sticks to which S2 was added (Figure 2).

The registered results show that in the samples of the high quality wheat flours, PM1 and P1, the content of antioxidants is lower.

The content of antioxidants is higher in the oat flour and whole wheat sticks, both in the control samples and the samples with addition of S2. The addition of 3 % of S2 to the recipes resulted in an increase of the total content of polyphenols; with 41.67 % in P2 samples of oat flour sticks, with 56.17 % in P3 samples of whole wheat flour sticks and with 15.21 % in P1 (Figure 2).

The sensory evaluation was also performed by assessing the organoleptic and sensory qualities of the finished products (Figure 3a) based on the scoring scale [38].

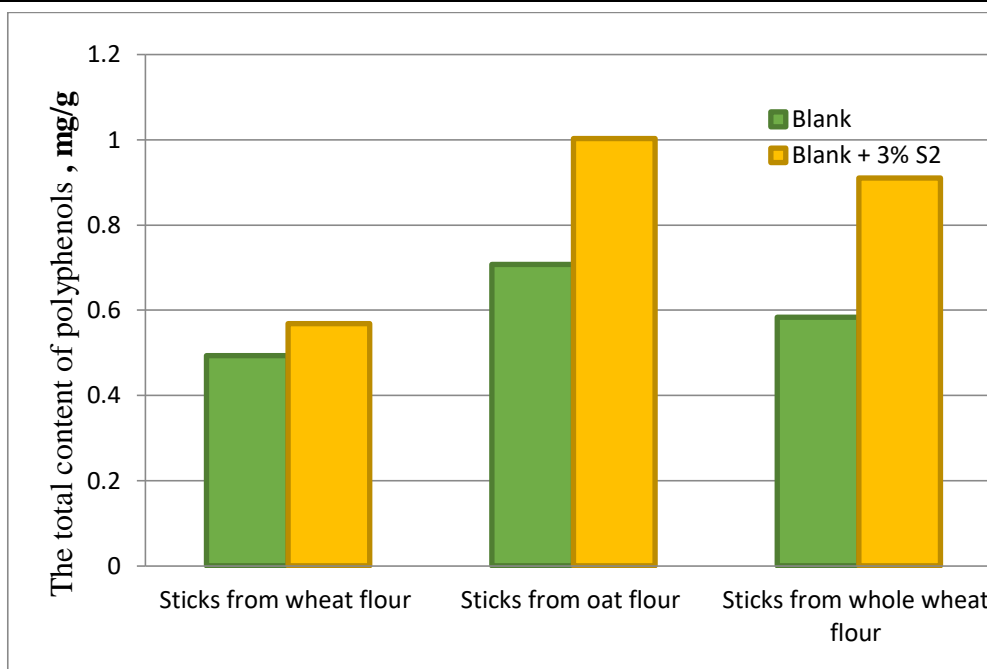


Figure 2. The variation of the total content of polyphenols in sticks.

Note: Results are expressed as average \pm standard deviation ($n = 3$). Comparison at a significance level of 95 % ($p < 0.05$).

According to the normative requirements [37, 45], the sticks must correspond to the indices specified in Table 4.

Table 4

The sensorial characteristics of sticks [38, 39].

Exterior appearance:	Description
Shape	A shape of sticks
Surface	Specific to the product; no impurities; with a smooth surface or a lumpy and wavy surface
Color	From light yellow to dark brown or dark greenish brown, according to the recipe used
Sliced	Loosen, well baked, with no traces of unkneaded flour
Taste and flavor	Pleasant, specific to the product, no foreign taste and smell
Tenderness	Tender, slightly crumbly. The sticks with addition of S2 are slightly harder.

The experimental samples were analyzed sensorially by 5 evaluators, using a 0-5-point rating system. Each evaluator had his own sensory assessment sheet. A score value from 0 to 5 was given for each sensorial characteristic. The average scores were computed based on the results (Figure 3b).

Considering the data exhibited in Figure 3b, we can affirm that the sample from high quality wheat flour with the addition of S2 had the highest scores in terms of shape, surface, color, tenderness and taste, while the sticks from oat flour were favored in terms of smell and taste. The sticks from whole wheat flour with addition of S2 had the lowest scores as some of the evaluators were repelled by the persistent taste of bran. Notwithstanding, the 3 products obtained a high average score, with the evaluators being interested in including the sticks in their daily diet.

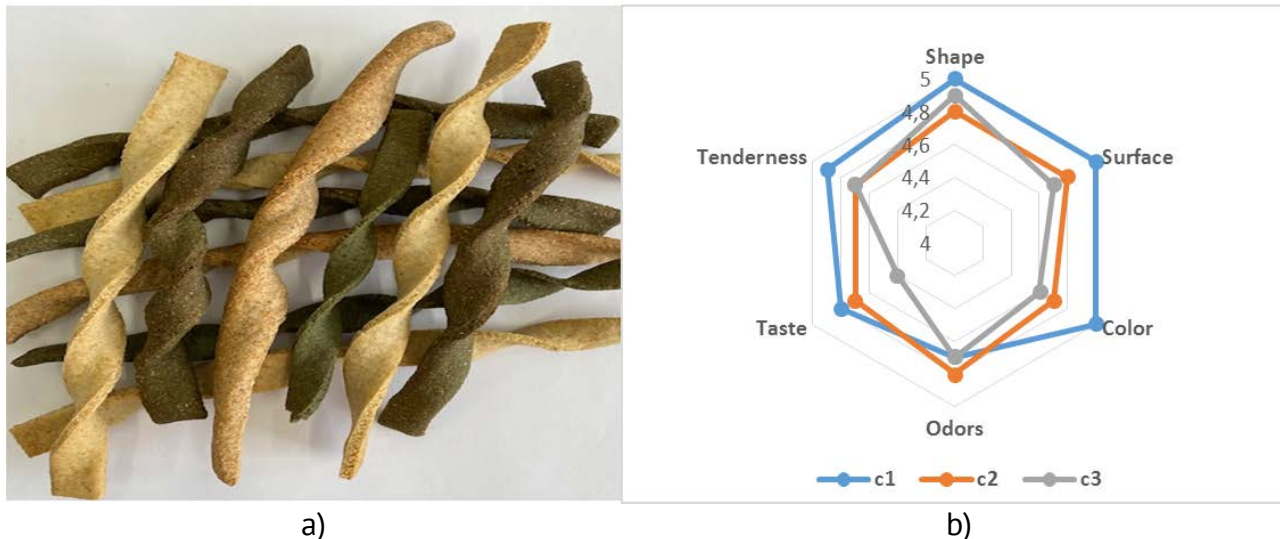


Figure 3. a) Assortment of elaborated sticks; b) Profile diagram of samples with S2: c1 - Sticks from wheat flour with spirulina; c2 - Sticks from oat flour with spirulina; c3 - Sticks from whole wheat flour with spirulina.

Conclusion

For manufacturing reasons are being proposed 3 types of bread sticks, with the addition of 3 % of *Spirulina platensis* based S2 preparation: from high quality wheat flour (P1), from oat flour (P2) and from whole wheat flour (P3). The assessment of the qualities and technological properties of the flours and semi-finished products resulted in registered parameters within the permissible limits.

After testing the nutritional and functional character of the finished products, it was found out that the incorporation of the 3 % S2 preparation in the sticks leads to a growth in the total content of polyphenols, namely with 41.67 % in P2 samples of oat flour sticks and with 56.17 % in P3 samples of whole wheat flour. The addition of S2 leads also to a decrease in the content of reducing sugars; by 12.56 % in P1, by 2.50 % in P2 and by 2.19 % in P3, compared with the control samples.

The fat content of cyanobacterial origin increases in the sticks with addition of S2, with almost 3.2 % in sample P1, with 4.4 % in P2 and with 6.0 % in P3, compared with the control samples.

Research shows that the S2 obtained from microalgae biomass can be applied as natural food dyes due to the elevated content of pigments: chlorophylls, carotenes and phycocyanin, all with health benefits.

The sensorial assessment of the finished products was conducted on a 0-5-point rating system. The finished products with addition of S2 obtained a score of 4.4 points from a total of 5.

Research studies show that the application of the *Spirulina pl.* based preparation enhances the nutritional value of the bakery products by contributing with amino acids, polyunsaturated fat acids, minerals, vitamins and bioactive substances, which the conventional products consumed on a daily basis lack. Moreover, this research proposes the production technology together with the establishment of the technological parameters and quality indices of the finished goods – Sticks fortified with *Spirulina platensis* ingredients.

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