EVALUATION OF NUTRITIONAL AND SENSORY PROPERTIES OF BREAD ENRICHED WITH SPIRULINA

Yaiche Achour Hafsa[*1], **Doumandji** Amel[1], **Sadi** Samia[2], **Saadi** Sidahmed[1]
[1]Faculty of Life Sciences, Departement of Agricultural Sciences, Blida 1 University
Soumaâ Road, B.P. 270 - 9000. Blida, Algeria
[2]Technical Institute of Livestock, Baba Ali, Algiers, Algeria
* E-mail: hafsa_yah@hotmail.fr

Abstract
This study aims the improvement of the nutritional balance of bread, beforehand we prepared control and enriched breads by a percentage of 1 and 3% of dry biomass of a local microalgae spirulina. The evaluation of the nutritional values of these breads is done on the basis of their chemical composition and the acceptability of enriched breads was estimated by a sensory test. It was noticed that the volume and the specific volume of enriched breads, were slightly influenced by the addition of spirulina, the difference was significant ($p<0.05$). In addition, the enrichment by spirulina improved the nutritional quality of bread, a better increase on the rate of proteins was obtained for the bread with a rate of 3%, the value is estimated at 9.98%. Furthermore of proteins, ashes also showed an improvement in the bread, the values are 1.86 and 2.31% for 1 and 3% enriched bread, respectively. Moreover, for the rest of nutriments (fat, crude fiber, carbohydrates) the values remain almost unchanged. The results of the sensory test showed that the bread supplemented by 1% of spirulina seem to have more preferred color, bread enriched with 3% was the least appreciated, otherwise all enriched bread presented a good global acceptability.

Keywords: *bread, improvement, spirulina, evaluation, acceptability*

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I. INTRODUCTION

Spirulina which is a microalgae was proposed in human food by several scientists and nutritionists thanks to its exceptional nutritional qualities. It is considered as unconventional food resource which can contain until 70% of proteins (Benahmed-Djilali, 2012). It appears as microalgae of the hope which will have a leading role to be played to take up the challenge of food self-sufficiency and to serve as remedy with certain diseases which affect in particular developing countries (Fox, 1999).
Food fortification which consist in the incorporation, of food resources rich in proteins or in micronutrients, in a widely consumed and accessible basic food such as bread, to improve its nutritional balance (Razafiarisoa et *al*., 2008).
Bread is a basic food of which the consumption is increasingly strong in developing countries. It is characterized by its low-protein content. This two elements, a high consumption and low-protein content, makes bread an ideal carrier for a protein fortification which is one of the strategies of proteino-energy fight against malnutrition, and also a fortification by other nutriments such as minerals and vitamins (Meite et *al*., 2008).
Besides, there are several applications of spirulina in the human food such as instant noodles for children (Xu, 1993); drinks (Zeng and Liang, 1995); tablets (Yamaguchi, 1997) and couscous (Doumandji et *al*., 2012). Concerning the researches on cereal-based food, most fortifications were devoted to legumes seeds such as bean, soya (Abdel-Kader, 2001; Dhingra, 2002) and sesame (El-Adawy, 1995).
Therefore, in the prospect of valuation and exploitation of spirulina, it seems judicious to undertake studies about the fortification of bakery products (bread) by a dry biomass of spirulina with the aim of improving their nutritional profiles, and the evaluate the effect of the incorporation of this microalgae on the nutritive value of bread was done on the basis of physical, chemical and sensory parameters.

2. MATERIAL AND METHODS

2.1. Biological material

The biological material used during this present study is an isolated autochthonous microalgae, it is spirulina (*Arthrospira fusiformis*), as small green dry pellets, it was collected in farm located in southern of Algeria (Tamanrasset). Spirulina pellets were milled, the powder obtained is stored in a sealed box, away of moisture, air and light.

2.2. Preparation of spirulina enriched bread samples

We prepared three breads: control bread without addition of spirulina and breads added by 1 and 3% of dry biomass of spirulina. The ingredients of each bread types are shown in Table 1.

For each essay, we added in 100g of flour 2g of dry yeast, 2g of sugar and 5g of fat and the volume of water required. Instant yeast, spirulina dry biomass and the other ingredients are directly added to flour, while salt is diluted in the water volume used. The kneading of dough was made in a BOMANN (KM 367 CB) automated mixer machine, in an average air temperature of 20 ± 2 °C and in 90rpm.

The first fermentation follows the kneading and lasts 45 minutes. The dough was then molded manually and placed into an aluminum pan (12×10×5cm) and proofed for 1 h. It was then baked at 250 ± 10 °C for 20 min in an electrical oven, until obtaining colored crust. The same conditions are applied for enriched breads. The baked loaf was cooled at the ambient temperature 1h prior to packing in polyethylene bags. All loaves were stored at room temperature before analysis.

Table 1: Control and enriched breads formulation

Ingredients	Breads		
	Control (g)	Enriched 1.0%	Enriched 3.0%
Flour	100	100	100
Salt	2	2	2
Instant yeast	2	2	2
Sugar	2	2	2
Water	55	55	55
Fat	5	5	5
Spirulina	-	1	3

2.3. Breads characterization

a. Physicals characteristics according to Meite et *al*. (2008)

Control and enriched breads, once cooled were characterized by determining the following physicals parameters:

- The specific volume (VSp) was calculated dividing the value of the volume (cm^3) by the weight (g) of each sample.

- The density is obtained by the following formula (1):

$$\text{Density (g/cm3)} = \frac{\text{Weight of bread}}{\text{Loaf volume of bread}} \quad (1)$$

- The average thickness bread crust (ATC) is the average of the superior crusts dimension, the lower crusts and the side crusts.

A number of five loaves randomly chosen were taken to measure the physical parameters.

b. Nutritional analysis

Methods of analysis used to determine the chemical compositions were the following:

The moisture content was determined by using procedure described by AOAC (1990), the moisture content of each sample was determined by weighing 5 g of the sample into an aluminum moisture can. The sample was then dried to constant weight at 130 °C ± 2 °C. Ash content was obtained by incineration at 550 °C (NA 732/1990). WEENDE method was used to determinate crude fiber (AFNOR. NFV03040, 1977).

The Protein content was determined using Gerhardt Kjeldatherm protein digestor and BÜCHI B-324 distillation apparatus (Kjeldahl method) according to the procedure of AOAC (1990). Crude fat extracted in a Soxhlet extractor with petroleum ether and quantified gravimetrically. The total carbohydrates are obtained by calculation.

The energy values were calculated theoretically using the following conversion factors 4.0, 4.0, and 9.0 kcal g^{-1} for protein, carbohydrates and fat, respectively, according to the method described by Paul and Southgate (1979).

c. Sensory evaluation

Bread samples coded with different numbers were presented to ten panelists who were asked to rate each sensory attribute by assigning using five point hedonic scale. The breads were evaluated for different sensory attributes appearance, texture, color, aroma, taste and overall acceptability.

2.4. Statistical analysis

Data were evaluated by analysis of variance (ANOVA), using SYSTAT 7.0. Each experiment was repeated at least twice and the values were presented in terms of means ± standard error SE.

3. RESULTS AND DISCUSSION

Physical characteristics of control and enriched breads

The specific volume, density and average thickness bread crust are presented in Table 2.

Figure 1 illustrates a representative image of the crumb structures of control and enriched breads. The enriched breads showed slight difference in the specific volumes, the difference is significant ($p<0.05$). According to Figueira et *al*. (2011), the addition until 4% of dry biomass of spirulina does not present a large difference in specific volume of bread, on the other hand the addition of 5% of spirulina reduces significantly this volume.

The decrease in the specific volume of breads can be explained by the action of the enzyme transglutaminase which catalysis the formation of the covalent connections enters proteins. In the case of the incorporation of the spirulina in the dough of bread and of made by the wealth of this microalgae in proteins, there will be an increase of the available rate of proteins for the enzyme, and causes the formation of the cross-links between proteins, what makes the dough rigid and prevents expanding of gas, and by subsequently reduction of the specific volumes of breads (Moore et *al*., 2006).

Densities of prepared breads are very close, revealed no significant ($p>0.05$) difference, the density remains almost unchanged, this means that the addition of spirulina does not cause a change in the loaf density. It is noted that the density is inversely related to specific volume.

The average thickness crust of control and enriched breads present values going from 0.13 to 0.15 cm. They present no significant difference ($p>0.05$).

Nutritional composition

Results of nutritional analyses of breads prepared with 1 and 3% of spirulina and control bread were present in Table 3.

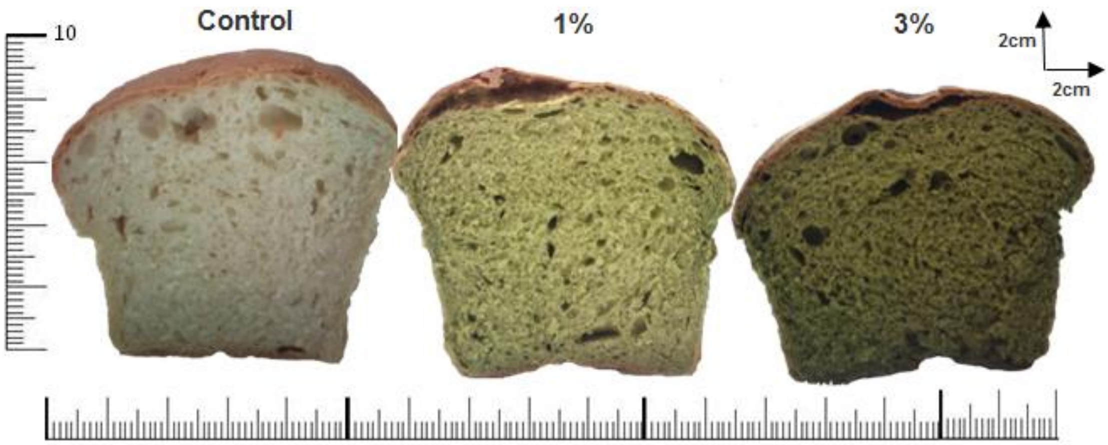

Fig. 1: Bread cross-sectional views from control and spirulina enriched breads (1 and 3%)

Table 2: Physical properties parameters of control and enriched breads

Formulation	VSp (cm^3 g^{-1})	Density (g cm^{-3})	ATC (cm)
S1	2.27 ± 0.01 a	0.44 ± 0.01 a	0.13 ± 0.01 a,b
S2	2.19 ± 0.01 b	0.46 ± 0.01 a,b	0.15 ± 0.005 a,c
S3	2.14 ± 0.01 b	0.47 ± 0.01 b	0.14 ± 0.008 b,c

S1 0% (Control), S2 1%, S3 3% spirulina powder; Values with the same letters have no significant difference (p>0.05)

Table 3: Nutritional composition of control and enriched breads

Composition (%)	S1	S2	S3
Moisture	41.06 ± 0.16 a,b	38.60 ± 0.02 a,c	15.90 ± 0.01 b,c
Ash	1.76 ± 00 a	1.86 ± 0.05 a	2.32 ± 0.23 a
Fat	3.78 ±0.03 a,b	4.12 ± 0.17 a,c	4.91 ± 0.16 b,c
Protein	8.18 ± 0.03 a	8.53 ± 0.04 b	9.98 ± 0.04 c
Crude fiber	2.69 ± 0.05 a,b	2.41 ± 0.25 a	2.34 ± 0.08 b
Carbohydrate	42.53	44.48	42.53
Energy Kcal/100g)	236.86	249.12	254.23

S1 0% (Control), S2 1%, S3 3% spirulina powder; Values with the same letters have no significant difference (p>0.05)

Moisture: The moisture content of the control bread has slightly higher moisture content (41.06%). Results showed that the moisture content gradually decreased with the increase of spirulina level added, revealed significant (p>0.05) difference. This decrease is due probably to the addition of the spirulina in their dried form.

Ash and fat content: The ash content increased from 1.76 to 2.32% with increase in the percentage of spirulina, there is significant (p<0.05) differences between the values. The increase in ash content is due to the high mineral content of spirulina. The amount of improvement is estimated at 31.81% for bread enriched with 3% of spirulina, a lower improvement (5.68%) is showed for 1% enriched bread.

A similar trend was reported by Figueira et *al*. (2011), they reported that the incorporation of spirulina in bread formulation improve ash level. However, the amount of improvement depends on the ash content of the strain of spirulina used, also depends on several other factors such as composition of culture medium.

Data reveals that the fat content increased with the level of supplementation, there is significant difference between control and enriched breads (p<0.05). The fat content of the bread increased from 3.78 to 4.91% with increase in level of spirulina from 0 to 3%.

Proteins: It was found that the protein content in the enriched bread increased by values ranged from 8.18% for control bread to 9.98% for bread enriched with 3% of spirulina, the improvement is estimated, respectively, at 4.28 and 22% for breads enriched by 1 and 3% of spirulina. This could obviously be due to the significant quantity of protein in spirulina, as reported by several authors (Falquet and Hurni , 2006; Morais et *al*., 2006 and Charpy et *al*., 2008). A hundred grams of control and enriched breads provides, respectively, 14.35; 14.96 and 17.50% out of the daily protein requirements based on FAO RDAs (1985).

Crude fiber: Bread is poor in crude fiber, the values samples of breads prepared ranged between 2.34 and 2.69%, there is no difference significant (p>0.05). The addition of spirulina did not affect the crude fiber content, this could probably be due to the lower fiber content of spirulina (Pierlovi, 2007; Alvarenga et al., 2011). The weak content in fiber is interesting in the case of diet low in fibers.

Carbohydrates: The content in carbohydrate in bread was more important. Data showed no change in carbohydrates values between control and enriched breads. Figueira et *al*. (2011), reported that the addition of spirulina decrease slight the carbohydrate content of bread.

Energy value: The calorie content of the breads has been increased from 236.86 to 249.12 kcal for bread enriched by 1% of spirulina and to 254.23 Kcal for bread enriched by 3%. This improvement is estimated at 5.18 and 7.33% for breads enriched by 1 and 3%, respectively.

Sensory evaluation

The notations given for control and enriched breads are represented in the figure 2. The differences between both enriched and control breads are more important for color, than for aroma, taste and texture.

The color descriptor class 3% incorporated bread as the least appreciated, but for the overall acceptability it was considered acceptable by 60% of panelists. The color of the bread is an important sensory characteristic for consumers (Hathorn et *al*., 2008). Furthermore, the control bread and bread supplemented by 1% of spirulina seem to have a more preferred color.

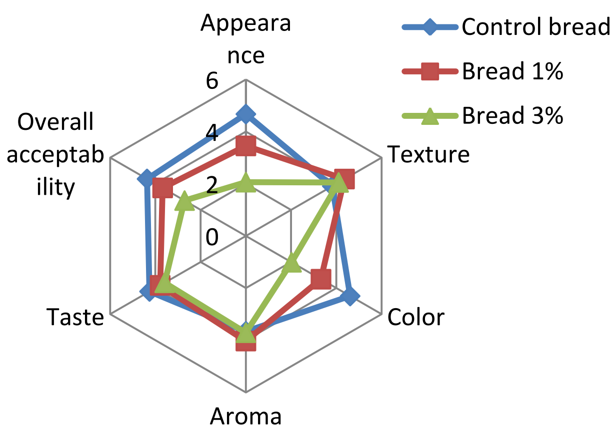

Fig. 2 Sensory evaluation and overall acceptability of breads supplemented with 1 and 3% of

For the texture, enriched breads (rated 4.80 and 4.29 for an enrichment of 1 and 3% rate, respectively) show an almost similar quality with respect to the control bread with a rating of 4.7. The odor descriptor class breads in the same position, it is important to note that the characteristic aroma of spirulina was completely masked even at the 3% supplementation level. In general, all formulations were acceptable by the panelists.

Figueira et *al*. (2011), and for 36 panelists, 22 of them classified bread 3% spirulina as desired, but on the other hand they recorded a total refusal for bread enriched by 5% of spirulina. Moreover, they have retained the formulation with an enrichment rate of 3%.

4. CONCLUSION

The finding of this research revealed that, the supplementation of bread with spirulina affected slightly some its physical characteristics. The color of the fortified samples attained more green color as the fortification was increased. The sensory analysis indicated that bread with 1% of spirulina was the best, the bread with 3% was less appreciated because of the green color. Bread supplementation with spirulina resulted in a significant increase in protein, minerals and fat content. Adding spirulina in bakery products is a useful strategy to increase the consumption of proteins in human diet.

A novel breads product, fortified with spirulina was successfully produced. More studies should be conducted to investigate the possibility of using spirulina as an ingredient in other food products in order to increase applications of such value-added food ingredient.

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