Scientific Papers. Series D. Animal Science. Vol. LXV, No. 1, 2022
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

# THE ENRICHMENT OF BREAD WITH ALGAE SPECIES

**Ducu-Sandu STEF[1], Adrian RIVIS[1], Teodor Ioan TRASCA[1], Mircea POP[2], Gabriel HEGHEDUS-MÎNDRU[1], Lavinia STEF[1], Adela MARCU[1]**

[1]Banat University of Agricultural Sciences and Veterinary Medicine of Timisoara, 119 Aradului Street, Timisoara, Romania
[2]Iasi University of Life Science, 3 Mihail Sadoveanu Alley, Iasi, Romania

Corresponding author email: adelamarcu@usab-tm.ro

***Abstract***

*The goal of this paper was to highliht the use of some algal species in bread fortification. Using data fom scientific literature, two directions were followed: highlighting the role and nutritional value of algae species; the analisys of potential benefits of the bread fortification. Food enrichment consists in the incorporation of food resources, rich in proteins, desired lipids or micronutrients, in a widely consumed and accessible basic food, to improve its nutritional balance. Bread, which is a high carbohydrate food, is habitually traditionally consumed with almost all foods in our country. White bread contains 35-43% moisture, 6-16% proteins, 45-58% carbohydrates, 0.5-1.5% lipids, 0.5-1.5% ash, and 1-1.5% salt, and 100 gram bread has approximately 250-270 calories. Nutritional value of the traditional bread types are increased by adding them foods additives such as walnuts, grapes, and sunflower seeds. Also, the micro and macroalgas are valuable sources for the bread fortification. The algal biomass shows promising qualities as a novel source of protein for bread. Compared to conventional bread, the average nutritive quality of most of the breads enriched with algae was superior, or at least equal. According with the analized data all the enriched breads presented a good global acceptability, even though the lower levels of the algae contents were more appreciated for color.*

***Key words:*** *algas, bread, health, nutritive value.*

## INTRODUCTION

In our days, humans seek alternative nutritional sources and tendency to natural and additive-free food. Bread is considered a staple food worldwide because of its nutritive value, low price and its simplicity of use (Kuijsten et al., 2005). The developed countries such as United States of America, Japan, England, Germany, and Norway benefit from the nutritional richness of microalgae (Becker, 1994).

The food industry consumes large amounts of algae known to provide a wide variety of nutrients. The characteristics of these algae combined with the great potential for cultivation have drawn the attention of industries to their exploration. Algae are easily obtained on moist land or aquatic surfaces, freshwater or saltwater media and are an important source of essential compounds for human nutrition (Rocha et al., 2007).

One of the most important algae types cultured today is *Spirulina platensis*. It has a high biomass productivity in hot and sunny climates (Richmond, 1986). 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), is rich in vitamin B12 (193 μg/100 g) and gamma linoleic acid and a source of calcium and iron (1043.62 and 338.76 mg/100 g) (Cifferi, 1983; Richmond, 2004; Morsy et al., 2014).

Spirulina has a special value among the other algae types. It is the a lack of cellulose in its cell wall, contains high amount of iron, which makes it important in anemia disease. Also, *Spirulina* is a natural resource rich in GLA (approximately 1% of its dry weight) (Takeuchi 1978). It is an energy supplement

for elderly people. In Japan, 73% of people aged over 50 eat *Spirulina*. 10 grams of Spirulina contains only 36 calories (Seshadri, et al., 1992). *Spirulina platensis* is digestible because 86% of

its cell wall is composed of digestible polysaccharide (Li & Qi, 1997).
In nature, Spirulina platensis is found intensively in alkaline waters. Macroalgal biomass can be produced in culture tanks under controlled conditions, or collected from natural environments. (Ereno, 2010).
It appears as microalgae of the hope which will have a leading role to be played to take up the challenge of food selfsufficiency and to serve as remedy with certain diseases which affect in particular developing countries (Fox, 1999).
There are several applications of spirulina in the human food such as instant noodles for children (Xu, 1993); drinks (Zeng & Liang, 1995); tablets (Yamaguchi, 1997) and couscous (Doumandji et al., 2012). Most fortifications, on cereal-based food, were devoted to legumes seeds such as bean, soya (Dhingra, 2002) and sesame (ElAdawy, 1995).
In the prospect of valuation and exploitation of the algae species, the main goal of this paper was to analyze and evaluate the effect of the incorporation of this algas on the nutritive value of bread based of physical, chemical and sensory parameters.
The goal of this paper was to highliht the use of some algal species in bread fortification.

## MATERIALS AND METHODS

### Biological materials

The biological materials used in these studies were:
The biological materials used in these studies were:
- (a) an isolated autochthonous microalgae spirulina (*Arthrospira fusiformis*), as small green dry pellets, which was collected in farm located in southern of Algeria (Tamanrasset) (Yaiche et al., 2014);
- (b) *Spirulina* (*Arthrospira*) *platensis* (Burcu et al., 2016);
- (c) *Spirulina platensis* (Figueira et al., 2011);
- (d) *Cladophora* spp. and *Ulva* spp. (Menezes et al., 2015).

The composition of algas is very important because, according to Schwochow & Zanbon (2007) the composition may vary by time of year that it is collected. In Table 1 are shown the main characteristics of the algae species used in the analized papers, acording with the authors presentation.

Table 1. Characterization of the biomass of algae applied in the formulation of the breads

| Determinations | *Cladophora* spp. *and Ulva* spp.[d] | *Spirulina platensis*[b] |
|---|---|---|
| Moisture [%] | 7.0 ± 0.19 | 6.7 |
| Ash [%] d.b. | 26.3 ±1.04 | - |
| Protein [%] d.b. | 8.7 ± 2.42 | 86.0 |
| Fat [%] d.b. | 1.1 ± 0.28 | 3.3 |
| Fiber [%] d.b. | 3.9 ± 0.62 | - |
| Carbohydrates [%] d.b. | 60.0 ± 2.87 | - |
| Caloric value [kcal $100g^{-1}$] | 168.9 ± 3.52 | |
| Digestibility [%] | 45.0 ± 1.36 | 84 |
| Carotenoids [$\mu g.g^{-1}$] | 378.6 ± 0.02 | |

Values are means ± SD of analyses performed in triplicate; d.b: dry basis.

The lipid content in algae is low, ranging from 1-5%, *Ulva lactuca* also shows high levels of omega 3 and 6. The mineral fraction of some algae represent 36% of total dry weight. (Patarra, 2008). The fiber content varies with the algal species analyzed, with an average of 30 - 40% dry weight (Tabarsa et al., 2012).
Spirulina contains 50-70% protein, 20% carbohydrate, 5% lipid, 7% minerals and 3 to 6% moisture. Therefore, unlike the proteins obtained from meat and dairy products, it is a protein resource which is low lipid, low-calorie, and cholesterol-free (Richmond, 2004).

### Preparation of spirulina enriched bread samples

The analyzed data on the fortification of bread with algae species were varied, as types of algae and as percentages of participation of algae in the formulation of bread. Thus, the percentage of participation varied between 1 and 10%, with eight different levels.
The (micro and macro) algae species levels from bread, the main characteristics evaluated and the authors were shown in Table 2.

Table 2 The algae species levels from bread and the main characteristics evaluated

| Biomass of the algal in bread, [%] | The characteristics evaluated | Researchers |
|---|---|---|
| *Spirulina* *(Arthrospira fusiformis)* 0, 1 and 3 | - chemical composition (protein, fat, crude fiber, carbohydrates, ash); the specific volume; the acceptability | [(a)] Yaiche et al., 2014 |
| *Spirulina platensis* 0, 10 | - nutrient composition, (protein, lipid, Ca, Mg and Iron); volatile compounds; microbiological and sensory properties; | [(b)] Burcu Ak et al., 2016 |
| *Spirulina platensis* 0, 2, 3, 4, 5 | - nutritional quality; the specific volume, crumb hardness; crumb color | [(c)] Figueira et al., 2011 |
| *Cladophora* spp. and *Ulva* spp. 0, 2.5, 5.0 and 7.5 | - nutrient composition and caloric value; technological properties; sensory evaluation. | [(d)] Menezes et al., 2015 |

## RESULTS AND DISCUSSIONS

### a. Physicals characteristics.

The physical characteristics of control and enriched breads are presented in Table 3.

Table 3. Physical characteristics of control and enriched breads

| Paper | Biomass of the algal in bread [%] | The specific volume ($cm^3\,g^{-1}$) | Hardness (g) | |
|---|---|---|---|---|
| | | | Fresh | 24 h |
| a | 0 | 2,27 | - | - |
| | 1 | 2,19 | - | - |
| | 3 | 2,14 | - | - |
| c | 0 | 3.11 | 215.05 | 431.71 |
| | 2 | 3.03 | 308.48 | 337.07 |
| | 3 | 3.09 | 289.24 | 288.91 |
| | 4 | 3.10 | 277.39 | 300.49 |
| | 5 | 2.43 | 460.01 | 377.45 |
| d | 0 | 3.75 | 252.72 | 469.38 |
| | 2.5 | 3.50 | 254.99 | 414.99 |
| | 5.0 | 3.74 | 386.73 | 615.10 |
| | 7.5 | 3.54 | 232.95 | 502.15 |

Yaiche et al. (2014) noticed slight differences in ***the specific volumes*** of the the enriched breads. The specific volumes decreased with the increasing of the algae content in the bread.

The data varied between 2.14 $cm^3\,g^{-1}$, for bread with 1% Spirulina (*Arthrospira fusiformis*) and 3.74 $cm^3\,g^{-1}$, for bread with 5% *Cladophora* spp. and *Ulva* spp.

According to Figueira et al. (2011), the specific volume was not affected by the addition of up to 4% of alga, but a decrease of 22% in the volume of the bread were noted with the addition of 5%.

From all the macroalgal biomass added in the evaluated samples, the formulation with 5.0% ($w.w^{-1}$) was the one with the highest specific volume. (Menezes et al., 2015)

The incorporation of the algae species, which are wealth in the proteins, in the dough of bread result in an increase of the availabality of proteins for the enzyme, and causes the formation of the crosslinks between proteins. This fact makes the dough rigid and prevents expanding of gas, and respectively reduction of the specific volumes of breads (Moore et al., 2006).

The data for ***densities*** varied between 0.44 and 0.47 g $cm^{-3}$. The values of densities were very closed density remaining almost unchanged. The addition of spirulina does not cause changes in the bread density. Furthermore, 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 (Yaiche et al., 2014).

The ***crumb hardness*** was not affected by the addition of up to 4% of alga, but an increase of 113% in crumb hardness of the bread was noted with the addition of 5% (Figueira et al., 2011).

The addition of macroalgal biomass had no significant difference in the measured hardness of fresh bread and after 24 hours of baking except for the fresh bread enriched with 5% ($w.w^{-1}$) biomass, which was different from the control, presenting greater hardness (Menezes et al., 2015).

Figueira (2011) found that the hardness of the breads was unchanged with the addition of up to 4% ($w.w^{-1}$) of algae, the hardness only increased when 5% ($w.w^{-1}$) of algae (based on flour) was added.

### b. Nutritional and sensory analysis

The enrichment by spirulina improved the nutritional quality of bread (Figure 1), a better increase on the rate of **proteins** was obtained for the bread with a rate of 3%. The value was estimated at 9.98%. For the rest of nutriments (fat, crude fiber, carbohydrates) the values remain almost unchanged (Yaiche et al., 2014).

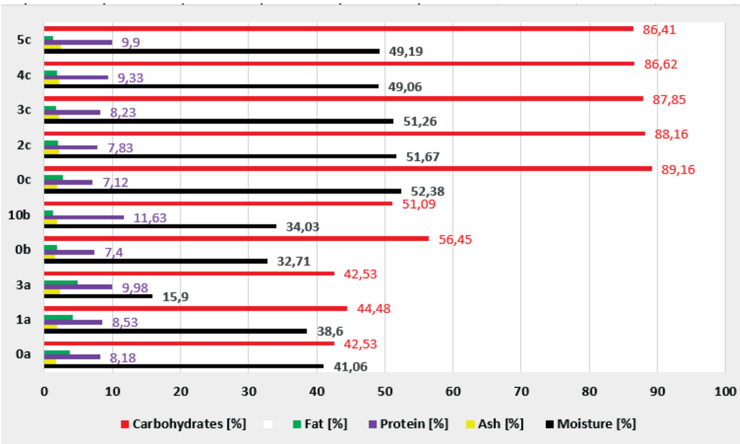


Figure 1. The nutritional quality of bread

Figueira et al. (2011) have shown that the addition of *Spirulina* resulted in products with improved nutritional quality, with a significant increase of 39.04% in the protein content as well as of some essential amino acids (threonine, methionine, isoleucine and leucine), when compared to bread without the addition of the alga. A smaller, but significant protein increase was found by Menezes et al. (2015). In this case, the increase in the concentration of macroalgal biomass in the bread resulted in a protein increase from 16.5 to 18.5% (w.w$^{-1}$). The content of protein reported by Burcu et al. (2016) was 7.40% when microalgal was not added, respectively 11.63% for 10% microalgal content.

According to Figueira (2011), **the lipid** content of bread enriched with *Spirulina,* with samples spiked with 2, 3, 4 and 5% (w.w$^{-1}$), ranged from 1.24 to 2.81% (w.w$^{-1}$) and the lipid content was reduced with the addition of *Spirulina,* this occurred probably due to the smaller amount of this components in the algae biomass. Menezes et al. (2015) reported for lipid concentration values ranging from 7.0 to 17.0% (w.w$^{-1}$), with the increase in biomass there was a decrease in the lipid content, by about 5% (w.$^{w-1}$). Also, Burcu et al. (2016) presented a significant decrese of lipid content, from 1.91% to 1.36%, when 10% microalgal content was added.

Burcu et al. (2016) noticed an increase for the **moisture**, from 32.71 to 34.03%, when the *Spirulina platensis* content was raised from 0 to 10%. Oppositelly, all other authors highlited that the moisture content gradually decreased with the increase of spirulina level added. Both, Yaiche et al. (2014) and Menezes et al. (2015) showed small differences in water contents of the analyzed samples. According to Yaiche et al. (2014), the moisture content gradually decreased with the increase of spirulina level added, revealed significant ($p$>0.05) difference. The registered values were 41.06, 38.60 and 15.90% for 0, 1 and 3% microalgae contents. The decrease is due probably to the addition of the spirulina in their dried form.

Figueira et al. (2011) reported that the incorporation of spirulina in bread formulation improve **ash** (total mineral content) level. The data reported by (Menezes et al., 2015) were ranging from 1.92 to 2.52%, with the increase in biomass there was a slightly increase in the ash content. The ash content between all the breads did not have any significant difference, except for the bread formulation with 7.5% (w.w$^{-1}$), which differed significantly due to the mineral content (2.5%) present in macroalgae. Also, Yaiche et al. (2014) reported an improvement for the ash in the bread, the values are 1.86 and 2.31% for 1 and 3% enriched bread, respectively. The amount of improvement was estimated at 31.81% for bread enriched with 3% of spirulina.

The reported data for calcium, magnesium and iron are presented in Figure 2.

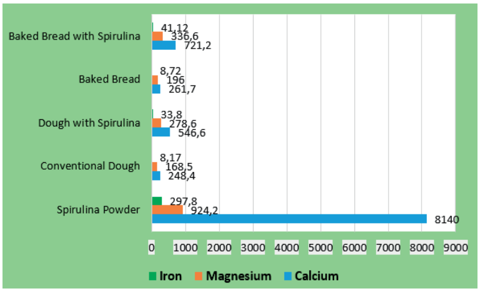


Figure 2. Calcium, magnesium and iron contents of *Spirulina,* dough, and breads (ppm)

Although all the cited authors analyzed the content of total substances, only Burcu et al. (2016) highlighted several mineral elements, namely ***calcium, magnesium and iron***.

The highest values in calcium (8140 ppm), magnesium (924.2 ppm), and iron (297.8 ppm) were detected in *Spirulina.* The lowest values were identified in conventional bread dough and in baked bread without *Spirulina.* The amounts of calcium, magnesium and iron in conventional bread was much lower than those of the bread with *Spirulina*. Approximately 5 times more iron was detected in baked bread with *Spirulina*.

Figueira et al. (2011) reported that the addition of spirulina decrease slight the ***carbohydrate*** content of bread. Also, Yaiche et al. (2014) found no change in carbohydrates values between control and enriched breads. On the other hand, Menezes et al. (2015) showed that the carbohydrate content was 65% (w.w$^{-1}$) on average, reduced with addition of macroalgae, all breads differed significantly from the control bread.

In relation to the attributes ***color, odor and consistency***, there was no significant difference at 95% level of significance between the bread formulations containing 2.5, 5.0 and 7.5% (w.w$^{-1}$) of macroalgal biomass (Menezes et al., 2015). Yaiche et al. (2014) noticed that all enriched bread presented a good global acceptability. Anyway, the bread supplemented by 1% of spirulina seem to have more preferred color, bread enriched with 3% being the least appreciated. Also, Figueira et al. (2011), who evaluated breads containing 3% and 5% (w.w$^{-1}$) of *Spirulina platensis*, showed that was no significant difference between the breads of the different concentrations of microalgal biomass. Burcu et al. (2016) were reported that *Spirulina* addition in the proportion of 1% or 4% made no difference.

## CONCLUSIONS

The algal biomass can be produced in a controlled environment, or collected in natural environments Adding spirulina in bakery products is a useful strategy to increase the consumption of proteins in human diet. The algal biomass shows promising qualities as a novel source of protein for bread. Compared to conventional bread, the average nutritive quality of most of the breads enriched with algae was superior, or at least equal. According with the analized data all the enriched breads presented a good global acceptability, even though the lower levels of the algae contents were more appreciated for color.

## REFERENCES


Becker, W.E. (1994). *Microalgae-Biotechnology and Microbiology.* Cambridge Univ. Press Publishing House.

Benahmed-Dilali, A. (2012). Analysis of technological skills of dates (*Phoenix dactylifera* L.) enriched with Spirilina. Study ofrheological, nutritional and antibacterial properties. Boumerdes, Algeria: M'hamed Bougara-Boumerdes university, PhD thesis.

Burcu, A., Avşaroğlu, E., Işık, O., Özyurt, G., Kafkas, E., Etyemez, M., & Uslu, L. (2016). Nutritional and Physicochemical Characteristics of Bread Enriched with Microalgae *Spirulina platensis. Int. Journal of Engineering Research and Application,* 6(12), 30-38.

Cifferi, O. (1983). Spirulina, the Edible Microorganism. *Microbiological Reviews*, 47(4), 552.

Dhingra, S., & Jood, S. (2002). Physico-chemical and nutritional properties of cereal-pulse blends for bread making. *Nutrition and Health, 16*(3), 183-194.

Doumandji, A., Chader, S., Alili, D., Hamrouche, D., & Haouari, S. (2012). INAPI, *Couscous enrichi en spiruline.* Brevet N° 120576: 10.

EL-Adawy, T.A. (1995). Effect of sesame seed proteins supplementation on the nutritional, physical, chemical and sensory properties of wheat flour bread. *Food Chemistry, 59*(1), 7-14.

Ereno, D. (2010). Versatilidade Marítima. *Revista de Pesquisa Fapesp., 178,* 66-71.

Figueira, F.S. (2011). Elaboration of gluten-free bread enriched with the microalgae *Spirulina platensis. Brazilian Journal of Food Technology, 14*(4), 308-316

Fox, R.D. (1999). *Spiruline, Technique pratique et promesse.* Aix-en- Provence, F: Edisud Publishing House.

Kuijsten, A., Arts, I.C.W., Van't Veer, P., & Hollman, P.C.H. (2005). The relative bioavailability of enterolignans in humans is enhanced by milling and crushing of flaxseed. *J. Nutr., 135*, 2812–2816.

Li, D.M., & Qi, Y.Z. (1997). *Spirulina* Industry in Chine: Present status and future prospects. *Journal of applied Phycology, 9*, 25-28.

Menezes, B.S., Coelho, M.S., Meza, S.L.R., Salas-Mellado, M., & Souza, M.R.A.Z. (2015). Macroalgal biomass as an additional ingredient of bread. *Int. Food Research Journal, 22(2),* 812-817.

Moore, M.M., Heinbockel, M., Dockery, P., Ulmer, H.M., & Arendt, E.K. (2006). Network Formation in Gluten-Free Bread with Application of Transglu-taminase. *Cereal Chemistery, 83,* 28-36.

Morsy, O.M., Sharoba, A.M., ELDesouky, A.I., Bahlol, H.E.M., & Abd El Mawla, E.M. (2014). Production and evaluation of some extruded food products using *Spirulina algae*. *Annals of Agric. Sci., Moshtohor, 52(4)*, 495–510.

Patarra, A.R.F. (2008). *Pesquisa de Ácidos Gordos em macroalgas marinhas do litoral dos Açores*. Universidade do Porto, dissertação de mestrado.

Richmond, A. (2004*) Biological Principles of Mass Cultivation. (A. Richmon editor). Handbook of Microalgal Culture: Biotechnology and Applied Phycology.* Oxford, UK: Blackwell Science Ltd. Publishing House, 125-177.

Richmond, A. (1986). *Outdoor Mass Cultures of Microlagae. (A. Richmond Editor). Handbook of Microlagal Mass Cultures of Microalgae*. Boca Raton, Florida, SUA: CRC Press Publishing House, 285-329.

Rocha, F.D., Pereira, R.C., Kaplan, M.A.C., & Teixeira, V.L. (2007). Produtos naturais de algas marinhas e seu potencial antioxidante. *Revista Brasileira Farmacognosia, 17(4),* 631-907.

Schwochow, R.Q., & Zanboni, A.J. (2007). O Estuário da Laguna dos Patos: um exemplo para o ensino de ecologia no nível médio. *Revista Cadernos de Ecologia Aquática, 2(2),* 13–27.

Seshadri, C.V., & Jeeji Bai, N. (1992) *Spirulina National Symposium.* Shri Amm., Murugappa Chettiar Research Center (MDRC), Madras, India.

Tabarsa, M., Rezaei, M., Ramezanpour, Z., & Robertwaaland, J. (2012). Chemical compositions of the marine algae *Gracilaria salicornia* (Rhodophyta) and *Ulva lactuca* (Chlorophyta) as a potential food source. *Journal Science Food Agriculture, 92(12),* 2500-2506.

Takeuchi, T. (1978). *Clinical Experiences of Administration of Spirulina to Patiens with Hypochronic Anemia.* Tokyo Medical and Dental Univ. Japan.

Xu, C.W. (1993). *An instant algal noodle and its production method.* Chinese Patent CN1077 857A.Technology 3 (2): 79–88.

Yaiche, A.H., Doumandji, A., Sadi, S., Saadi, S. (2014). Evaluation of nutritional and sensory properties of bread enriched with *Spirulina. Annals. Food Science and Technology,* 270-275

Yamaguchi, K. (1997). *Recent advances in microalgal bio-science in Japan, with special sweetening tablet, WIPO.* Patent Application, WO/2003/00192.

Zeng, Y., & Liang, M.S. (1995). Production of Spirulina drink. *Food Sciences, 16(7)*, 39–418.

# WILD LIFE MANAGEMENT, FISHERY AND AQUACULTURE