Effect of *Spirulina platensis* and kelp biomass addition on the fatty acid composition of wheat bread

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Abstract

Introduction. The aim of the present study was to study the effect of biomass of some edible algae – *Spirulina platensis* and kelp – addition on the content of saturated and unsaturated fatty acids in wheat bread.

Materials and methods. Bread was obtained from wheat flour with the addition of biomass of kelp and *Spirulina platensis* in the form of powder in the amount of 2 or 4% by the weight of flour. The extraction of total lipids was performed by the conventional method, the methyl esters of fatty acids were analyzed using a gas chromatograph equipped with a flame ionization detector.

Results and discussion. It was found that enrichment with biomass of kelp and *Spirulina platensis* added in the amount of 2 and 4% by the weight of wheat flour changes the content of saturated and unsaturated fatty acids in bread. As the different algal species have a different fatty acid profile, the addition of two aquacultures to the wheat flour had different effects. In terms of saturated fatty acids, the incorporation of kelp biomass in the bread recipe caused an increase in the content of stearic, arachidonic and heneicosanoic acids, while enrichment with biomass of *Spirulina* led to an increase in the content of caproic, palmitic, arachidonic acids and, especially, of heneicosanoic acid. In the control bread, the amount of heneicosanoic acid was 0.17 g/100 g of fat. In the bread enriched with 2 and 4% of kelp, the amount of heneicosanoic acid was in 2.2 and 3.5 times higher than in control, respectively; in the bread enriched with with 2 and 4% of *Spirulina platensis* – in 3.4 and 3.1 times higher than in control, respectively. Seaweed addition also affects the content of unsaturated fatty acids in wheat bread. When kelp was included in the bread recipe, there was an increased content of oleic and α-linolenic acids, while in the case of paulinic acid, enrichment with *Spirulina platensis* was more efficient.

Conclusions. Fortification of wheat bread with biomass of edible algae kelp and *Spirulina platensis* is an effective way for increasing the content of some fatty acids in it. The effect of biomass of *Spirulina platensis* addition is more pronounced.

Introduction

Fatty acids are a major structural component of lipids (de Carvalho et al., 2018). They are a source of energy for cell growth, especially in childhood (Shahidi et al., 2008). It is well known that polyunsaturated fatty acids are of great physiological importance (Simopoulos, 1999). The total lipid intake and the consumption ratio of saturated fatty acids (SFA) has increased significantly in the Western diet in recent decades (Simopoulos, 2016). In order to reduce the saturated fat content of processed foods, the food industry is facing a challenge to replace animal fat by vegetable fat, which has a high content of unsaturated fats (Tavella et al., 2000). On the other hand, there has been a growing public awareness of the benefits of essential fatty acids (Kaur et al., 2014). However, most of them are either not synthesized at all or are synthesized in insufficient quantities by the human body, which necessitates their intake as supplements or enriched food products (Kaur et al., 2014). Predominance (over 50%) of omega-6 linoleic acid in grain cereals is a major reason for the imbalanced omega-3/omega-6 ratio consumption in western diets (Fradique et al., 2013). This limitation can be overcome by enrichment of food products with sources of omega-3 polyunsaturated fatty acids (Barrow et al., 2009). Therefore, among the main tasks of the food industry is the development of product formulations with better nutritional characteristics (Osuna et al., 2014). According to Petrovna et al. (2022) enrichment of daily consumed food products with essential fatty acids is an innovative approach, which is most advantageous for people that do not require major changes to their dietary habits.

Incorporating bioactive ingredients, rich in different valuable compounds, into popular foods such as bread, have grown rapidly due to the increased consumer health awareness (Ibrahim et al., 2016). It is considered that bread prepared from refined flour has lower nutritional value than whole grain bread and does not adequately meet the requirements for many macro- or micro-nutrients (al-Kanhal et al., 1999; Škrbić et al., 2008). Due to its relatively low cost, availability and widespread consumption, bread is a suitable product for incorporation of functional ingredients, including omega-3 fatty acids (Dziki et al., 2014). In recent decades, different research teams have worked on fortifying bread with natural compounds due to the demands for healthier food (Melilli et al., 2019; 2020; Sillitti et al., 2016).

Incorporation of edible seaweeds to increase nutritional value of different food products including wheat bread are presently very popular (Stabnikova et al., 2021). Despite the quantitative differences in chemical composition, seaweed is a sustainable and almost inexhaustible source of polyunsaturated fatty acids. They are characterized by an optimal ratio about 1.0 of omega-6: omega-3 fatty acids. According to the recommendations of the World Health Organization, to prevent inflammatory, cardiovascular problems and diseases of the nervous system this ratio should be less than 10. Prabhasankar et al. (2009) prepared pasta, incorporating wakame (*Undaria pinnatifida*) as an ingredient at different ratios of semolina to wakame (100:0; 95:5.0; 90:10; 80:20 and 70:30). Authors reported that compared to the control (1:15.2), the ratio of omega-3 to omega-6 fatty acid in wakame enriched pasta was 1:3.4. The importance of algae lipids lies in their potential as an alternative source for the production of functional foods with increasing content of essential fatty acids, such as eicosapentaenoic acid, docosahexaenoic acid, and their precursor α-linolenic acid (Ferreira et al., 2019).

Nutritional characterization of seaweed and their application in food products preparation are well studied (Caporgno et al., 2018; Lafarga, 2019; Sanjari et al., 2018). The total lipid content and the fatty acid of different algae species is well known (Gosch et al., 2012; Jay et al., 2018; Rodrigues et al., 2015). For example, *Spirulina* has lipid content 5.6 –

7.0% including linoleic and γ-linoleic fatty acids (Othes et al., 2001). *Chlorella vulgaris* contains approximately 35–40% lipids, with up to 27% α-linolenic and 24% linoleic acid (Freitas, 2017). *Spirulina* sp. has been frequently claimed as the cheapest source of γ-linoleic acid (Choopano et al., 2016). Nevertheless, knowledge about the effect of supplementation of wheat bread with some edible algae on the fatty acid composition of bread are limited. Due to their valuable chemical composition, microalgae and brown algae are among the most widely used as a food additive, also in the bakery industry. Most often, enriching bread with these algae aims to increase its protein, mineral and fiber content (Ak et al., 2016; Saharan et al., 2017; Yaiche et al., 2014). The effect of this aquaculture on the fatty acid profile of wheat bread has been less studied.

The present study focuses on the impact of some of the most commonly used as supplements in the food industry algae *Spirulina platensis* and kelp on the fatty acid amount in wheat bread. The optimal amount of algae added was determined by preliminary experimental studies. It was found that the biomass of algae mentioned above in the amount of 2 and 4% by the weight of wheat flour has a clear positive effect on the nutritional value of bread, without compromising its sensory characteristics and consumer acceptance. The aim of this study was to investigate the effect of addition of *Spirulina platensis* and kelp biomass in amounts of 2 and 4% by the weight of wheat flour on the content of saturated and unsaturated fatty acids in bread.

Materials and methods

Materials

For the preparation of the bread samples, the following materials were used:

- Commercial wheat flour type 500 with the following properties: moisture content – 12.8% ; gluten content – 27.07% ; release of gluten – 6 mm; titratable acidity – 2 °H;
- Water – according to ISO 6107-1:2004;
- Commercial yeast (Lesafmaya);
- Salt – according to Codex Standard for Food Grade Salt CX STAN 150-1985;
- *Spirulina platensis* powder (average chemical composition: protein 64 g/100 g; fat 8.2 g/100 g of which saturated 3.42 g; carbohydrates 16.1 g/100 g, of which sugars 0.52 g, fiber 7 g/100 g).
- Kelp powder (average chemical composition: protein 5.3 g/100 g; fat 4.2 g/100 g of which saturated 0.9 g; carbohydrates 12.0 g/100 g, of which sugars 0.5 g, fiber 1.25 g/100 g).

Methods

Dough and bread composition

The composition of the bread samples is presented in Table 1.

Table 1

Bread samples composition

Ingredients	**Bread samples**				
	Control sample	**Sample S2 – with 2% *Spirulina platensis***	**Sample S4 – with 4% *Spirulina platensis***	**Sample K2 – with 2% kelp**	**Sample K4 – with 4% kelp**
Wheat flour, g	250	245	240	245	240
Water, cm^3	140	145	155	145	155
Yeast, g	3.37	3.37	3.37	3.37	3.37
Salt, g	3.25	3.25	3.25	3.25	3.25
S. platensis, g	–	5	10	–	–
Kelp, g	–	–	–	5	10

Bread preparation

Bread was prepared from type 500 wheat flour by a two-phase method. Initially, knead the yeast, flour and water dough in a 1:1 ratio in a kneading machine (Labomix 1000, Hungary). Pre-mixed *Spirulina platensis* and kelp algae (powder) in the amount of 2% or 4% by the weight of flour are added to the mixing water (combinations K2 and K4, for the breads prepared with kelp and combinations S2 and S4, for the breads prepared with *Spirulina platensis*, respectively). The control sample was prepared only with wheat flour. The dough thus prepared matures for 4 hours at 33 °C and then mixes the dough to obtain a homogeneous mass by adding the remainder of the flour according to the formulation and salt (1.3 kg/100 kg flour). The bread dough divides into pieces by 440 g and forms, matures for 55 minutes at 38 °C (Tecnopast CRN 45–12, Novacel ROVIMPEX Novaledo, Italy). After the end fermentation, the pieces of dough were put into an electric oven (Salva E-25, Spain) pre-heated to 200–220 °C. The baking time was 24 min, until the temperature in the center of the bread crumb reached 96-98 °C. After baking, the bread was allowed to cool down for 3 h at room temperature.

Determination of fatty acid composition

The extraction of total lipids was performed by the conventional method, as the methyl esters of fatty acids were analyzed using a gas chromatograph "Shimadzu GC-17A" equipped with an automatic injector (AOC 2), a Restek (19091N-213) column (100 m length × 0.32 mm inside diameter, and 0.5 µm film thickness), and a flame ionization detector (FID).

The tested sample was placed in a suitable flask and 4 ml of methanolic NaOH solution and boiling aid were added. A Graham condenser was connected to the flask. If the fatty acids contain more than two double bonds, the air from the flask was removed by blowing with dry nitrogen for a few minutes. The sample is boiled for 5 to 10 minutes, shaking the flask periodically. Then 5 ml of boron trifluoride methanol solution through the upper end of the condenser were added. Boiling lasts 3 minutes. 1 to 3 ml of isooctane are added to the boiling mixture through the upper end of the condenser. When the heating of the flask is completed 20 ml of NaCl solution are added immediately. The flask should be closed and shaken vigorously for at least 15 s. Saturated NaCl solution is added so that the liquid level is up to the neck of the flask. The two phases are separated in a separating funnel. 1-2 ml of the upper isooctane layer are placed in a 4 ml vial and anhydrous sodium sulphate is added to remove all traces of water. The isooctane solution thus obtained can be injected (ISO 5508:1990). The temperature of the injector and detector was kept at 250 °C. The injection volume was 1 μl. Fatty acids were identified by comparison of their retention times with those of authentic standards and reported as g/100 g fat.

Results and discussion

Effect of *Spirulina platensis* and kelp addition on the content of saturated fatty acids in wheat bread

The results on the influence of *Spirulina platensis* and kelp algae addition on the amount of saturated fatty acids (SFA) in the different samples of bread are presented in Table 2.

Table 2

Influence of *Spirulina platensis* and kelp on the content of saturated fatty acids in wheat bread

Saturated fatty acids	**Content of saturated fatty acids in the bread samples, g/100 g fat**				
	Control	**K2 with 2% of kelp**	**K4 with 4% of kelp**	**S2 with 2% of *S. platensis***	**S4 with 4% of *S. platensis***
Caproic acid C 6:0	0.19	0.06	0.12	0.27	0.41
Capric acid C 10:0	0.21	0.08	0.10	0.11	0.21
Lauric acid C 12:0	0.45	0.25	0.21	0.24	0.19
Myristic acid C 4:0	0.14	0.04	0.02	0.07	0.13
Palmitic acid C 6:0	8.46	9.11	8.19	8.54	8.79
Stearic acid C 18:0	3.01	3.84	3.16	3.07	2.84
Arachidic acid C 20:0	0.15	0.20	0.19	0.19	0.25
Heneicosylic acid C 21:0	0.17	0.38	0.61	0.58	0.52

As it can be seen from the results, the amount of saturated fatty acids in the control sample ranged from 0.14 g/100 g fat (for myristic acid) to 8.46 g/100 g fat (for palmitic acid). Palmitic and stearic acids were predominant in quantity, and for all other fatty acids the reported amounts were below 1 g/100 g of fat. The addition of algae in the bread recipe has an effect on the amount of saturated fatty acids, and in this case the influence of both the species and the amount of aquaculture is clearly seen. It's known that the fatty acid composition depends on the species – the alga *Porphyra spp.* have the lowest content of saturated fatty acids (17.4% of the total fatty acids), while *Plocamium brasiliense* have the highest – 74% of the total (Gressler et al., 2011).

The content of caproic acid in the control sample was low – 0.19 g/100 g fat. There was a twofold increase in its content when enriching wheat bread with 4% alga *S. platensis*. This fatty acid acts as a membrane stabilizer – it supports the formation and maintains the stability of cell membranes. Enriching bread with seaweed did not increase the amount of capric, lauric and myristic acids. Other authors showed results that do not match ours. Fradique et al. (2013) found that when enriching pasta with two types of marine microalgae from the class *Haptophyceae*, the amount of myristic acid (14:0) increased from 0.14% in the control sample to 2.14% in the sample enriched with algae. However, it depends on the spice of algae used.

In the control sample of bread the highest content of palmitic acid – 8.46 g/100g fat was obtained. Similar results for the content of palmitic acid in bread were published by Lazova-Borisova et al. (2019) – 10.40 g/100 g fat. Of all the tested samples with a maximum content of palmitic acid, the one prepared with the addition of 2% kelp algae (9.11 g/100 g fat) stands out. For the other samples, the quantities are comparable to those in the control sample. In their study, Rodrigues et al. (2015) found that seaweed *S. muticum*, *S. polyschides* and *C. tomentosum* are characterized by low fat content (0.6–3.6%), combined with a specific fatty acid profile, with a predominance of palmitic and arachidonic acid. Another study (Jay et al., 2018) also focuses on the fact that palmitic acid is predominant in the fatty acid profile of different algae species – in *Chlorella vulgaris* its amount reaches 22.8%, and in *Nannochloropsis gaditana* – 53.4%. Fradique et al. (2013) study the effect of *Isochrysis galbana* and *Diacronema vlkianum* on the fatty acid composition of pasta. They point out that both types of algae are rich in palmitic acid (2711 mg/100 g DW for *Isochrysis galbana* and 1320 mg/100 g DW for *Diacronema vlkianum* respectively). That's why after the incorporation of aquacultures palmitic acid (16:0) is the main SFA present in raw pastas. In the control sample, palmitic acid represents 21.75% of the total fatty acids, while in the enriched sample – 23.67%. For a long time, high intake of palmitic acid has been associated with harmful health effects. In fact, it is the most common saturated fatty acid, representing 20–30% of the total fatty acids in the human body and can be obtained through food or synthesized endogenously. To maintain the balance of membrane phospholipids, the optimal intake of palmitic acid in a certain ratio with unsaturated fatty acids, especially omega-6 and omega-3 (Carta et al., 2017) is crucial.

The amount of stearic acid increases when enriching bread with kelp seaweed, and when using *S. platensis,* 2%, the reported result was similar and lower in the sample with 4%. Probably the reason is that kelp brown algae is rich in this fatty acid, unlike *Spirulina platensis*. This makes sense because algae of different species have different fatty acid contents, and those of the same species can vary greatly depending on different growing conditions, techniques and cultivation environment. Relatively low content of stearic acid, which does not affect its amount in fortified wheat products, found other authors too (Fradique et al., 2013).

The content of archaic acid was influenced (but not significantly) by the inclusion of algae in the bread recipe. In contrast, in the case of heneicosanoic acid, there was a clear difference in the results for the tested samples. In the control sample, the amount was 0.17 g/100 g fat. The addition of both types of aquacultures led to an increase in the content of this fatty acid. In the enriched samples the quantities were as follows: for bread with 2% of kelp in 2.2 times higher than in the control, for bread with 4% of kelp in 3.53 times, for bread with 2% of *S. platensis* in 3,4 times, for bread with 4% of *S. platensis* in 3.05 times higher.

Other authors have also studied the fatty acid profile of different species of algae. According to Gosch et al. (2012) the highest relative share of C16:0 (palmitic acid) is in relation to the total fatty acid content of red algae, followed by green and brown. Another study found that *Spirulina platensis* contained 33.68 – 66.75% saturated fatty acids and 28.20 – 47.78% polyunsaturated fatty acids. Eicosapentaenoic acid and docosahexaenoic acid were found only in individual samples (Diraman et al., 2009).

Until recently, it was thought that high saturated fatty acid intake was associated with some negative health effects (Kromhout et al., 2000). However, more recent studies show that this view is not true (Mozaffarian et al., 2004). A number of scientific studies have proven the ability of saturated fatty acids to be transformed into unsaturated fatty acids in the human body. Each of the saturated fatty acids from C12:0 (lauric acid) to C18:0 (stearic acid) is converted to the corresponding monounsaturated acid under the action of the enzyme Δ9-desaturase (stearoyl-CoA-desaturase), but with different efficiency. Evidence has been presented that palmitic acid (C16:0) can also be desaturated from the enzyme Δ6-desaturase (Guillou et al., 2003) to sapienic acid (C16:1n-10) (Ge et al., 2003).

Effect of *Spirulina platensis* and kelp algae addition on the content of unsaturated fatty acids in wheat bread

According to Polat et al. (2013), the content of monounsaturated fatty acids (MUFA) in different algae species varies from 12.52% to 32.94%, with the highest content found in *Dasya rigidula* algae harvested in autumn. Oleic acid is a monounsaturated omega-9 fatty acid found in various foods of animal and plant origin. The content of oleic acid in algae varies greatly depending on the species, region and season of extraction. Thus, in green algae *Ulva lactuca,* harvested off the coast of northern California in November, the oleic acid content was 1% (Khotimchenko et al., 2002), while in *U. lactuca*, obtained from the shores of the North Sea in September/October, the amount reached 20% (van Ginneken et al., 2011).

The results on the effect of *Spirulina platensis* and kelp algae on the oleic acid content of wheat bread are presented in Figure 1.

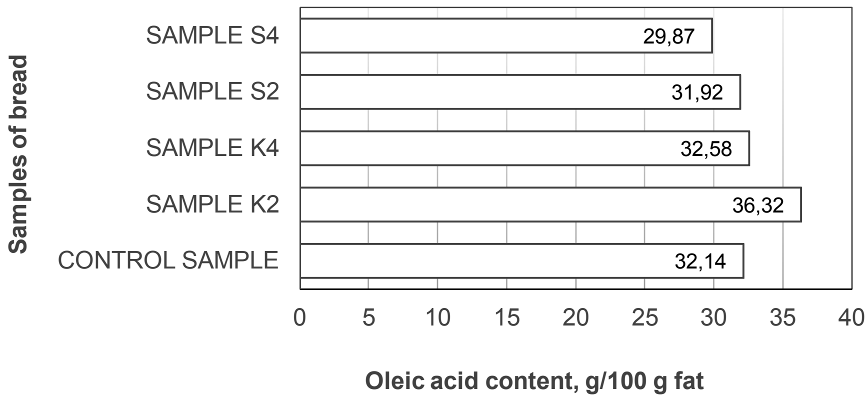

Figure 1. Effect of addition of algae *Spirulina platensis* and kelp on the oleic acid content in wheat bread

Source: author's research

The amount of oleic acid reported in the control sample is 32.14 g/100 g fat and it is comparable to the results found for samples K4, S2 and S4. Giaretta et al. (2018) found the content of oleic acid in wheat bread 24.53 mg/100 g of total lipids, indicating that it is the predominant monounsaturated fatty acid in bread. The most pronounced influence on the content of this fatty acid in wheat bread had the enrichment with 2% of kelp seaweed – there was an increase of 13%. This result is supported by data published by Matanjun et al. (2008). According to the authors, brown algae, which includes kelp, is rich in oleic acid. Silva et al. (2013) studied the fatty acid profile of ten brown macroalgae and pointed out that oleic acid was in general the most abundant monounsaturated fatty acid, representing 2.3–12.1% of total content. Khotimchenko et al. (2002) also found this acid to be one of the major MUFA in other brown algae species. That is why enriching bread with kelp is more effective in increasing the oleic acid content. Another study evaluated the partial replacement of pea flour by *Chlorella sorokiniana* biomass powder to increase the nutritional quality of gluten free bread. The oleic acid was the primary fatty acid found in the bread samples, ranging from 46.4 to 50.6% of the total fatty acids (Diprat et al., 2020).

Paulinic acid is also monounsaturated, but contains 20 carbon atoms and is an omega-7 fatty acid. It is involved in the metabolism of lipids and fatty acids, and is also needed for the formation and maintenance of cell membranes. The results obtained in determining the content of paulinic acid in the tested bread samples are presented in Figure 2.

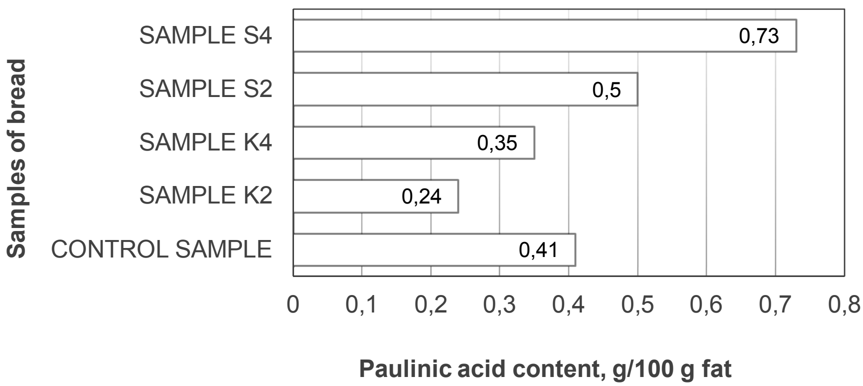

Figure 2. Effect of algae *Spirulina platensis* and kelp addition on the paullinic acid content in wheat bread
Source: author's research

Experimental results show that the inclusion of kelp algae in the recipe is accompanied by a reduction in the amount of paullinic acid in wheat bread. In its enrichment with *Spirulina platensis* an increase in the available amount was reported, and it is weaker when the aquaculture is added in the amount of 2% by the weight of flour – by 18%. In the sample prepared with 4% of *Spirulina platensis*, the amount of paulinic acid was 1.78 times higher than in the control sample, 3 times higher than in sample K2 and 2.08 times higher than in sample K4. There is no specific literature data on the content of paullinic acid in *Spirulina platensis*, but the results presented in this study give a reason to believe that this kind of algae is rich in paullinic acid.

The linoleic acid content of the control bread sample was 54.37 g / 100 g fat. Very close to this are the results published by Lazova-Borisova et al. (2019) – 54.09 g/100 g fat (although in rye bread). Another study points out that the linoleic acid and the α-linolenic acid were the only unsaturated fatty acids in bread, representing around 23 and 5.5% of total fatty acids, respectively (Diprat et al., 2020). When kelp seaweed was included in the composition of wheat bread, the amount of linoleic acid decreased insignificantly compared to that in the control sample. Enrichment with 4% of algae *Spirulina platensis* led to an increase in the content of this fatty acid by 2.35%, while at lower doses the effect was less significant. Diraman et al. (2009) published research, according to which *Spirulina platensis* is a rich source of γ-linolenic acid, which represents 4.07 – 22.51% of fatty acids. The results for the composition of 10 strains of *Spirulina* show the highest content of γ-linolenic acid and linoleic acid, if it grown at 20 °C (Mühling et al., 2005), which proves the influence of environmental factors. The data are also confirmed by other authors, according to which *Spirulina* algae are rich in essential fatty acids (Belay et al., 1993; Duda-Chodak, 2013).

Until now, fish oil was considered the main source of omega-3 and omega-6 long-chain polyunsaturated fatty acids. It should be noted, however, that they are not synthesized in the body of fish, but in seaweed and phytoplankton, which are their main food source (Nordy et al., 1989). It is therefore of interest to determine the effect of addition of kelp and *Spirulina platensis* biomass on the α-linolenic acid content in wheat bread. The experimentally obtained results are presented in Figure 3.

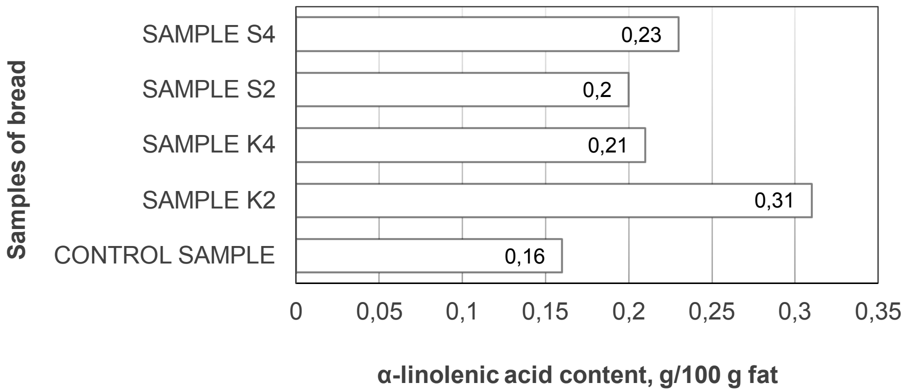

Figure 3. Effect of algae *Spirulina platensis* and kelp addition on the content of α-linolenic acid in wheat bread

Source: author's research

As it can be seen from the figure, the lowest content of α-linolenic acid was deterimined in the control sample – 0.16g/100g fat. Enrichment with both types of aquacultures led to an increase in the amount of this essential fatty acid. The values reported for samples K4, S2 and S4 vary within very narrow limits, while sample K2 had the highest content – 0.31 g / 100 g of fat, which was almost twice as high as in unenriched bread. This is due to the fact that seaweeds, and more precisely brown algae (including kelp), produce polyunsaturated fatty acids, especially long chain fatty acids of the ω-3 series (Colombo et al., 2006). Kumari et al. (2010) emphasized that the availability of linoleic acid, α-linoleic acid, γ-linoleic acid and other polyunsaturated fatty acids with proven nutraceutical effect, indicates the potential of brown macroalgae to be included in functional foods. In terms of the other type seaweed used in the study Shabana Ali and Arabi Saleh reported that the content of α-linolenic acid in *Spirulina* powder was about 8.87% (Ali et al., 2012). Fatty acid profile of *S. platensis* includes saturated fatty acids (46.9%), monounsaturated (7.8%) and polyunsaturated fatty acids (42.8%) with γ-linolenic acid as the most abundant PUFA (Sahbazizadeh et al., 2015). The effect of *Spirulina* on the amount of fatty acids in other bakery products has been studied. Cookies contain γ-linolenic acid of 2.54; 2.78; 2.80 and 2.73% at 0, 0.5, 1 and 1.5% of *S. platensis* microalgal biomass incorporation, respectively. The levels of γ-linolenic acid were increased in fortified cookies, even after baking, whereas all the other fatty acids, mainly provided by shortening, showed large variations. The authors suggested that the microalgae cells could resist thermal treatment, encapsulating the fatty acid molecules, thus protecting them from oxidation (Prabhasankar et al., 2009).

Different species of algae have a different fatty acid profile, and there is no consensus among the authors which factor is crucial – genetic characteristics or environmental conditions. Some authors believe that more important are the genetic features (Matanjun et al., 2008; van Ginneken et al., 2011), while others consider the influence of the environment to be decisive, including: temperature (Colombo et al., 2006), harvesting season of aquaculture (Denis et al., 2010), salinity of sea water (Floreto et al., 1998) and its mineral content (Sanina et al., 2004). Japanese researchers have found that in *Spirulina platensis* a higher content of polyunsaturated fatty acids (and in particular – γ-linolenic acid) can be achieved by culturing the algae in direct light, and then leaving them in the dark for a week (Hirano et al., 1990).

Different authors highlight that algae have been reported overall to have a low lipid content, but their fatty acid composition is superior to those of the terrestrial vegetables (Darcy-Vrillon, 1993; Susanto et al., 2016). They are rich in polyunsaturated fatty acids with nutritional value and thus have to be studied extensively for biotechnological and food applications (Chandini et al., 2008).

Conclusions

1. The enrichment of wheat bread with seaweed has an impact on the content of fatty acids. As different species of algae have a different fatty acid profile, the two aquacultures used in the study (*Spirulina platensis* and kelp) affect the amount of individual fatty acids differently.
2. The inclusion of kelp in bread recipes leads to an increase in the content of some saturated fatty acids – stearic, arachidonic and heneicosanoic acids. When *Spirulina platensis* (at the amount of 2 or 4% on the basis of flour) is added to the raw materials for bread making, the amount of caproic, palmitic, arachic and heneicosanoic acids increases.
3. The amount of unsaturated fatty acids is also affected by the enrichment of wheat bread with algae. When kelp is included in the bread recipe, a higher content of oleic and α-linolenic acids is measured, while in the case of paulinic acid, enrichment with *Spirulina platensis* is more efficient.

These findings confirm the importance of algae incorporation in traditional foods (such as wheat bread) as an easily accessible way to enhance the nutritional value. It can be definitely said that with appropriate selection of the types and quantities of added aquaculture, the desired impact on the fatty acid profile of bread and the resulting healthy effect for consumers can be achieved.

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