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A Study on Spirunia as a Protein Alternative for Aging Society

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Abstract

Spirulina is known to be more useful abroad than in Korea because it contains more protein than Chlorella, the same microalgae. In the past, sources of animal protein were diverse, but since it takes a long time to receive protein along with environmental pollution, we thought that spirulina could attract attention as a new protein source. In this study, application cases were analyzed in foods in the fields of acorn cake, tofu, dumpling skin, fish cake, white bread, pound cake, salad dressing, and yogurt and so on. As a result of centrally analyzing antioxidant and sensory evaluation, it was confirmed that the results were effective enough to develop products in tofu, dumpling skin, fish cake, and pound cake. It is thought that development of food in other fields will be possible if an additive amount that can match the consumer's preference is found by supplementing the mixing ratio. If it is used as a main raw material for existing food rather than as a raw material for health functional food, consumer preference can increase and quality can be further improved, and it can be suggested as a good alternative for an aging society.

Keywords: Spirulina, Quality properties, Sensory test, Aging society.

Major classifications: Food Nutrition, Healthy Food

1. Introduction

Recently, 'Generation MZ' is paying a lot of attention to the environment and health. If food was selected based on the taste and convenience of food around 2010, various standards such as animal welfare, eco-friendliness, and health are emerging after 2020. Accordingly, companies are constantly launching new products that focus not only on taste and convenience, but also on the environment and nutrition. Then you need to think about why people care about the environment and health. Climate change caused by global warming has changed so much that people can feel it with their skin, raising people's awareness. This awareness has developed into a change in people's daily life to protect the environment, and in particular, participating in the reduction of disposable straws, cups, and plastics is a representative example. In addition, as meat consumption increases, the livestock business has a significant impact on the environment, and alternative measures are urgently needed to solve this problem. Protein is the main component of the body, such as various organs, enzymes, and hormones, and is a substance used not only as a constituent of the human body but also as an energy source. The building blocks of protein are amino acids, and some essential amino acids must be ingested through food. For this reason, protein is one of the essential foods in our table. Proteins can be typically divided into vegetable and animal proteins. In the case of animal protein, it is usually produced through livestock, and not only contaminates the environment due to manure, gas, etc. generated by raising livestock, but also the growth rate is slow. In addition, the high content of saturated fat and cholesterol causes chronic diseases such as high blood pressure and diabetes when consumed in large amounts. On the other hand, in the case of vegetable protein, it is possible to minimize the occurrence of contamination, and the growth rate is faster than that of animal protein, and since it has a high dietary fiber content, it helps to maintain health. Therefore, consuming plant protein rather than animal protein is more environmentally and nutritionally beneficial. Usually, people think of beans and mushrooms as plant proteins. Because alternative protein foods using soybeans or mushrooms are readily available in daily life, consumers' preference is high, and companies also use soybeans or mushrooms as alternative proteins. As the use of these raw materials increases in the future, the increase of land and manpower is an essential factor when agriculture flourishes, but the use of soybeans and mushrooms is limited due to the lack of farmland and population decline. The raw material that can make up for these shortcomings is microalgae. Since it can be easily grown in the sea with only water and light, it can be mass-produced, and it is nutritiously excellent as it has a very high content of protein, dietary fiber, and micronutrients compared to beans and nuts. Examples include spirulina and chlorella. Spirulina has been used as a raw material in various cultures for thousands of years, and Korea has also been used as a raw material for health functional foods since the early 1960s. Until recently, it has been widely used as a raw material for health functional food, but its utilization as food is very low (Byeon, 2017). So, we would like to talk about the sustainable development potential for the generalization of Spirulina so that it can be easily used in the diet.

2. Theoretical background

2.1. Basic Properties of Spirulina

Spirulina, the oldest alga on Earth, is a microalgae with a spiral shape of 300-500 μm in length and 8 μm in diameter. It is a multicellular organism with a thin cell wall and has been widely used as a food resource for a long time together with chlorella (In, 2008). Spirulina, which has a history of about 3 billion years, has been used as the main ingredient of health functional foods since the 1960s, because spirulina contains a lot of biologically active substances. Spirulina includes protein, carbohydrates, fat-soluble dietary fibers, essential amino acids, large amounts of minerals (calcium, iron, potassium, magnesium, zinc, manganese, selenium, germanium, etc.), vitamins (beta-carotene, Vit-B1, B2, B6, B12, Vit-E, inositol, folic acid, etc.), and pigments (Liu, 2016). Spirulina contains a variety of nutrients, but the largest portion of it is protein. Spirulina is a high-protein organism containing 55% to 70% protein. Chlorella, the same microalgae, also contains more protein than beans and eggs, but contains the largest amount of spirulina (Kim, 2003). Chlorella accounts for 50%, beans and eggs account for 39%, and 12%, respectively. As can be seen from the content, it is judged that there is sufficient possibility as a raw material for animal protein replacement foods using spirulina (Kwak, 2021). Fat accounts for 6-9%, of which 70% to 80% are glassy fatty acids, mainly linolenic acid and linoleic acid, which are unsaturated fatty acids. Carbohydrates are 15-20%, and representative examples include glucose, rhamnose, mannose, and xylose. It has been recognized for its functionality in promoting and maintaining health because it contains ingredients that help physiological activity along with the supply of spirulina nutrients. In addition, anticancer and antioxidant effects appear, and are very effective in suppressing the growth of viruses and bacteria and enhancing immunity. In fact, in Japan, it has been reported that the administration of spirulina along with diet to diabetic patients achieved good results. In the case of diabetic patients, there is a limit to converting fat into an energy source because the body does not burn fat well, and the protein of spirulina serves as an energy source. As such, spirulina has been consistently used as a main ingredient in health functional foods because it has abundant nutrients and various physiologically active ingredients and effects (Park, 2010).

2.1.1. Phycocyanin

Phycocyanin protein accounts for the largest portion of spirulina. Phycocyanin protein serves as a light harvest antenna that absorbs the light energy required for photosynthesis in southern bacteria, red algae, and algae. It is a water-soluble protein and is classified into three types: Phycocyanin, picoerythrin, and allophycocyanin according to the maximum absorbance. Phycocyanin means bird pico (Phyco), and cyanin (Cyan) is Greek for blue (Jang, 2015). Phycocyanin is a blue pigment found in southern birds, red birds, and underground plants, and in particular, southern birds have their own blue color because they contain a large amount of phycocyanin. Various birds contain phycocyanin pigments, but spirulina has high culture efficiency and contains a large amount, so currently, phycocyanin is extracted the most from spirulina. Extraction methods include Water extraction, Homogenization, Freezing-thawing, and Sonication methods, and recently chromatography is also used to obtain higher purity phycocyanin (Cha, 2012). Phycocyanin is the first water-soluble pigment extracted in the 1980s and exhibits very strong fluorescence, and is a key ingredient necessary for southern birds to be used as food, cosmetics, and drugs. It has antioxidant, anti-inflammatory, anti-cancer, antiviral effects and it has recently been found to have brain protection effects, which is effective in neurodegenerative diseases such as ischemic stroke, schizophrenia, Parkinson's disease, and Alzheimer's disease (Choi, 2018). It is also used as a natural pigment for ice cream and cosmetics and is also used as a fluorescent marker (Cha, 2012). As the most representative example, the administration of C-Phycocyanin (50 mg/kg weight) extracted from blue-green algae to mice with acute lung damage by LPS reported that LPS(lipopolysaccharide)-related ALI(acute lung injury) could potentially be used in treatment by inhibiting inflammatory response and apoptosis in lung tissue (Leung PO et al., 2013). As such, research on phycocyanin is also being actively conducted, and in particular, the number of papers and patents in the field of biotechnology is also increasing recently. Since phycocyanine with such various effects contains the most spirulina, the utilization of spirulina should be increased.

2.1.2. Carotenoid

Carotenoid are organic pigments that plants, algae, bacteria, and fungi synthesize into fats and organic metabolites. More than 600 types of carotenoid have been identified and are also called tetraterpenoids. Carotenoid are known as isoprenoid compounds and are useful biologically active substances. A hydrocarbon-based carotenoid composed of eight isoprenoids has a symmetrical structure of a head-to-tail pattern except for the center. The central methyl groups are located at Nos. 1 and 6, and the remaining non-telomeric methyl groups are located at Nos. 1 and 5, and carotenoid are named based on this structure. Carotene is composed of only carbon and hydrogen, and contains α-carotene and lycopene as molecules that do not contain oxygen, and xanthophyll is a molecule containing oxygen, and lutein and zeaxanthin (Jo, 1995). The structure of carotenoid is formed of a polyene chain of up to 40 carbons, and the terminal has a functional group partially containing an annular or oxygen. In biochemical terms, carotenoid are light sensitive hydrophobic pigments in the membrane of phototroph. It is predominantly yellow, red, brown or green, of which it absorbs light from the blue spectrum, and is found in some flowers and fruits (Kim, 2014). Carotenoid absorb light energy and absorb light of short wavelengths to transfer energy to the photometric reaction center. Carotenoid are used in various ways in plants, insects, animals, and humans. First, in the case of plants, it is used in the process of photosynthesis. Lutein, β-carotene, violaxanthin, and neoxanthin, which are components of carotenoid, contribute to the formation and safety of chloroplasts. In addition, in the case of light, plants catalyze photo-oxidation reactions to produce free radicals that can be harmful to cells, which carotenoids protect. Insects and animals, it helps to reproduce attractions and seeds. In particular, it is an important component in the color of the epidermis and muscles, and serves as a tissue growth differentiation control material and visual pigment. In particular, β-carotene, lutein, astaxanthin, lycopene, and zeaxanthin, which are components of carotenoid, are used. Zeaxanthin and lutein protect the eyes from ultraviolet rays, and studies of aging-related eye diseases have shown that they reduce deterioration of late senile macular degeneration, especially when supplemented. It also prevents cataracts and macular degeneration, and delays the rate of visual degeneration. Lycopene has a high antioxidant power, so it has excellent effectiveness in preventing and treating diseases caused by harmful oxygen. Astaxanthin is the most potent antioxidant and is a red pigment. It protects the skin from ultraviolet rays and increases high-density fat protein. In addition, it improves immune function and reduces the growth of oral cancer and breast cancer. In particular, β-carotene is oxidized and decomposed in the body through two nuclei to produce two molecules of vitamin A, which suppresses harmful oxygen and is effective in preventing adult diseases and suppressing aging (Goo, 2016). In addition, it contributes greatly to the antioxidant effect of spirulina, which is contained in large amounts in spirulina compared to other vegetables. Therefore, it is considered that in-depth research on the natural antioxidant effect using spirulina should be conducted.

2.1.3. Tocopherol

Tocopherol is a biological antioxidant and is an organic compound with vitamin E activity, a fat-soluble vitamin. The generic term for tocopherol is vitamin E (Jang, 2012). All of these lipids have long isoprenoid side chains and substituted aromatic rings through which cell membranes can penetrate. Depending on the functional group attached to the tocopherol, tocopherol can be classified as alpha, beta, gamma, and delta, each tocopherol has eight optical isomers. Tocopherol is hydrophobic and binds to lipids and cell membranes accumulated inside and lipoproteins in the blood. Lipids present in the cell membrane are easily attacked and oxidized by oxygen and free radicals due to peroxidation (Lee, 2007). At this time, the aromatic ring contained in tocopherol reacts with the chains of the oxidized lipids and breaks these chains. This action is an antioxidant action, and has the function of removing oxygen and free radicals, preventing oxidation of cell membrane lipids, and reducing cell damage. It also protects the lipid bilayer of enzymes and other proteins. Among the tocopherol components, alpha tocopherol is secreted into the blood from the liver, and other beta, delta, and gamma tocopherol are almost excreted. Since it has a structure similar to vitamin K, another fat-soluble vitamin in addition to antioxidant function, excessive intake of tocopherol is also known to interfere with the anticoagulation, a function of vitamin K, by acting competitively with vitamin K. In general, there is tocopherol in eggs or vegetable oils, and animals bred for lack of food have weakened muscles, turned skin into needles, and showed symptoms such as weakness and infertility. People with vitamin E deficiency can develop hemolytic anemia as the cell membrane of red blood cells becomes vulnerable to oxidative damage. However, in general, adults have a significant storage volume of vitamin E, resulting in a very rare deficiency.

2.2. Characteristics of food

2.2.1. Dotori - Muk (Acorn Jelly Salad)

Muk is unique gel-like food that is unique to Korean, and it has no special taste, but it is smooth and fresh, so it stimulates our appetite. As dietary life improves, the texture and flavor felt from food along with new perceptions of traditional food are important, and the characteristics of Dotori-Muk are also being reevaluated. Recently, along with physical research on Dotori-Muk, studies on corn starch Muk, chestnut Muk, bean Muk, etc. with seaweed added have been conducted (Oh et al., 2012). However, not many studies have been reported on Dotori-Muk with added spirulina.

2.2.2. Tofu

Tofu, which has a digestion rate of 95%, is an excellent food containing 93% or more of soybeans, 85% or more of carbohydrates, 95% or more of fat, and 50% to 60% or more of vitamins. Since ancient times, tofu, which consumers often visit, is divided according to processing methods such as soft tofu, dry tofu, soft tofu, fried tofu, and pressed tofu. Recently, foods using tofu, such as tofu noodles, tofu tofu, and tofu doughnuts, have become diverse, and it seems to be an effort to improve nutritional ingredients by changing the main ingredients of existing foods to tofu. Although the number of tofu with various ingredients has increased, not many studies on tofu with spirulina have been reported.

2.2.3. Fish cake

Fish cakes are made by adding salt, starch, and other ingredients to fish tenderloin, and there are steamed, boiled, baked, or fried fish cakes. Fish cakes are rich in protein and calcium because they are the main ingredient of fish meat, and various other ingredients can be used as side ingredients to satisfy consumers' tastes, and are relatively inexpensive and convenient to cook and eat. Fish cakes are developed by adding various ingredients such as green onion, horse powder, and yellow flag powder, but no research on fish cakes using spirulina has been reported (Choi, 2017).

2.2.4. Dasik (Tea Confectionery)

Dasik finds its origin in the records that Dasik was made with tea leaf powder in the Three Kingdoms and offered offerings, and after that, various types of materials were used, such as starch candy and Songhwa Dasik. Dasik has a lot of room to develop as Korea's own food considering not only bright colors but also the application and nutrition of various ingredients. As the dessert industry increases, Dasik with various ingredients is increasing, but not many studies have been reported on Dasik with spirulina (Son et al., 2008; Kim et al., 2008).

2.2.5. Bread, pound cake

Bread is a food that is fermented by mixing flour with main ingredients, salt, sugar, butter, and yeast, and baked or squeezed over fire. Recently, the consumption rate of bread is increasing due to the dessert market craze and westernized diet. Because animal protein is used a lot, calories are very high and nutritious, so many products with functional raw materials are being developed. However, desserts with spirulina have not been developed, and not many studies with spirulina have been reported.

2.2.6. Yogurt

Yogurt is fermented milk using lactobacillus and can be seen as "fermented milk." Yogurt, which contains about 100 million to 1 billion lactobacillus, proliferates beneficial bacteria in the intestine and inhibits harmful bacteria to the extent that it is called a rose garden. Demand for yogurt has increased as the trend of eating out, such as well-being, simple meals for meals, and healthy foods, has emerged, and various studies are being conducted. Functional yogurt, which is good for the liver and stomach as well as the intestines, has been developed, and recently, yogurt that lowers blood pressure has also been developed.

Improving the nutritional aspects of food as well as taste has become a trend. Therefore, I would like to evaluate the possibility of commercialization through a paper on yogurt with Spirulina added.

2.2.7. Salad dressing

Recently, more and more people are eating salads as a substitute for a meal due to their westernized diet. Since vegetables themselves are not tasty, there are many people who eat them with dressing. There are many different dressings, but among them, dressing containing mayonnaise has a high fat content of 65%. Excessive consumption of fat increases the total calories and accumulates extra fat in the body, causing obesity and obesity causing chronic degenerative diseases. Therefore, it is necessary to improve the nutrients of mayonnaise-added dressing by adding highly antioxidant spirulina.

3. Research contents and Method

This study analyzes the papers on spirulina, and contains the contents of the material's sustainable development potential. Through RISS, which provides a variety of papers, the papers since 2000 were organized, and among them, 10 necessary papers were intensively analyzed and researched. The representative characteristics of spirulina were summarized, and the components contained in spirulina were arranged in detail. In addition, the results of the thesis on food using spirulina were summarized as a whole, and the improved effect was intensively analyzed by comparing the control group with the addition group. In addition, the possibility of product development was analyzed by focusing on the fact that the uniqueness of food is not lost when spirulina is added. Through this, the key part of this study is to make it easier to find spirulina in the diet rather than as a raw material for health functional food.

4. Results and Discussion

4.1. Dotori-muk

When producing acorn jelly with spirulina, 0.4 g, 0.8 g, and 1.2 g (e.g., 0.5%, 1.0%, and 1.5% respectively) of the spirulina raw material were added, and an experiment was conducted by comparing the control groups without spirulina (Oh et al., 2012). First, in the case of moisture, there is no significant difference between the additive and the control group, and the average value is 87%. The pH shows a lower value as the amount of addition increases, and the opposite high acidity increases as the amount of addition increases. In the chromaticity, the value of L and a decreases as the amount of addition increases, but the value of b increases as the amount of addition increases. In other words, as the amount of addition increases, green and blue appear darker. Texture was subdivided into hardness, elasticity, cohesiveness, chewiness, and restorability. First, cohesiveness and restorability increase proportionally as the amount of addition increases. On the other hand, hardness and chewiness are the highest in the content of 1%, and there is no significant difference between 0.5% and 1.5%. There is no significant difference in cohesiveness in the control group and the additive. Antioxidant properties were evaluated with DPPH Radical Scavenging ability and total phenol content. First, the value of the DPPH Radical Scavenging ability and the total phenol content increased as the amount of addition increased, and in 1.5% it was IC_{50} 166.2 mg/ml and the total phenol content was 2,667.2 mg/ml. It can be seen that the antioxidant property is greatly increased when Spirulina is added. Finally, it is a sensual assessment of consumers' tastes. In the case of sensory evaluation, a nine-point scale was used, 10 people from Chungnam National University's Department of Food and Nutrition, and they responded to hardness, bitterness, elasticity, fishy taste, and preference color. There is no significant difference in hardness between the control group and the additive, and elasticity, color, fishy taste, and bitterness increase as the amount of addition increases. The preference is the highest at 0.5%, and the lower the preference is added. When combining the results of each item, it is appropriate to add only 0.5% of spirulina, considering the antioxidant properties and consumer preference, which are the strengths of spirulina, while maintaining the unique taste and elasticity of Dotori-muk.

4.2. Tofu

When producing tofu with Spirulina, 0.25g, 0.5g, 0.75g, and 1g of Spirulina raw material (0.25g, 0.5g, 0.75%, and 1% respectively) were added to prepare the tofu, and the control group without Spirulina was compared. The pH, chromaticity, and phycocyanin pigments, textures, antioxidants, and sensory evaluation were tested (Kim, 2010). Although there is no significant difference in pH of the tofu to which spirulina is added, the added sphere is higher than that of the control group, and the pH is also increased as the amount of added increases. . In chromaticity, the L value is the highest in the control group. The value a is the highest in the control group, and it decreases significantly as the amount of addition increases. The value of b increases with the addition of spirulina. The difference in the chromaticity of the head is thought to be due to the phycocyanin pigment of the spirulina. C-phycocyanin (C-PC) and phycoerythrin (PE) increase as the concentration of spirulina increases. In terms of antioxidant properties, the DPPH Radical Scavenging IC_{50} value is 150.7 mg/g in the control group and the 1% added amount is 82.5 mg/g, which decreases as the added amount increases, increasing the antioxidant property of the head. The increase in antioxidant properties is due to the increase in the content of spirulina and the increase in the content of phycocyanin. Texture was divided into robustness, chewability, adhesiveness, elasticity, cohesiveness, gumminess, and restorability. First, robustness, chewability, and gumminess increase as the amount of addition increases. However, there are no significant differences in elasticity, cohesion, and restorability. This is related to the decrease in the yield of tofu as the amount of addition increases, and it is believed that the moisture of tofu decreases according to the amount of addition, making the texture stronger. The sensory test was conducted with appearance, aroma, taste, texture, overall preference, and purchase intention evaluation. Although no significant difference occurred in all parts, it was the highest when 0.5% (g) of spirulina was added compared to the control group. In order to maintain the properties of tofu and antioxidant properties of spirulina, it is appropriate to add 0.5% or 0.5g of spirulina based on 100g of soybean to create a higher preference for consumers (Kim, 2010).

4.3. Dumpling skin

In this paper, the study of adding Spirulina to flour dough was conducted. When producing a dumping skin with Spirulina, 2g, 4g, 6g, and 8g of the Spirulina raw material (23, respectively) were added based on a weight of 200g containing Spirulina, and an experiment was conducted by comparing the control group without Spirulina. Experiments were conducted on moisture content, weight and volume, turbidity, chromaticity, texture, antioxidant, and sensory test. The moisture content of the dumpling skin increases as the amount of addition increases (Nam, 2018). From this, it can be seen that Spirulina has a higher moisture binding force than flour. The weight and volume of the dumpling skin increase in the additive compared to the control group, but there is no significant difference between the additive. The turbidity indicates the degree of loss of solids during cooking, the control group is the highest, and the turbidity decreases as the amount of addition increases. The DPPH Radical Scavenging IC_{50} value is 150.7 mg/g in the control group and the 1% added amount is 82.5 mg/g, which increases as the added amount increases (Nam, 2018). Therefore, it can be determined that the addition of Spirulina to the dumpling skin has an antioxidant effect compared to the general dumpling skin. The chromaticity was measured by L, a, and b values, and L values decreased as the amount of addition increased. The values of a and b are the highest in the control group and lower as the amount of addition increases. In terms of texture, the results of hardness, cohesiveness, elasticity, gumminess, and chewability were measured. The hardness was the highest in the control group compared to the additive. The control group has the highest cohesiveness and chewability, but each characteristic increases as the amount of addition increases. The control group has the highest elasticity and adhesion, but each characteristic decreases as the amount of addition increases. All five characteristics showed different results depending on the amount added, but there was no significant difference between the control group and the added sphere. Sensory test evaluated color, aroma, taste, texture, and overall preference. Color, aroma, taste, and overall preference are all the highest when 2% (i.e., 4 g) is added, and the control group is the highest only in terms of texture. Therefore, it is considered most appropriate to add 4g of Spirulina to 196g of flour, considering the consumer's preference, as it has an antioxidant effect of Spirulina. However, although the overall preference is the best at 2%, it is necessary to develop a product, noting that the preference is not as good as that of the control cell when more than 1% of Spirulina is added.

4.4. Fish cake

Fish cakes with spirulina were prepared by steaming, and 0.3 g, 0.6 g, 0.9 g, and 1.2 g (each 0.5%, 1.0%, 1.5% and 2.0% of spirulina) were added based on a total of 300g. This paper experimented on moisture content, pH, chromaticity, texture, antioxidant, sensory test, and sensory preference (Choi, 2017). First, there is no significant difference in water content between the control group and the additive, and the pH decreases proportionally as the amount of addition increases. The chromaticity decreases as the amount of addition increases, and the value of a decreases as the amount of addition increases, and the value of b decreases. That is, it can be seen that due to the blue color of phycocyanin, the degree of green color of fish cake increases. Texture was tested on hardness, adhesion, cohesion, elasticity, chewability, and restorability. Hardness and adhesion are the highest in the control group, and decrease as the amount of addition increases. Cohesion is also the highest in the control group, but decreases as the amount of addition increases. On the other hand, the control group has the lowest elasticity, and increases proportionally as the amount of addition increases. Chewability is the highest in 1.5% of spirulina added spheres, but the control group is very high compared to the added spheres. There is no significant difference in restorability between the control group and the additive. Antioxidants were evaluated with total polyphenol content and DPPH Radical Scavenging ability. First, the total polyphenol content is 28.24mol in the control group and 99.94mol in 2% of spirulina, which increases proportionally as the amount of addition increases. DPPH Radical Scavenging Capacity also increases as the amount of addition increases. That is, it can be seen that antioxidant properties increase proportionally according to the amount added. The sensory test evaluated appearance, spirulina smell, fishy smell, savory taste, unpleasant taste, hardness, and elasticity. The appearance was evaluated for the darkness of the color, and it increased as the amount of addition increased. As the amount of added increases, the smell of spirulina increases and the fishy smell decreases. There is no significant difference between savory and unpleasant flavors depending on the amount added. Hardness and elasticity are the highest at 1% and 2% added, but there is no significant difference. Since it was measured by a person, not a machine, sensual elements are complexly included, so complementary points are needed. The sensory preference was subdivided into color, smell, texture, taste, and preference. Color and odor are the highest at 1.5% added amount, and in the case of color, the preference is lowered when a large amount is added, and the preference for odor is increased compared to the control group. Texture, taste, and preference are the highest at 1% of the added amount, and the added sphere has a higher preference than the control group. As a result, the preference degree is very high compared to the control group, and in particular, it is very excellent at 1% of the added amount of spirulina. The possibility of commercialization is considered to be very high because the overall preference is excellent when spirulina is added. Therefore, 1% of the added amount is most suitable to maintain the characteristics of fish cake and to harmonize the effect of spirulina well.

4.5. Dasik (traditional Korean pressed cookies)

Among various Dasik types, spirulina was added to Dasik using beans and black sesame, and the components according to Dasik, which contained 10, 20, and 30 g of spirulina based on a total of 100 g, were compared. The water content, chromaticity, texture, antioxidant, sensory test, and strength characteristics were tested (Son et al., 2009; Kim et al., 2008). First, both soybean and black sesame Dasik increase the moisture content in accordance with the increase in the amount added, and the L and a values of the chromaticity decrease as the amount added increases. . However, in the case of value b, the bean Dasik decreases as the amount of addition increases, but there is no significant difference in the addition part for black sesame Dasik, and there is a significant difference between the additive and the control group. Texture tested both soybean Dasik and black sesame Dasik on hardness, adhesiveness, elasticity, avidity, gumminess, and chewability. First, the hardness decreases as the amount of soybean Dasik increases, but the black sesame Dasik decreases. In terms of adhesion, there is no significant difference between the conventional additive and the control group, and the black sesame Dasik decreases as the amount of addition increases. Elasticity and avidity have no significant difference between the control group and the additive in both soybean Dasik and black sesame Dasik. However, elasticity is the highest in the control group. In the case of gumminess, bean Dasik decreases as the amount of addition increases, but black sesame Dasik increases. Finally, the chewability decreases in the additive compared to the control group in soybean Dasik, and there is a significant difference between the additive ports, and black sesame Dasik increases proportionally as the amount of addition increases. The antioxidant properties were experimented on DPPH radical scavenging ability and hydroxyl radical scavenging activity. In the case of DPPH radical scavenging of soybean and black sesame Dasik, the IC_{50} value is 112.3 mg/ml and 76.6 mg/ml, respectively, in the control group, and in 30% of spirulina, 26.3 mg/ml and 58.2 mg/ml, respectively. In addition, in the Hydroxyl radical scavenging activity, the control group was 100.7 mg/ml and 56.2 mg/ml, respectively, and decreased to 32.9 mg/ml and 45.7 mg/ml in 30% of spirulina addition. It can be seen that both soybean and black sesame polyacids lower the IC_{50} value as the amount of addition increases, that is, the antioxidant increases. Sensory test evaluated appearance, taste, aroma, texture, overall preference, and purchase intention. Soybean Dasik has the highest control group in all items, and there is no significant difference between the additional sections. In particular, it decreases as the amount of addition increases in overall preference and purchase intention. In the case of black sesame Dasik, there was little significant difference in each evaluation element, it was the highest at 20% of the spirulina addition amount, and it decreased rapidly when the addition amount increased to 30%. The strength characteristics were evaluated for gloss, color, spirulina scent/taste, softness, and moistness. The gloss is highest when both soy and black sesame Dasik have 20% added spirulina. In the case of color, soybean Dasik is the highest at 30% of spirulina and black sesame at 20%. The aroma and flavor of Spirulina both increase with the addition of soybean and black sesame Dasik. In the case of soybean Dasik, the degree of softness increases as the amount of addition increases, and black sesame Dasik decreases as it increases. There is no significant difference in the degree of moisture in the case of soybean Dasik, and black sesame Dasik decreases as the amount of addition increases. As a result, it was found that the same Dasik, but showed different values depending on the main material. However, the same result came from the most important part, the overall preference diagram. Therefore, in order to maintain the characteristics of Dasik and to harmonize the strengths of spirulina well, it is very suitable to set the amount of spirulina added to 20%.

4.6. Bread, pound cake

When producing bread with Spirulina, based on a weight of 240 g including Spirulina, an additive was prepared by adding 1 g, 2 g, and 3 g (the content is 0.4%, 0.8%, and 1.2%, respectively) (Nam, 2018), and an experiment was conducted by comparing the control group without Spirulina. When producing a pound cake with spirulina, 2.5 g, 5 g, 7.5 g, and 10 g of the spirulina raw material (0.25 g, 0.5 g, 7.5 g, and 10 g, respectively) (Byeon, 2017), were added to prepare an additive, and the control group without spirulina was compared. The pH of the bread and the pound cake increases as the amount of spirulina added increases, and the L values, a values, and b values decrease as the amount of added increases. The volume of bread decreases as the amount of bread added increases, but the pound cake gradually increases. In cake products, it is explained that the proportion of dough is affected by mixing conditions such as the type of flour, temperature, and time, and the use of chemical expanders. The pound cake has a DPPH radical scavenging ability of 2.27% in the control group and 18.77% in the addition amount of 10%. On the other hand, the paper on the quality characteristics of bread did not deal with the DPPH radical scavenging experiment, but the C-PC and APC values increased as the amount of Spirulina added, so it could be determined that the antioxidant property was increased in both products. Texture was experimented by dividing into hardness, gumminess, adhesiveness, cohesiveness, and chewiness. First, hardness decreases as the amount of addition increases in both. However, on the contrary, elasticity, cohesiveness, gumminess, and chewability are the highest in the control group, and decrease as the amount added increases. The sense test of bread was divided into taste and strength characteristics, and the taste was subdivided into color, aroma, taste, texture, overall taste, and purchase intention. The strength characteristics were evaluated for color, spirulina scent, taste, elasticity, and moisture. The pound cake was divided into sensory characteristics and sensory preference maps to conduct sensory test. The sensory characteristics were subdivided into the darkness of color, spirulina smell, unpleasant smell, taste, sweetness/soft/moisture concentration, and adhesion, and the sensual preference was evaluated by dividing into appearance, aroma, taste, texture, and overall preference. There were so many sensory test elements that only the common evaluation elements of the two papers were analyzed. In terms of sensual preference, the flavor of the scent decreases as the amount of addition increases. The taste was higher in the additive than in the control group, but considering that the control group had the highest overall preference for bread, it is more appropriate to add Spirulina to the pound cake than bread. Therefore, it is appropriate to add 2g of Spirulina to bread based on 240g of flour (Kang, 2011) and 7.5g of Spirulina to pound cake based on 100g of flour (Byeon, 2017) in order to maintain the properties of bread itself, increase sensual preference, and produce antioxidant bread.

4.7. Yogurt

In the production of yogurt with spirulina, 0.20g, 0.40g, and 0.80g of the Spirulina raw material (e.g., 0.25%, 0.5%, and 1.0%, respectively) were added to prepare an additive, and an experiment was conducted by comparing the control group without spirulina. pH, acidity, chromaticity, texture, antioxidant, and sensory test were experimented (Choi, 2008). The pH decreases significantly as the amount of addition increases. Acidity increases as the amount of addition increases. On the other hand, there is no significant difference in sugar content between the additive and the control group. The viscosity increases as the amount of addition increases. The chromaticity was measured at L values, a values, and b values, and L values decrease as the amount of addition increases, and a values increase as the amount of addition increases, and there is no significant difference in B values. The number of lactic acid bacteria increases with the addition of Spirulina. The DPPH radical scavenging IC_{50} value was 130.91 mg/mL of the control group and 1.0% 71.05 mg/mL of the added amount, which decreased as the amount of Spirulina added increased. In addition, the hydroxy radical scavenging IC_{50} value is 68.10 mg/mL of the control group and 1.0% 42.98 mg/mL of the added amount, which decreases as the added amount increases. That is, the antioxidant property increases as the amount of addition increases. The sensory test evaluated Spirulina color, aroma, appearance, taste, aroma, and overall preference. In the taste and aroma of Spirulina, each characteristic increases as the amount of addition increases. It is all the same in appearance, aroma, taste, and overall preference, but the control group is lower than the additional sphere until 0.25% of Spirulina is added. On the other hand, when 0.5 to 1% of Spirulina is added, the preference rapidly decreases. Therefore, considering the overall results, 0.2 g of Spirulina powder should be contained compared to 76.76 ml of milk to develop functional products with antioxidant properties.

4.8. Salad dressing

Salad dressing with spirulina added was experimented by dividing the control group into 0.07% (g), 0.14% (g), 0.28% (g), 0.55% (g), and 1.09% (g) based on a total of 100g. The test items are physical properties, viscosity, emulsion stability, color, antioxidant, and sensory test (Xhin et al., 2005). First, physical properties were analyzed by dividing into hardness, adhesion, elasticity, and cohesiveness. Hardness and adhesion increase proportionally as the amount of addition increases. Elasticity is the highest at 0.55% and 1.09% added, and there is no significant difference in the rest. There is no significant difference overall, but it increases as the amount of addition increases. The viscosity does not differ significantly from the control group from 0.07% to 0.28% but increases significantly from 0.55%. There is no difference between the emulsion stability control group and the additive. In the case of colors, the L value and the value decrease as the amount of addition increases, but the b value increases. Antioxidants were divided into DPPH radical scavenging and TBARS radical scavenging. First, the IC_{50} value of the DPPH radical scavenging function was 114.63 mg/ml in the control group and 1.09% in the added amount was 102.14 mg/ml, which significantly decreased as the added amount increased. Similarly, the IC_{50} value of the TBARS radical scavenging function is 6.85 μg/ml in the control group and 1.09% of the added amount is 6.54 μg/ml, which is significantly decreased as the amount of added increases. In other words, antioxidants increase proportionally as the amount of addition increases. Finally, the sensory test evaluated the color, aroma, taste, viscosity, and overall preference. The color is highest at 0.14% and 0.28% of the added amounts, and is significantly lower in the control group and the rest of the added spheres. The aroma and taste are highest at 0.28% and decrease as the amount of addition increases. There is no significant difference in viscosity, and the overall preference is the highest at 0.28% of the added amount, and there is no significant difference in the rest. As a result, in order to harmonize the consumer's taste with the antioxidant effect of spirulina while maintaining the characteristics of the dressing with mayonnaise, the added amount of 0.28% is very excellent.

5. Conclusion

Spirulina is a high-protein microalgae containing 55-70% protein. Although there are various sources of animal protein in the past, it is judged that Spirulina can be attracting attention as a new source of protein because it takes a long time to receive supply along with environmental pollution. When synthesizing the papers used in this study, due to the increase in consumer preference due to the addition of spirulina, it is judged that the quality can be further improved by using it as the main ingredient of existing foods rather than raw materials for health functional foods. In this study, application cases in the fields of acorn jelly, tofu, dumpling skin, fish cake, Dasik, bread, pound cake, salad dressing, and yogurt were analyzed. As a result of the analysis focusing on antioxidant and functional evaluation, in the acorn jelly paper, 0.4 g, 0.8 g, and 1.2 g (each 0.5 g, 1.0%, and 1.5% content) of the spirulina raw material are added based on 80 g of spirulina. The antioxidant property increases as the amount of spirulina added increases, and the IC_{50} value is 166.2 mg/mL at 1.5%. Among the sensory test items, there is no significant difference in hardness, and elasticity, color, fishy taste, and bitterness increase as the amount of addition increases. The preference is the highest from 0.5% to 4.9, and the lower the preference is added. In a paper on tofu, a spirulina raw material was added 0.25g, 0.5g, 0.75g, and 1g (content of 0.25g, 0.5%, 0.75%, and 1%), based on a weight of 100g containing spirulina, to prepare an additive. The antioxidant property increases as the amount of spirulina is added, ranging from 1% to 82.5 mg/g. Among the sensory test items, robustness, chewability, and gumminess increased as the amount of addition increased, and there was no significant difference in elasticity, cohesiveness, and restorability. As the amount of fish cake added increases, the antioxidant property increases, and in the control group, the antioxidant property is 17.21%, and the amount added is 2.0% to 29.05%. Among the sensory preference chart items, color and smell are the highest at 1.5% added amount, texture, taste, and preference are the highest at 1% added amount, and are 6.40, 6.37, and 6.13, respectively. In the paper on dumpling skin, based on a weight of 200 g including spirulina, 2 g, 4 g, 6 g, and 8 g of the spirulina raw material (the content is 1 g, 2 g, 3%, and 4%, respectively) was added to produce an additive. Antioxidants increase as the amount of addition increases, and the control group is 37.85% and the amount of addition is 66.22%. Among the sensory test items, color, aroma, taste, and overall preference are all the highest at 2% of added amount, and the control group is the highest only in terms of organizational sense. Dasik was divided into soybean Dasik and black sesame Dasik, and the components according to Dasik containing 10g, 20g, and 30g of spirulina were compared based on a total of 100g. Antioxidants increase as the amount of addition increases, and IC_{50} values are 112.3 mg/mL and 76.6 mg/mL, respectively, in the control group, and IC_{50} values are 26.3 mg/mL and 58.2 mg/mL, respectively, in 30% of addition. Among the sensory test items, soybean

Dasik has no significant difference in all items. In the case of black sesame Dasik, there was little significant difference in each evaluation factor, and it was the highest from 20% to 6.2 with spirulina added amount, and it decreased rapidly when the added amount increased to 30%. In the paper on bread, when preparing bread to which Spirulina was added, 1 g, 2 g, and 3 g (the contents are 0.4%, 0.8%, and 1.2%, respectively), of the spirulina raw material were added based on a weight of 240 g including spirulina. As the amount of spirulina added increases, the C-PC and APC values increase, so the antioxidant property increases. Among the sensory test items, the color is the highest when 0.8% is added to the control group, and the scent decreases as the amount of addition increases. The taste is the highest at 0.8%, and the texture decreases as the amount of addition increases. The overall preference and purchase intention are the highest in the control group, the hardness decreases as the amount of addition increases, and other items show no significant difference. In the paper on the pound cake, 2.5 g, 5 g, 7.5 g, and 10 g of the spirulina raw material (e.g., 0.25 g, 0.5 cm, 7.5 cm, and 10% respectively) were added to prepare an additive based on a weight of 100 g including spirulina. The antioxidant property increases as the amount of spirulina added increases, ranging from 10% to 18.77%. Among the sensory test items, the appearance, texture, and aroma are generally high, and there is no significant difference in taste. The overall preference increases as the amount of addition increases, but decreases rapidly at 10%. Hardness, gumminess, cohesiveness, chewability, and elasticity decrease as the amount of addition increases, and increases as only adhesion is added. In a paper on yogurt, based on a weight of 76.76 g including spirulina, 0.20 g, 0.40 g, and 0.80 g (content of 0.25 g, 0.5%, and 1.0%, respectively), of the spirulina raw material was added to prepare an additive. The antioxidant property increases as the amount of addition increases, and ranges from 1.0% to 71.05 mg/ml. Among the sensory test items, the taste and aroma of spirulina increase as the amount of addition increases. When 0.25% is added to the appearance, taste, aroma, and overall preference, the control group is lower than the additive, but it decreases rapidly at 0.5-1%. In the salad dressing paper, based on a total of 100 g, the experiment was conducted by dividing the control group into 0.07% (g), 0.14% (g), 0.28% (g), 0.55% (g), and 1.09% (g). The antioxidant properties increase as the amount added increases, and the IC_{50} value is 114.63 mg/mL of the control group and 1.09% of the added amount is 102.14 mg/Ml. Among the sensory test items, color is the highest at 0.14% and 0.28% added, and scent and taste are the highest at 0.28% to 7.50 and 8.0, respectively. There is no significant difference in viscosity, and the overall preference is the highest at 0.28% to 7.97, and there is no significant difference in the rest. Taken together, it was confirmed that the results were valid enough to develop products in tofu, dumpling skin, fish cake, and pound cake. It is considered that it will be possible to develop foods in other fields if the mixing ratio is supplemented to find an additional amount that can match the consumer's preference, and it will be applicable to other food groups. Therefore, in order to improve the nutritional aspects of food and contribute to environmental problems, research on Spirulina suitable as an alternative protein should be conducted more actively.

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