

# **Spirulina platensis: An excellent protein source for food supplementation**

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## **Abstract:**

Spirulina is a blue green, filamentous algae, rich in macro & micro nutrients. It also proposed many therapeutic properties such as anti-inflammatory, antiviral, antioxidant effects. Due to its high nutritional profile, it is supposed as excellent source of protein & is used for protein enrichment and fortification. The use of spirulina as a protein supplement in population with protein malnutrition is considered as feasible as it has several advantages when compared with other agricultural protein source. Spirulina typically contains about 55-70% protein. It is good source of vitamin B12, copper & iron. Spirulina protein is low in calories. Well balanced chemical composition of spirulina (good quality protein, balanced fatty acid profile, vitamins, antioxidants & minerals) superior to that of traditional foods & interesting health promoting effects can be applied in the formulation of novel food products. Research shows that Spirulina may have antioxidant, pain relief, anti-inflammatory and brain protect properties. Many antioxidants in spirulina have anti-inflammatory effects in the body. Spirulina platensis has been used in bakery, confectionary, dairy products, and extruded products and in snacks for nutritional enrichment. This article provides application of spirulina platensis in food supplementation.

**Key words:** Anti-inflammatory, enrichment, fortification, protein malnutrition, spirulina platensis, supplementation.

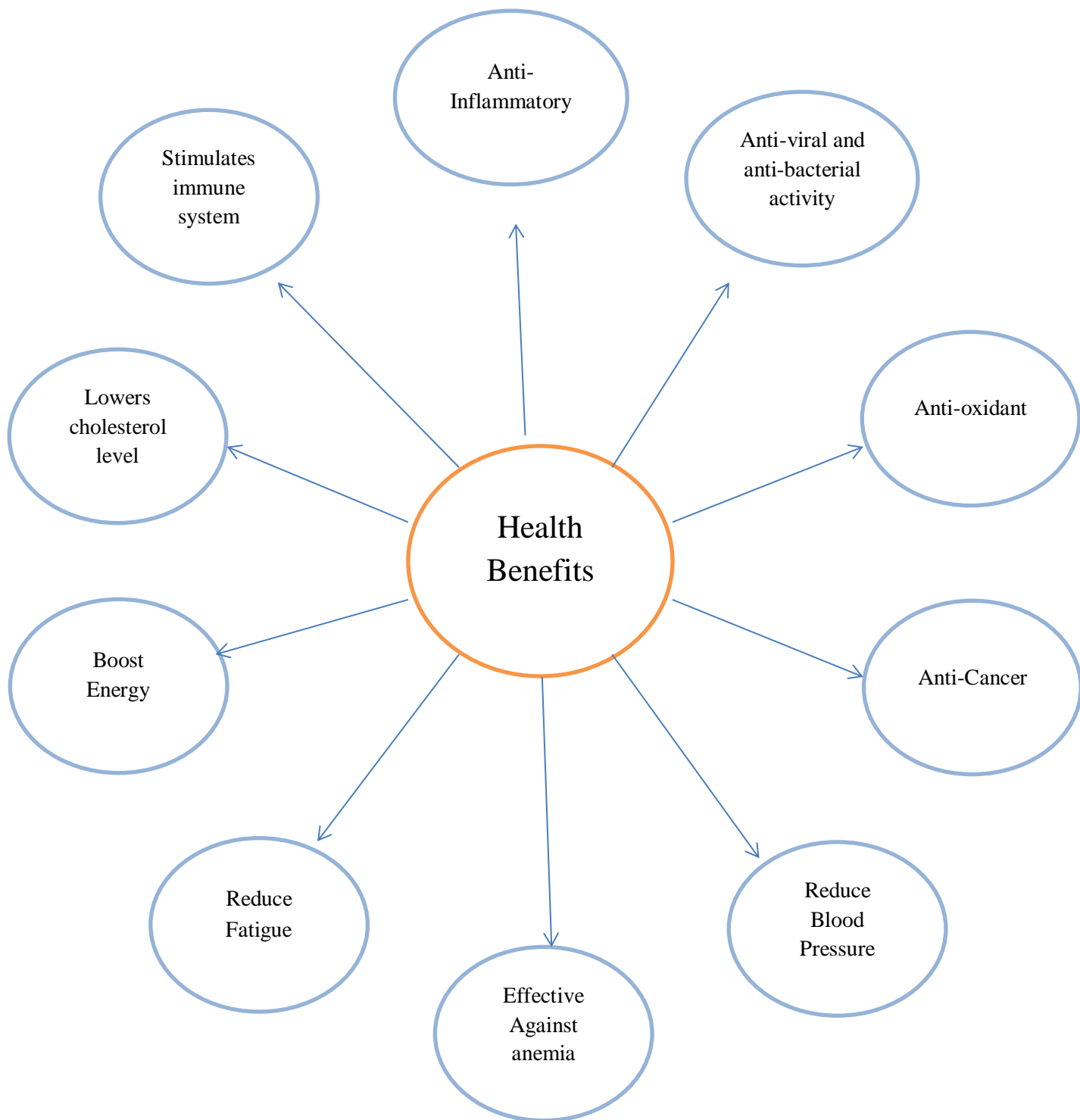
## INTRODUCTION

According to UNICEF 2016 data, 22.9% of children worldwide under the age of five had stunted growth. Stunting is the impaired growth & development that children experience from poor nutrition & inadequate psychosocial stimulation<sup>(1-2)</sup>. Around 50% of all deaths in children under five years are attributable to under nutrition. India is home to about one third of all malnourished children in the world malnutrition continues to be a major public health problem throughout the developing world<sup>(3)</sup>. Tackling protein deficiency related conditions among the youngest section of the population is the need of the hour<sup>(2)</sup>. Addition of a healthy amount of complete protein in our diet is very important. Spirulina is gaining more attention from medical scientists as a nutraceutical & source of potential pharmaceutical<sup>(29)</sup>. Spirulina is one of great or excellent protein source. It is approximately 55-70% complete protein in its natural state. This is higher than virtually any other protein food<sup>(3)</sup>.

Spirulina platensis is a photosynthetic microalgae with fibrous filamentous that belongs to the cyanobacteria family<sup>(4-30)</sup>. Spirulina platensis has gained popularity & acceptance in the food processing industries as a food supplement. It has very high profile of macronutrient & micronutrient contents. It is rich in amino acids, unsaturated fatty acids, minerals & vitamins. It consists of 55-70% protein, 15-25% polysaccharide, 5-6% total lipid, 6-13% nucleic acids & 2.2-4.8% minerals. Spirulina has potential health benefits including immunomodulation, antioxidant, anticancer, antiviral & antibacterial activities as well as positive effects against malnutrition, hyper lipideamia, diabetes, obesity, inflammatory allergic reactions. Spirulina as a supplement is mostly a pro-inflammatory agent. It enhances antioxidant activity & promotes the production of antibody & cytokines in both healthy & diseased animal models<sup>(2)</sup>. The supplementation of spirulina platensis in food has been seen an emerging trend in several studies in past decades.

We have summarized nutritional content of spirulina and their health benefit.

**Fig 1: Represents the health Benefits of spirulina platensis**



**Fig 2: Represents Nutritional Value of Spirulina Platensis**

<b>Spirulina</b>	→	Calories	2.9% (Cal/g)
	→	Protein	65-72%
	→	Carbs	15-75%
	→	Fibers	3-7%
	→	Lipids	4-7%
	→	Minerals	6-12 mg/g

In table 1 and table 2 we have summarized the essential and non-essential amino acids, their content and health benefits respectively

**Table 1**

Essential amino acids	Mg/100g	Health benefits
Isoleucine	6.49	<ul style="list-style-type: none"> <li>• Ant aging</li> <li>• Anti-inflammatory</li> <li>• Improves vision disturbance</li> <li>• Detoxifies nitrogen waste</li> <li>• Boost muscle growth</li> </ul>
Leucine	7.89	<ul style="list-style-type: none"> <li>• Helps in weight loss</li> <li>• Protects body against liver &amp; cholesterol cancer</li> <li>• Controls blood sugar level</li> <li>• Controls cholesterol level</li> </ul>
Lysine	4.73	<ul style="list-style-type: none"> <li>• Improves mineral absorption &amp; retention</li> <li>• Important for normal muscle growth</li> <li>• Helps in healing of wounds</li> <li>• Supports hair growth</li> </ul>

		<ul style="list-style-type: none"> <li>• Helps in treatment of cold sores by blocking arginine</li> <li>• Prevents bone loss</li> </ul>
Methionine	2.43	<ul style="list-style-type: none"> <li>• Boost immunity</li> <li>• Helps in proper growth of new blood vessels</li> <li>• Helps in treatment of liver diseases &amp; colorectal cancer</li> <li>• Plays important role in Parkinson's disease treatment</li> <li>• Builds bone strength</li> </ul>
Phenylalanine	4.42	<ul style="list-style-type: none"> <li>• Precursor of tyrosine</li> <li>• Improves ADHD symptoms in the short term</li> <li>• Treat depression</li> </ul>
Threonine	4.58	<ul style="list-style-type: none"> <li>• Helps in treatment of various nervous system disorders</li> <li>• Treats different types of depression</li> <li>• Aids in maintaining healthy skin, teeth, collagen, elastin &amp; muscle tissue</li> <li>• Helps in metabolism</li> </ul>
Tryptophan	1.93	<ul style="list-style-type: none"> <li>• Healthier &amp; better quality sleep</li> <li>• Relief from depression &amp; anxiety</li> <li>• Increased emotional well being</li> <li>• Strengthened pain tolerance</li> </ul>
Valine	6.08	<ul style="list-style-type: none"> <li>• Essential for mental focus, muscle co-ordination &amp; emotional calm</li> <li>• Used for muscle growth, tissue repair &amp; energy</li> </ul>

**Table 2**

Essential amino acids	Mg/100g	Health benefits
Alanine	7.52	<ul style="list-style-type: none"> <li>• Used to make proteins</li> <li>• Used to break down tryptophan &amp; vitamin-B6</li> <li>• Source of energy for muscles &amp; central nervous system</li> <li>• Strengthens the immune system</li> <li>• Helps the body to use sugars</li> </ul>
Arginine	7.51	<ul style="list-style-type: none"> <li>• Reduce high blood pressure</li> <li>• Corrects inborn errors of urea synthesis</li> <li>• Treats heart diseases</li> <li>• Anti-inflammation of digestive tract</li> </ul>
Aspartic acid	11.17	<ul style="list-style-type: none"> <li>• Improves stamina</li> <li>• May enhance immune system</li> <li>• May protect from toxins, neural and brain disorders</li> </ul>
Cysteine	1.11	<ul style="list-style-type: none"> <li>• Neutralizes free radicals</li> <li>• Prevents kidney and liver damage</li> <li>• Improves psychiatric disorders</li> <li>• Stabilizes blood sugar</li> <li>• Improves immune function</li> </ul>
Glutamic acid	13.69	<ul style="list-style-type: none"> <li>• Treat intellectual disorders</li> <li>• Treat low blood sugar in people with diabetes</li> <li>• Prevent nerve damage in people having chemotherapy</li> </ul>

		<ul style="list-style-type: none"> <li>• Promotes muscle growth</li> </ul>
Glycine	5.24	<ul style="list-style-type: none"> <li>• The main amino acid in collagen</li> <li>• Improves sleep quality</li> <li>• Protect liver from alcohol induced damage</li> <li>• Protect heart</li> </ul>
Histidine	2.78	<ul style="list-style-type: none"> <li>• Helps in growth, repair of damaged tissues</li> <li>• Helps protect nerve cells</li> <li>• Protects eyes from inflammation</li> <li>• Prevents oxidative stress</li> <li>• Prevents blood clots</li> </ul>
Proline	4.35	<ul style="list-style-type: none"> <li>• Vital for nerve conduction &amp; brain function</li> <li>• Helps in weight loss</li> <li>• Prevents skin problem</li> <li>• Aids in elimination of toxins &amp; waste</li> </ul>
Serine	4.56	<ul style="list-style-type: none"> <li>• Precursor of glycine &amp; cysteine</li> <li>• Important in cell communication within brain</li> <li>• Treats brain diseases</li> <li>• Improves Huntington's disease</li> <li>• Combats depression</li> <li>• Helps in relief from anxiety</li> </ul>
Tyrosine	3.61	<ul style="list-style-type: none"> <li>• Helps the body build protein &amp; reduce enzymes, thyroid hormones &amp; the skin pigment melanin</li> <li>• Helps the body to produce neurotransmitters</li> </ul>

		<ul style="list-style-type: none"> <li>• Precursor for epinephrine, norepinephrine &amp; dopamine</li> </ul>
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### Application:

Spirulina platensis can be regarded as an alternative & promising ingredient for food fortification or enrichment due to its nutritional composition, nutraceutical & therapeutic functions. It is considered as a sustainable protein source for food. This novel source of protein is commonly used in food supplementation including bakery, dairy, extruded products, and confectionary and in snacks to increase nutritional content.

### 1] Bakery products:

#### 1.1. Bread:

Bread is an excellent source of energy & protein has a vital role in feeding people throughout the world. It is one of the most popular bakery products generally made from wheat flour which is limited in vitamins, minerals, antioxidants & dietary fiber<sup>(7)</sup>. Therefore it can be fortified with spirulina powder to improve its nutritional quality<sup>(30)</sup>.

Huda Abdul Rahman owyed Al-Jumayi, made bread using wheat flour fortified with 20% hull less barley which contained beta-glucan as a natural antioxidant & dietary fiber & also it was supplemented with spirulina platensis powder at 2.5, 5.0, 7.5 & 10% levels for additional nutrients. Results indicated that the water absorption, dough development time & stability time increased gradually by increasing the level of spirulina platensis powder. The results also indicated that 7.5% the addition of spirulina platensis have not any negative effects on the shelf life of the loaves of bread improved the nutritional value<sup>(7-8)</sup>.

Fortification of wheat bread with some edible algae-kelp & spirulina platensis in the amount of 4% by the weight of the flour is an effective approach for increasing the content of thiamine & riboflavin in bread<sup>(8)</sup>.

Addition of the spirulina decreased the hardness of the bread & increases the springiness rate among the bread samples<sup>(4)</sup>.



Ehab, Amira, Mohamed, Soher reported the addition of 0.7% spirulina powder in shamy bread to promote nutritional value, results recorded shows a higher value of protein, ash, crude fiber, zinc & iron compared to normal bread<sup>(9)</sup>.

When bread dough is supplemented with spirulina platensis a type of microalgae rich in nutrients, it enriched the nutritional content of the bread in terms of protein, calcium, Mg & Fe. No mold growth was detected in spirulina added bread which was stored at room temperature <sup>(10)</sup>.

## 1.2. Cookies

Cookies are widely consumed baked products, appreciated for their organoleptic properties, versatility, convenience, texture & appearance. Introduction of functional ingredient beyond traditional nutrients is an attractive approach to design new product.

Fortification of cookies with spirulina platensis microalgae is highly effective method for increasing the nutrients in children's diet due to its simplicity, low cost and convenience <sup>(11)</sup>.

Koloocheh are the sweet Traditional Iranian nutritional cookies. Koloocheh fortified with spirulina platensis showed increase content of iron, protein & y-linolenic acid, according to organoleptic evaluation by hedonic tests, samples fortified with 1-1.5% spirulina platensis received record highest scores<sup>(11-12)</sup>.

The spirulina fortified cookies contained 2.55% moisture, 6.25% protein, 20.43% fat, 1.18% crude fiber, 4.07% ash i.e. cookies fortified with spirulina were significantly high in nutrients<sup>(12)</sup>.

Cookies with 8% spirulina powder with 75% little millet flour was highly acceptable in both nutritional value & physico-chemical properties <sup>(13)</sup>.

5-15% spirulina powder in cookies made it more firm & hard to break. It may help maintain their integrity & reduce breakage during packaging & distribution. Increasing the content of spirulina from 5-15% increased the odor intensity by 19.6%. Addition of spirulina powder effects both taste & degree of acceptance of cookies. Adding spirulina enhanced the nutritional value of the cookies by increasing the protein content of the cookies, enriched the cookies with vitamins, minerals, omega-fatty acid which have significant health benefits to school children<sup>(1)</sup>.

## **2] EXTRUDED PRODUCTS:**

### **2.1 Pasta products**

Pasta products are simple composite of semolina durum wheat & water made with extrusion technology <sup>(14)</sup>. Pasta is considered a basis popular & favorite food for all age groups <sup>(15)</sup>. Pasta products are well accepted by consumers for their sensory attributes, low cost, ease of preparation & transportation. Pasta is mainly used as an energy source due to its complex carbohydrate content, being regarded as product with low glycemic index <sup>(16)</sup>. Pasta contains low protein, so the enhancement of protein content of pasta through spirulina is very important approach to solve the problem of protein malnutrition <sup>(15)</sup>.

Value added Extruded product can be made by incorporating spirulina powder upto level of 5%. The macro & micro nutrient content of extruded product will be enriched by incorporation of spirulina powder <sup>(17)</sup>.

Sensory evaluation test indicated greater acceptability of pasta fortified with spirulina platensis powder at a concentration of 0.25 % <sup>(14)</sup>. It is enriched product, having both nutritional & sensory characteristics i.e. functional food that will be available to the community <sup>(14-24)</sup>.

The samples with spirulina powder fortification recorded an increase in proteins & dietary fiber contents. The novel pasta formulation offers a broad spectrum of new food products specific for people who take care to the nutritional quality diet <sup>(16)</sup>.

## **3] DAIRY PRODUCTS:**

Milk & dairy products have an important role in human diet due to their nutritional benefits from proteins, minerals & vitamins. Microalgae are known to be rich in protein, amino acids, vitamins & various minerals, as well as polysaccharide, sterols & fatty acids. They have great potential to be used as fortification products in dairy as they contain various macro components i.e. polysaccharides & sulphated polysaccharides as stabilizer & micro components i.e. polyunsaturated fatty acids as bioactive compounds & pigments as a coloring agent posing important functional characteristics <sup>(21)</sup>.

Spirulina platensis has been studied as potential natural resource for dairy products fortification. Incorporation of dried spirulina in dairy products poses major sensorial challenges due to its characteristics odor & its insolubility in food formulations <sup>(19-21)</sup>.

Spirulina enriched fresh cheeses were produced by the addition of powdered spirulina in different concentration. Spirulina, like most micro algae is known to possess an undesirable odor. Methods have been investigated to reduce odor in soft cheese by using activated charcoal absorption, heating, lysozyme enzymatic hydrolysis, and fermentation & solvent extraction. Fermentation & ethanol extraction are more preferred methods to reduce algal odor in soft cheese. The cheese with 0.25% & 0.5% incorporated spirulina are most preferred as they possessed less intense odor & algal taste of spirulina <sup>(21)</sup>.

Processed cheese analog was fortified with 2.4 & 6% of spirulina platensis in powder form & 4% of these algae in slurry form. It has been tested for chemical, rheological & sensory properties as fresh & within 3 months of cold storage i.e. 5-7 °C. 2% fortified processed cheese analog showed the best sensory properties followed by 4% fortified sample, but 6% was unacceptable <sup>(18)</sup>. With respect to powder form of spirulina, application of slurry form showed improved physical, sensory, rheological properties of processed cheese analog <sup>(18-21)</sup>. Fortified processed cheese showed an increase in the content of protein, ash, fiber, selenium, zinc, iron, magnesium & potassium. Also showed an increase in antioxidant properties of cheese <sup>(18-19)</sup>.

Spirulina platensis also incorporated into ice creams, result showed that addition of 1% & 1.2% spirulina platensis were considered as the best concentration for soft cheese and ice creams respectively. Addition of spirulina platensis gave significant effect to protein, total solid, fat, total sugar, over run, melting point & sensory properties of ice cream <sup>(19)</sup>.

#### **4] Snacks:**

Snacks are very popular today among all generations of human beings especially in children. These foods are generally refined, rich in fat, carbohydrates & energy, but lacking in dietary fiber & micronutrients. Therefore, nutritional enrichment of these food products with spirulina platensis can be advantageous to use as carrier of nutrients due to their simple manufacturing process, better shelf life, high acceptability and consumption <sup>(22)</sup>.

Snack bars are ready to eat food & are increasingly present in the diet of children. Studies have been carried out aiming for the introduction of spirulina platensis powder into formulations of snack bars in order to provide healthier food for the consumers <sup>(23)</sup>.

The addition of 2% & 6% of this microalgae(spirulina platensis) resulted in an increase of 11.7% & 29.9% in protein content respectively, besides significantly affecting the color of the snack bars, evaluation showed that

the snack bars enriched with 2% & 6% of spirulina had the attributes appearance, flavor & taste enjoyed by schoolchildren. Therefore, the use of spirulina as an ingredient of snack bars designed for infant feeding is considered promising as an alternative to improve their nutritional health <sup>(23)</sup>.

Sev (snacks) from wheat Bengal gram flour supplemented with different levels of spirulina powder (2, 4, 6 & 8%). These snack products were found acceptable up to 6% level of supplementation of spirulina powder.

Consumption of food products using spirulina platensis supplementation can go a long way in improving the nutritional status & health of the population especially for those suffering from protein energy malnutrition <sup>(22)</sup>.

Chocolates designed with 2% (w/w) of spirulina, exhibited adequate protein content & rich amino acid profile with significant increase in the daily intake of essential amino acids, histidine & arginine for infants and children <sup>(20)</sup>.

Spirulina platensis along with Bengal gram, groundnut, cornflakes & other ingredients was used to make 7 variant of a novel nutrition bar & control sample (without spirulina). The bars were evaluated for nutritional quality, textural parameters, color attributes & sensory qualities. The protein content of the bar was found to be 167% more than the control sample. The spirulina enriched bar gained acceptability in terms of sensory qualities, hence it is a potential product for undernourished children with protein deficiency <sup>(2)</sup>.

## CONCLUSION:

Spirulina platensis, a multicellular, photosynthetic prokaryote (algae), contains a high amount of protein, vitamins & minerals superior to many foods as example soybeans. Thus spirulina platensis was recognized as nutritious food by the United Nations World Food Conference. Due to high amount of nutritive ingredients spirulina has long history as dietary supplement. Hence spirulina platensis has been used in many food supplementation e.g. bread, cookies, cheese, ice cream, snack bar, pasta products including spaghetti etc. For nutritional enrichment.

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## REFERENCES:

- 1) D.M.El Nakib, M.M. Ibrahim, N.S Mahmud, E.N Abd El Rahman. Incorporation of Spirulina platensis in Traditional Egyptian Cookies as a source of Natural Bioactive molecules & functional ingredients: preparation & sensory Evaluation of Nutrition snack for School Children. European Journal of Nutrition & Food Safety. 9(4): 372-397, 2019
- 2) A. Kumar, V. Mohanty & P. Yashanswini. Development of high Protein Nutrition Bar Enriched with spirulina platensis for undernourished children. Current research in Nutrition & Food Science. Vol. 06, No(3) 2018
- 3) Ammatul Fatima & Dr. Sangita srivastava. Development of Fortified Food Products using Spirulina combating malnutrition. International Journal of Home Science: 3(2): 698-700, 2017
- 4) Somayeh Sanjiri, Hamid sarhadi & Fatima shahbadi. Investigating the effect of spirulina platensis microalgae on Textural & Sensory properties of Baguette Bread. Journal of Nutrition & Food Security. 3(4): 218-225, 2018
- 5) Foure A., Bendahan D. Is branched chain amino acids supplement an efficient nutritional strategy to alleviate skeletal muscle damage: A system review nutrients. 9(10): 1047-1059, 2017
- 6) Akram M., Asif Hm. Uzair, M. Akhtar N., A. Saleh SMA. Amino acids: A review Article. Journal of Medicinal Plants, 5(17): 3997-4000, 2011
- 7) Huda Abdal Rahman owyed Al Jumayi. Enrich Nutritional value for Baldy Bread Fortified with spirulina(arthospira platensis) microalgae. Life science journal, 16(9); 2019
- 8) Rosen chochkon, Deuka zatenaz Dana stefanova. Effect of Spirulina platensis & kelp algae on the content of Thiamine & Riboflavin in wheat bread. Ukranian food Journal. Vol. 10, 2021
- 9) Ehab Th. El- said, Amira sh. Soliman, Mohamed S. Abbas, Soher E. Aly. Treatment of Anemia & Malnutrition by Shamy bread fortified with spirulina, quinoa and chickpea flour. Egyptian journal of chemistry. Vol. 64, No.5 pp. 2253-2268, 2021
- 10) Burcu Ak., oya Isik, Ebru kalkas, ozyurt. Nutritional & physico-chemical characteristics of Bread Enriched with micro algae spirulina platensis. Journal of Engineering Research & Application, vol. 6, Issue 12, (part-4), pp. 30-38, 2016
- 11) S. Shah bazizadeh, k.k hosravi, sara Sohrabvandi. Fortification of Iranian Traditional cookies with spirulina platensis. Annual Research & Review in Biology. 7(3): 144-154, 2015

- 12) Ammatul fatima & Sangita Shrivastva. Development & comparative nutritional analysis of spirulina Fortified Cookies for Malnourished children & Women. International journal of Applied Home Science. Vol.2 (3 & 4), 107-113, 2015
- 13) A. Padma & R. Rajendran. Development & evaluation of spirulina Incorporated Little millet cookies. International journal of food fermentation Technol. 7(1): 119-122, 2017
- 14) Mostolizadeh S. ; Moradi Y. ; Mortazavi M.S ; Motallebi A.A., Ghani M. Effects of incorporation spirulina platensis powder in wheat flour on chemical, microbial & sensory properties of pasta. Iranian journal of fisheries sciences. 9(1), 410-420, 2020
- 15) Ahmed Hussein, G. Ibrahim, M. Kamil, M. El Shamarka, S. Mostaga, D. Mohamed. Spirulina enriched pasta as Functional Food Rich in protein & antioxidant. Bio interface Research in Applied chemistry, vol-11, Issue-6, 2021
- 16) Padelino L, Lecce L., chini Ziltelli G., Lo Grieco A., Torzillo, Conte A. Use of spirulina to enhance the Nutritional value of Durum wheat spaghetti. Food & Nutrition Journal, 2: 122, 2017
- 17) D. Vijayarani, S. Ponmalaghu, J. Rajathivya. Development of value added extruded product using spirulina. International journal of Health sciences and research. ISSN: 2249-9571, 2012
- 18) M.M. Tohamy, Hamdy A. Shaban, M.A. Ali & A.M. Hasanain. Effect of spirulina platensis as Nutrition source on the chemical, rheological & sensory properties of spreadable processed cheese. Journal of Biological sciences. ISSN: 1727-3048, 2018
- 19) Tri- Winarni Agustin, W. Farid Ma-ruf, Hidayat Meiny Suzery, Hadiyanto, soottawat Benjakul. Application of spirulina platensis on Ice cream & soft cheese with Respect to their Nutritional & sensory perspectives. Jurnal teknologi. 78: 2016
- 20) Oya Irmak Sahin. Effect of spirulina Biomass Fortification for biscuits and chocolates. Turkish Journal of Agriculture food science and Technology. 7(4): 583-587, 2019
- 21) L. Bosnea, Antonia Terpon, Eleni pappa, E. Kondyli, M. Mataragas, G. Markon, G. Katsaros. Incorporation of spirulina platensis on Traditional Greek Soft Cheese with respect to its Nutritional & sensory perspectives. Proceedings, 70,99. 2021
- 22) Seema, S. Jood & Mahima Kumari. Development of Healthy Snacks(sev) supplemented from spirulina platensis powder & organoleptic Evaluation. International journal of current Microbiology & Applied Sciences. ISSN: 2319-7706, vol. 10, No. D1, 2021
- 23) B.F. Lucas, Ana da Rosa, L.F. de Carvalho, M.G. de Morais, T.D santos, Jorge Alberto Vieira Costa. Snack bars enriched with spirulina for school children nutrition. Food Sci. Technol, Campinas, 40(suppl.1): 146-152, 2020
- 24) St. Grahl, Micha strack, Ramona weinrich, Daniel Morlein. Consumer Oriented product Development: The conceptualization of Novel food products Based on spirulina & Resulting consumer Expectations. Journal of food Quality, vol. 2018, Article ID 1919484, 11 pages.

- 25) Kazuya Masuda, Maureen chitundu. Multiple micronutrient supplementation using spirulina platensis & infant growth, morbidity & motor development: Evidence from a Randomized Trial in Zambia. Plus one. 2019
- 26) Ruma arora soni, k. Sudhakar. R.S. Rana. Comparative study on the Growth performance of spirulina platensis on modifying culture media Energy Reports 5; 327-336, 2019
- 27) Gregoire P., Jean-Max Rounet , B. Baroux, J. Baccon, B. Caporiccio. Iron Availability from Iron fortified spirulina by an in vitro Digestion/ Caco-2 cell culture Model. J. Agric food chem. 1625-1629.
- 28) M.o. Aljobair, Najla A. Albaridi, Amal N., Nora M. Alkehayez. Physico chemical properties nutritional value & sensory attributes of a nectar developed using date palm puree & spirulina. International Journal of Food Properties. 2021
- 29) H. Aiking, "Future protein supply". Trends in Food science & Technology, vol. 22. No. 2-3, pp. 112-120, 2011
- 30) B.AK. E. Avsaroglu, O.Isik, G. Ozyurt, E. Kafkas & L.uslu, "Nutritional & physico-chemical characteristics of bread enriched with micro algae spirulina platensis. International Journal of Engineering research & application, vol. 6, no. 12, pp. 30-38, 2016
- 31) B.vaz da silva, J.B. Moreira, M.G. de Morais & J.A.V. costa, "Microalgae as a new source of bioactive compounds in food supplements". Current opinion in Food science, vol. 7, pp. 73-77, 2016
- 32) N.S. Parimi, Manjinder Singh, J.R. Kastner, Keshar C. Das, Parastoo Azadi. Optimization of protein extraction from spirulina platensis to generate a potential co product & a biofuel feedstock with reduced Nitrogen content. Frontiers in energy Research. 2015