

## Nutritional composition, application and health benefits of selected non-conventional food sources, and their fortified products

Omada, Adams Akogwu\*, Arogba, Sunday Salifu, and Atanu, Francis Onakpa

Department of Biochemistry, Kogi State University, PMB 1008, Anyigba, Kogi State, Nigeria.

Corresponding Author E-mail: [adamsomada@gmail.com](mailto:adamsomada@gmail.com)

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**ABSTRACT:** Non-conventional food sources of plant origin, also known as underutilized plant species are basically enriched with nutrients and bioactive compounds which can provide both nutritional and health benefits. Some non-conventional food sources such as Soybean, *Spirulina*, *Moringa olifera*, edible mushrooms and their products are prominent sources of macro- and micro-nutrients with exceptional health benefits. These food sources are basically recommended for human consumption as a result of their potential benefits as functional food and their capacity to be utilized as nutraceutical products to prevent or treat protein and micro-nutrient deficiency diseases. *Spirulina* and soybean are pivotal in functional food formulations due to their high protein content and remarkable quality. Unlike other staple plant food sources, Soybean, *Spirulina*, *Moringa olifera* and edible mushrooms and their products are not popular globally, but currently, they are being used as substitutes in food supplements and food fortification. They have enormous potential uses but are very less explored. They can be utilized as suitable natural products by undernourished population to ameliorate malnutrition, and protect the body from several types of chronic diseases that result malnutrition.

**Keywords:** Edible mushroom, Fortification, *Moringa olifera*, Soybean, *Spirulina platensis*, Non-conventional

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### INTRODUCTION

Nutritional deficiency is a major problem affecting many developing nations and their foreign associates. This problem affects more than 33 percent of the world population, particularly in sub-Saharan Africa where almost one individual out of four persons is undernourished (Chauvin *et al.*, 2012). The major deficient nutrients are basically protein and micro-nutrient.

Their deficiencies are the renowned causes of hidden hunger, malnutrition and many nutritional disorders with negative effects on human health and development. Micro-nutrient deficiencies also affect the economic productivity through secondary physical and mental challenge. To prevent this problem, researches have suggested food fortification strategies as one of the

effective and safe mean of preventing nutrient deficiencies. Food fortification in this case is most effective if it uses staple food as a medium of delivering the needed nutrients into human diet (Das *et al.*, 2013). In line with the fortification strategies, innovative food products containing new ingredients have been designed to meet human nutritional need and increase the consumption rate. This is basically achieved by deliberately incorporating various underutilized vegetable species, rich in some nutrients into staple food. The practice improves the nutritional quality of food supply and provides a public health benefit with minimal risk (Milião *et al.*, 2022). As a result, increasing attention has been shifted to some classes of microalgae, cereals, legumes, tubers, leafy vegetables and fruits rich

in nutrients but not fully utilized, often known as non-conventional food sources for the development of novel, more effective and nutrient rich food, which can be used to prevent or reverse malnutrition (Miliao *et al.*, 2022).

Non-conventional food sources of plant origin are commonly used to add variety and greater nutritional value to daily diet due to their exceptional nutrient content. In addition, they are reliable and cheaper alternative sources of healthy food which can replace or complement current conventional or staple food. These underutilized plants have the potential to be used not only in daily food preparation as an ingredient in soups, salads, but also as a source of dietary supplements, for new food formulations and product development. They are also rich with bioactive compounds with antioxidant potential, among others (Gaban and Borges, 2020). As a result of this, and the increased focus on a healthy diet based on the consumption of organic and natural food, incorporating non-conventional food sources rich in a particular nutrient into staple food is a major strategy used in enhancing the nutritional composition and health benefit of major staple food. Hence, this report provides an overview on the uses, nutritional, and health benefits of some non-conventional food sources, namely Soybean, *Spirulina platensis*, *Moringa olifera*, edible mushroom and their products.

## METHODOLOGY

Authors explored reliable information related to the uses, nutritional, and health benefits of some non-conventional food sources, specifically Soybean, *Spirulina platensis*, *Moringa olifera*, and edible mushroom in reputable published journal collections from PubMed, Scopus and Google scholar. Over 170 papers were reviewed, of which the referenced ones were appropriate for this review.

### Staple food

Staple food is routinely consumed and constitutes a significant proportion of calorie requirement of a standard diet in a community. It makes up the dominant part of a population's diet. Globally, grains such as legumes and cereals are majorly recognized staple food. Cereal including wheat, maize and rice are considered valuable among staple crops due to their worldwide consumption. Wheat is an important edible crops among cereals with about 67 percent global population consumption and grown all over the world. Legumes, particularly beans are next to cereals with respect to global consumption rate (Su *et al.*, 2017; Teye *et al.*, 2020). However most of the staple food usually consumed in Africa includes maize, wheat, rice, cassava, yam, sweet potato, sorghum, plantain, cocoyam, beans and bread.

In most cases, these staple food items do not meet the total nutritional needs of individual since most people live on diet based on one or more staple food that are mainly rich in carbohydrate but deficient in protein and other essential nutrients. Their consumption has led to the development of "hidden hunger" and other malnourished-associated diseases. Hence, in other to prevent these difficulties, it is necessary to incorporate affordable high nutrient food sources into an accepted staple or conventional food (Teye *et al.*, 2020).

### Non-conventional food sources

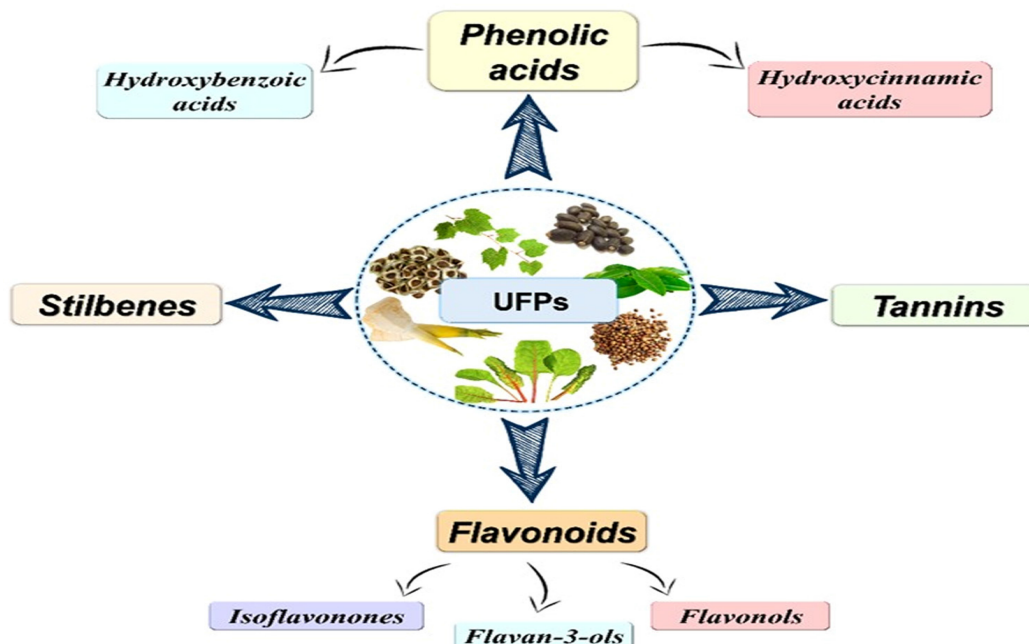
Non-conventional food sources of plant origin are non-staple and underutilized plant species whose potential are not fully explored for their contribution to food security and poverty alleviation. Majority of these plants and their products are rich sources of macro- and/or micro-nutrients with potential health benefits. They are majorly used to formulate functional food that aid specific body functions, with health-promoting properties when incorporated into major staple food. Example includes mango kernels which contained significant amount of phytochemicals and anti-nutrients and can only be made edible after series of processing the raw forms. Other non-conventional food sources are soybeans, *Spirulina platensis*, *Moringa oleifera*, mushrooms, rapeseed, pigeon pea and bambara nut (Kamotho *et al.*, 2017; Teye *et al.*, 2020).

### Conventional food sources bioactive compounds

Plant secondary metabolites are bioactive compounds which exhibit biological effects on human health. Phenolic compounds and carotenoids are considered prominent among the different forms of phytochemicals synthesized by plants (Figure 1). They possessed significant antioxidant activities which are largely utilized as an alternative source of medicine as well as pharmacological and supplement products. Non staple, specially the non-conventional food source of plant origin, called unconventional food plants (UFP) are rich sources of important phytochemicals, especially phenolic compounds. Different studies have quantified and identified biological properties of diverse phenolic compounds in non-conventional food sources. These properties include antioxidant, anti-inflammatory, antihemolytic, and antimicrobial (Pires *et al.*, 2018).

### Processing and technological characteristics of non-conventional food source products

Insufficient scientific information on the composition and the best form in which non-conventional food sources can



**Figure 1:** Major phenolics present in non-conventional food sources (Pires *et al.*, 2018).

be generally processed have limited its utilized by the food industry. As a result, several studies have suggested different processing techniques including drying of the plants materials (grains, leaves, vegetable peels, or stems) and further processing into powdered form or flour that can be utilized in food formulations. In this form, they can be commercialized in different regions. These flour types have been used as an option to increase food products protein and micro-nutrients composition (Miliao *et al.*, 2022). Increasing the protein composition of food help in the modification of rheological and physicochemical properties of the food, since the macromolecule is capable of performing a techno-functional function. For example, increase in protein composition has been linked with increase techno-functional properties such as oil absorption and water absorption capacity, which highlight the significant of protein to technological and physical aspects of formulated food. Furthermore, substitution of wheat flour with non-conventional food plant flourish an alternative possible means of producing a nutrient-rich baked products. However, since non-conventional food plant flour do not contain gluten, an important compound which influence the sensory and physical attributes of baked food. As a result, little substitution of wheat flour and other conventional flour with non-conventional flour for food production is possibly the best way of enhancing consumer's acceptability of the food products. This is because techno-functional and physical property alteration are influence sensory attribute, which further

affect the acceptability of the food products by the consumer due to change in the taste of the food. Moreover, production of industrialized food with innovative characteristics, especially with different flavours by bringing non-conventional food sources into staple food products is considered as a good strategy of diversifying products and increase the brand competition (Miliao *et al.*, 2022).

### **Non-conventional food sources as an alternative protein sources**

Exploration of alternative protein sources in human diet becomes necessary due to the fundamental biological functional they perform. Several plant protein are valuable alternative source of animal protein, which is capable of satisfying the protein requirement of individuals. It also possessed other advantages such as being versatile and inexpensive with less impacts on environment. Soybean and *spirulina* are the most consolidated sources of plant protein which are currently used in the formulation of baked products as well as several other products for the purpose of exploiting their techno-functional properties and nutritional value. Soy protein have great industrial applications due to their significant interfacial and nutritional properties. For instance, flours from some non-conventional food plants such as soybean and *spirulina* contained higher protein composition compared to other plant sources like beans and nuts. Hence, incorporating these high protein source

**Table 1:** Food to food fortification of staple food and their nutritional benefits.

Staple food	Non-conventional fortificants	food	Nutritional enhancements/benefits
Maize	<i>Moringa oleifera</i>		Increased the mineral composition and beta-carotene content.
	Soybean		Increased the protein content.
	Cowpeas, and green peas		The formulation had sufficient energy and protein to meet the energy and protein requirement for 6-month infants.
	Bambara flour		Enhanced protein, fat, and energy content increased in the composite flour.
Cassava	<i>Moringa</i> seed, melon seed and Soybean flour		It increased the protein, fat, and ash content but decreased carbohydrate content.
Sweet potato	Bambara nut		It increased the potassium, magnesium, phosphorous and iron contents.
Rice	Groundnut and Soybean		The diet was superior in protein and energy content as well as sensory evaluation.
	<i>Moringa oleifera</i>		It increased the mineral and beta-carotene levels.
Cocoyam	Cowpea		Significant increased the micro-nutrients and protein content of the flour.
Plantain	<i>Moringa</i> leaf powder		Increased protein, ash and contents of the meal.
Wheat	Groundnut and Soybean		Increased the mineral, protein content, and dietary fibre content.

Source: (Teye *et al.*, 2020).

and other non-conventional food into common staple food could possibly be conducted with the sole aim of increasing the micro-nutrients and protein composition of food products (Sa *et al.*, 2020).

### Fortification of staple food using non-conventional food sources

Fortification of food is the incorporation of essential nutrients in food materials rich in a particular nutrient into stable food, in order to correct or prevent one or more noticeable nutrients deficiency in that staple food. This practice was designed to tackle specific health conditions resulting from nutrient deficiency. It includes the iodization of salt to reduce iodine deficiency, fortification of cereals with vitamins and iron to reduce anaemia, fortification of wheat flour with vitamin A and folic acid to avoid neural tube defects and improve sight (Das *et al.*, 2013).

Nevertheless, the best and natural means of fortification is the substitution of staple food with high nutrient edible plant food materials. This was originally conducted by native people with information and experience of plant food, which subsequently transformed to current modern methods of substituting high nutrient and medicinal food sources into staple food. As a result, food-food fortification is considered natural and more sustainable to alleviate nutrient deficiencies (Kamotho *et al.*, 2017). For example, non-conventional protein food such as soybean is majorly utilized as an active ingredient in functional food, to increasing the protein content of some carbohydrate rich or protein depleted staple food. The fortification of malted sorghum flour with soybean flour increased the protein of the mixture from 7.3 to 19.2 %. The flour mixture with the highest substitution of soybean flour had higher protein content (Bolarinwa *et al.*, 2015).

### Micro-nutrient fortification versus enrichment of staple food

According to World Health Organization micro-nutrient fortification of food refers to the practice of deliberately increasing the content of any essential micro-nutrient (vitamins and minerals) in food regardless of whether the micro-nutrients were originally in the food before processing or not, in order to improve nutritional quality of the food supply and also to provide public health benefit with reduced risks to health, while enrichment is defined as being synonymous with food fortification and refers to the intentional addition of micro-nutrients to food which are lost during the processing (Table 1). Staple food of any region may deficient in specific nutrients due to the composition of the soil of the region or from an inherent insufficiency of a normal food. Addition of micro-nutrients to condiments and staple food can prevent the large-scale deficiency diseases (Awuchi, 2020).

### Nutritional and health benefit of selected non-conventional food sources

#### Soybean

Soybean (*Glycine max* cultivar), also called soja or soya bean is of the *Leguminosae* family. It is a native of Asia and generally believed to possibly originate from north and central region of China, from which it was introduced to other parts of the world including the tropical and subtropical regions (Figure 2). It is an important annual protein rich crop that can thrive on almost all types of soil, especially well-drained fertile loam soil. It produces more protein and oil than many other leguminous crops. The seeds mature for harvest between 3 - 4 months after planting, depending on the variety. Soybean usually bears one to three seeds per pod.



Figure 2:(A) Soybean plant (B) Soybean seeds

Table 2: Nutritional quality of Soybean protein compared to other protein source.

Protein	PER	BV	NPU	Limiting amino acid	Chemical score (CS)
Whole egg	3.8	87 - 97	91 - 94	None	100
Cow's milk	2.5	85 - 90	86	Sulphur amino acids	60
Beef muscle	3.2	76	71 - 76	Sulphur amino acids	80
Soybean	1.8	58 - 69	48 - 61	Sulphur amino acids	69
Maize	1.2	60	49 - 55	Lysine	55
Wheat	1.0	52	52	Lysine	57

Source: (Lokuruka, 2010).

**Footnote:** Protein efficiency ratio (PER) = [(weight gain of rats/weight of protein ingested) x 100]. Biological value (BV) = [(nitrogen retained/nitrogen absorbed) x 100]. Net protein utilization (NPU) = [(nitrogen retained/nitrogen ingested) x 100]. Chemical score (CS) = (mg of limiting amino acid in 1 g of test protein/mg of amino acid in 1 g of reference protein) x 100.

The seed varies in shape and size, from slightly spherical to flat and elongated. Its size ranges from 0.5 to 1.1 cm and weighed between 0.12 to 0.2 mg per seed (Mateos-Aparicio *et al.*, 2008; Dugje *et al.*, 2009). Soybean is one prominent leguminous crop which has drawn government interest with several awareness on its nutritional benefits as a functional food ingredient in food fortification due to its protein quality. Soybean protein contains well-balanced essential amino acids except for sulphur-containing amino acids like methionine. They also have desirable textures with endless possibilities to formulate various high protein quality soy-based food products. Due to their high protein content and its versatility in developing food products, soy protein have become an excellent and primary plant-based protein sources that are widely consumed by diverse populations worldwide (Qin *et al.*, 2022).

Soybean oil was reported to contain higher proportion of nutritionally essential fatty acids, considered to be favourable to the cardiovascular system. However, the compositions of soybean fatty acids are to a larger extent

dependent on the varieties of the soybean (Yever *et al.*, 2009). Study on the fatty acid composition of forty (40) soybean genotype obtained from India revealed that they contains about 34.2 - 53.8 % omega-6 fatty acid (linoleic acid) and 7.9 - 11.9 % omega-3 fatty acid (linolenic acid) (Balaji *et al.*, 2019).

### Soybean protein

Soybeans protein is particularly valuable because of its amino acid composition which complements that of cereals (Table 2). It is limited in sulphur-containing amino acids (methionine and cysteine) similar to most animal protein, but contains sufficient lysine to complement the lysine deficiency of cereals. For example, soybean-wheat or maize combination are complementary for lysine and sulphur-containing amino acids in food formulation. This accounted for the successful utilization and nutritional benefit of some cereal flour fortified with soy flour in some food products (Table 2). The protein content of soybeans (38 – 45 %) is higher than the protein content of other

**Table 3:** Amino acids, vitamins and essential nutrients in soybean (Dry weight basis).

Amino acid composition (g/16 g N)		Vitamins ( $\mu\text{g/g}$ )	
Aspartic acid	12.6	Riboflavin (B <sub>2</sub> )	0.9 - 1.2
Alanine	4.5	Thiamine (B <sub>1</sub> )	6.3 - 6.9
Threonine	4.1	<b>Vitamin E</b>	
Glycine	4.5	$\alpha$ -tocopherol	10.9 - 28.4
Valine	3.4	$\delta$ -tocopherol	24.6 - 72.5
Proline	5.5	$\gamma$ -tocopherol	150 - 190
Cystine	0.9	<b>Others (%)</b>	
Glutamic acid	19.8	Minerals	5.0
Serine	5.7	Isoflavone	0.1 - 0.4
Methionine	1.3	Saponins	0.1 - 0.3
Leucine	7.9	Linoleic acid	51
Tyrosine	3.9	Linolenic acid	7 - 10
Arginine	8.6	Oleic acid	23
Phenylalanine	4.9		
Histidine	2.6		
Lysine	6.2		

Source: (Shashanket *al.*, 2015).

legumes (20 – 30 %), and even much higher than that of cereals (8 – 15 %). The relatively high protein and biological value (BV) make soybean a highly valuable plant food with great potential (Lokuruka, 2010). Soybeans protein has higher biological value than some conventional plant source with a good profile of essential amino acids. It protein values form a transition between the cereal protein and animal protein, with respect to their biological and chemical evaluation systems. Nevertheless, the digestibility of soybeans protein is usually low when the only treatment is heating. Further processing treatments including soaking, de-hulling, fermentation, sprouting, grinding, and hot water extraction and defatting considerably reduce it ant-nutrients level and increases digestibility (Lokuruka, 2010).

### Soybean vitamins and minerals

Vitamin C is negligible in the mature beans, but is present in measurable quantity in immature and germinated beans (Table 3). Other water-soluble vitamins in soybean are the B-group particularly thiamine, riboflavin, niacin, pantothenic acid and folic acid. The main fat-soluble vitamins include vitamin A (retinol) and E (tocopherol). The Vitamin D and K content is negligible. Vitamin A exists as the pro-vitamin A, carotene. Similar to vitamin C, its content is negligible in the mature bean, but measurable in immature and germinated seeds (Lokuruka, 2010). Dried soybean contains an ash content of about 5 %, which is quite considerable. The major forms of minerals in soybean are sulphates, phosphates and carbonates. Potassium has the highest concentration in soybean, followed by phosphorus, magnesium, sulphur, calcium, chloride and sodium in that order. Trace minerals include silicon, iron, zinc, manganese, copper,

molybdenum, fluoride, chromium, selenium, cobalt, cadmium, lead, arsenic, mercury, and iodine. Like other components, minerals in soybean are influenced by variety, growing location and season (Lokuruka, 2010).

### Selected soybean food products

Food products made of soybean with high protein values include soy milk, tempeh (cooked and fermented soybean), defatted soybean flour, toasted soybean flour, soybean sauce, tofu (Figure 3). Soybeans fermentation is to produced miso, soy paste, tempeh and soy sauce. Steam treated soybean is used to produced full-fat soymilk, which can be further converted to tofu by coagulation (Figure 3). Natto is collected from the upper layer of soymilk during production. The defatted flour are rich in protein (50 %). It is the source of soy protein concentrate and soy protein isolate with protein content of 70 % and greater than 90 % respectively. It is also used to produce toasted soy flour. Soy protein isolate is used to make fermented to produce soy protein isolate (SPI), low-fat tofu and soymilk as well as a fermented isoflavone-protein enriched product (Barnes, 2010).

### Soybean health benefits

Soybean contains essential amino acid and secondary metabolites such as isoflavone (daidzein and genistein), to copherol with potent antioxidant properties. The effectiveness of soy protein consumption in lowering total cholesterol, low density lipoprotein, triglyceride, body fat and prevention of obesity has been demonstrated in animal and human trials. Reports have shown that the consumption of 25 g of soy protein per day could effectively decrease total and LDL cholesterol the levels as well as reduced risk of cardiovascular disease.

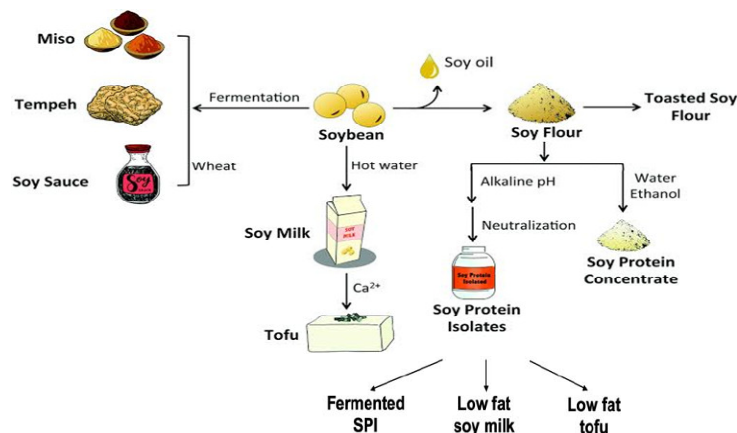


Figure 3: Processing soybean to commercial products (Barnes, 2010).

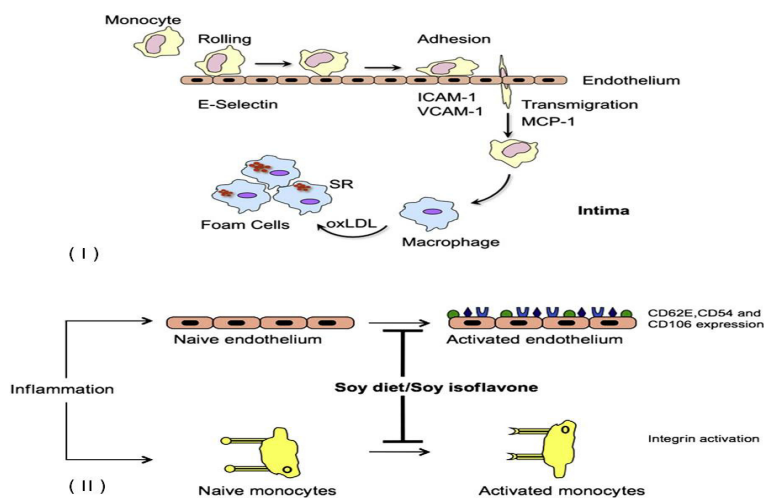


Figure 4: (I) Inflammatory process associated with atherosclerosis. (II) Soy/isoflavone diet blocks endothelial and monocytes activation (Nagarajan, 2010).

Several hypotheses for the anti-obesity impact of soy protein include restriction of hepatic lipogenic enzymes and fatty acid production, stimulation of muscular fatty acid oxidation, enhancement of plasma adiponectin levels, and enhanced fecal matter excretion (Shashank *et al.*, 2015).

Soybean isoflavones effects were identified as possible mechanism by which soy products exert health benefit on weight and other obesity-related disorders. Study has shown that soy isoflavones activate the peroxisome proliferator-activated receptor, thus increasing lipid metabolism and generating anti-diabetic benefits (Wang *et al.*, 2017). Soy isoflavones have demonstrated potent effects on reducing cholesterol levels in both animal and human trials, and such beneficial effects are significantly enhanced when dietary soy protein is consuming

compared to purified bioactive compounds (Wang *et al.*, 2017).

### Possible mechanism of soybean action on atherosclerosis

Soy isoflavones have antioxidants properties, capable of reducing the oxidation of LDL cholesterol and also induce vascular reactivity (Figure 4). The presence of modified LDL cholesterol in the blood vessel contributes to the formation of atherosclerotic plaques. This occur when cholesterol accumulation within the circulating monocyte-derived macrophage and thus its transformation into the foam cell in the blood vessel (Nagarajan, 2010). It was suggested that soy isoflavones could inhibit the effect of endothelial cell activation associated with



Figure 5: Provide the title of this figure:  
Source: www.spirulinasource.com

chronic diseases such as atherosclerosis by blocking the activation of inflammatory cells as well as the adhesion to the vascular endothelium (Figure 4). The atherosclerotic protection of soy isoflavones is also mediated through the regulation of monocyte activation (Nagarajan, 2010).

### **Spirulina**

*Spirulina platensis* (*Arthrospira*) is microscopic blue-green algae or cyanobacteria with two pigments, phycocyanin (blue) and chlorophyll (green) (Figure 5). It naturally grows in alkaline and warm media; in the sea and fresh water of Asia, Africa, Europe, South and North America and has long been utilized as a dietary supplement by people living around alkaline lakes. *Spirulina* is currently considered as a major source of protein and vitamin substitute to aquatic diet (Figure 5). This makes it popular among food industry producing functional food (Table 4). It is a rich source of macro- and micro-nutrients with high quality protein, containing all the essential amino acids, vitamins, minerals, essential fatty acid and several secondary metabolic with appreciable antioxidants properties, which made it a useful functional food (Table 4). As a result, *Spirulina* was recognized as one of the most nutritious food on the planet. This leads to the declaration of *Spirulina* by United Nations World Food as the best future food at a conference in 1974 (Jung *et al.*, 2019). Furthermore, *Spirulina* has proven to have acceptable organoleptic properties and also has not exhibited either acute or chronic toxicities, making it safe for human consumption (Gutierrez-Salmeán *et al.*, 2015).

### **Spirulina protein**

*Spirulina* contains an exceptional proportion of protein, ranging from 55 to 70 % of its dry weight bases,

depending on its source. It a complete protein source because, it contained all the essential amino acids. It has limiting amounts of sulphur-containing amino acids (methionine and cysteine) as well as lysine, compared to standard protein from eggs, meat and milk. However, it is superior to almost all other plant protein, including soybean and have no limiting factor to its amino acid assimilation. C phycocyanin molecule is one of the major protein present in *Spirulina* which accounted for about 20 % of its dry weight. It contains biliverdin homolog called phycocyanobilin (Jung *et al.*, 2019). *Spirulina* protein exhibits high nutritional value due to its high biological value (BV), net protein utilization (NPU), relatively high digestibility coefficient (DC) and protein efficiency ratio (PER) that is much higher than most vegetable protein (Table 5). This characteristic makes it a good protein supplement in human diet (Gutierrez-Salmeán *et al.*, 2015).

### **Spirulina vitamins**

*Spirulina* contains several important vitamins such B-group, vitamin C, vitamin D and vitamin E which promote the metabolism of diverse biomolecules. It has an appreciable amount of vitamin B-group similar to other sea weed. It is also a rich source of vitamin A precursor, the  $\beta$ -carotene. Human requirements of vitamin A are approximately 1 mg/day; hence 1-2 g of *Spirulina* will meet the requirement. Carotenoids are the second most important group of pigments found in algae. They serve as lipophilic antioxidants and are thought to be accountable for the healing property of carotene as antioxidant and anticancer agent. National Cancer Institute findings suggested that a daily intake of 6 mg  $\beta$ -carotene could be significantly reducing the risk of developing cancer. The intake of 4 g of *Spirulina* daily, is

**Table 4:** Selected nutrient composition of *Spirulin aplatensis* (100 g dry weight).

Nutrient	Amount	Amount
General composition	(g)	(g)
Protein	62.8	55.0 –70.0
Carbohydrate	-	15.0 – 25.0
Lipid	6.9	6.0 – 8.0
Mineral ash	7.5	7.0 – 13.0
Crude fiber	8.1	8.0 – 10.0
Vitamins	(mg)	(mg)
Thiamine (B <sub>1</sub> )	5.8	3.5
Riboflavin (B <sub>2</sub> )	4.7	4.0
Niacin (B <sub>3</sub> )	15.4	14.0
Pyridoxine (B <sub>6</sub> )	0.9	0.6
Folic acid (B <sub>9</sub> )	9.9	-
Pantothenate (B <sub>5</sub> )	0.1	0.1
Vitamin A (as retinol)		69.0
Vitamin E	9.9	10.0
Vitamin K	1.1	2.0
Minerals	(mg)	(mg)
Potassium	2085.3	1400.0
Sodium	1540.5	900.0
Phosphorus	2191.7	600.0
Calcium	922.2	700.0
Iron	273.2	150.0
Manganese	5.7	5.0
Zinc	3.6	3.0
Phytopigments	(g)	-
Phycocyanin	14.7	-
Chlorophyll	1.6	-
Total Carotenoids	0.6	-
beta carotenoids	0.3	-
Xanthophyll	0.3	-
References	Sharoba (2014)	Jung <i>et al.</i> (2019)

**Table 5:** Protein values of *Spirulina* compared to casein.

Characteristic	<i>Spirulina</i>	Reference protein (casein)	% of the reference
Biological value	75	87	86
Net protein utilization	62	83	75
Digestibility	85	95	89.
Protein efficiency	1.9	2.5	76

Source:(Gutierrez-Salmean *et al.*, 2015).

sufficient to provide 6 mg  $\beta$ -carotene as well as sufficient amount of vitamin B-group, iron and calcium. However, the  $\beta$ -carotene obtained as nutrients from 4 g of *spirulina* can be compared to or even more than those obtained from consuming over 100 g of land vegetables (Gutierrez-Salmean *et al.*, 2015; Soni *et al.*, 2017)

### ***Spirulina* minerals**

*Spirulina* is a rich source of potassium, with sufficient amount of iron, calcium, phosphorus, sodium,

magnesium, manganese and zinc. The most significant inorganic nutrients in *Spirulina* include iron, calcium and phosphorous. As a result, it is essential for individual at high risk of developing anemia due to insufficient quantities of hemoglobin in erythrocytes caused by iron deficiency (Figure 6). *Spirulina* iron content is substantially high than cereals and is usually considered as a good sources of iron. It does not have pericardium like cereals, hence it does not present phytates/oxalates that could chelate iron and lower its absorption like other vegetable such as spinach.



**Figure 6:** *Spirulina* products (Gumbo and Nesamvuni, 2017).

Its calcium and phosphorous contents are comparable to those of the milk. Hence, it play a major role in preserving bone, and reduces decalcification risk (Gutierrez-Salmean *et al.*, 2015). The use of *Spirulina* as a food supplement is widely accepted globally due to its exceptional nutritional benefit in fighting malnutrition. Examples of some *Spirulina* food products are given in (Figure 6).

### ***Spirulina* health benefits**

Several bioactive peptides extracted from *Spirulina* were demonstrated to possess antioxidant, anti-inflammatory, antimicrobial, antiviral, anticancer, immunomodulatory and anti allergic properties (Figure 7). It has been reported that the consumption of *Spirulina* could be useful in preventing or managing metabolic syndrome (Bobescu *et al.*, 2020).

### ***Spirulina* effects on body weight and lipid metabolism**

Evidence report on hypolipidemic effects of *Spirulina* on animal experiment revealed that intake of *Spirulina* significantly decreased body weight and reduced atherogenic lipid molecules such as total cholesterol, low-density lipoprotein cholesterol or very-low-density lipoprotein cholesterol, triglyceride levels but significantly increased high-density lipoprotein cholesterol levels, an anti-atherogenic molecule (Hamouda *et al.*, 2022). In addition, *Spirulina* contained H-b2, a glycolipid which inhibits pancreatic lipase activity in a dose-dependent manner. Furthermore, *Spirulina* phycocyanin and other bioactive molecules can increase the fecal excretion of cholesterol by decreasing its solubility. Phycocyanin also

exhibits anti-lipase activity (Yousefi *et al.*, 2019). Increased visceral adipose tissue is usually associated with increase in free fatty acid levels, insulin resistance, and decreased levels of adiponectin. This triggered the secretion of a polipo protein B and increased hepatic lipase activity, which causes hypertriglyceridemia (Hamouda *et al.*, 2022).

### ***Spirulina* effects on obesity**

Recent reports suggested that *Spirulina* consumption may be useful in the management of obesity due to its effects on food absorption and appetite modulation. The primary mechanism of *Spirulina* on body weight reduction involved the prevention of liver lipid accumulation, decrease oxidative stress and the reduction of the macrophages infiltration into visceral adipose tissue. Moreover, *Spirulina* is a rich source of essential amino acids, such as phenylalanine, which releases cholecystokinin. This molecule inhibits the appetite coordination center in central nervous system and works as a bodyweight suppressant (Fujimoto *et al.*, 2012).

### **Antioxidant**

*Spirulina* also exhibits potent antioxidant effects. Antioxidants are useful in the management of obesity, and they act by various mechanisms which include inhibition of lipase, modulation of energy expenditure, inhibition of adipocytes differentiation and regulation of lipid metabolism. C-phycocyanin, a major biliprotein in *Spirulina* possessed anti-oxidative, anti-inflammatory activities among several other biological activities was reported to be responsible for its antioxidant effects. It also inhibit cyclooxygenase-2 selectively (Hassan *et al.*, 2015).

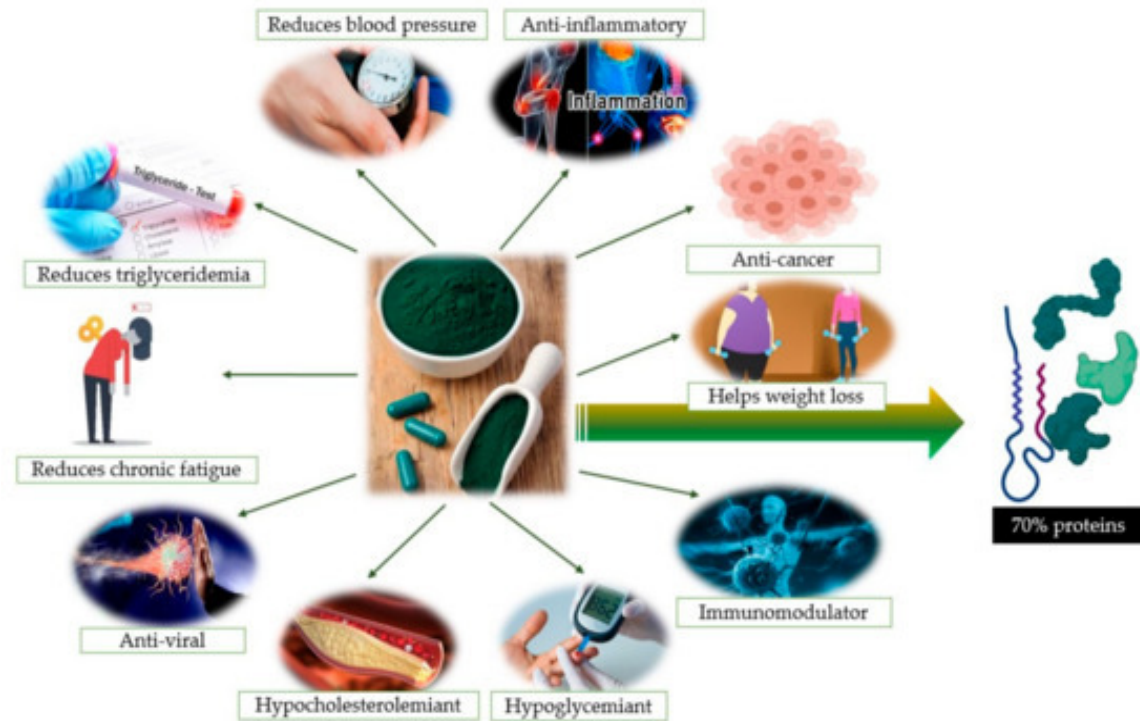


Figure 7: Health benefits of *Spirulina* supplementation (Bobescu *et al.*, 2020).



Figure 8: *Moringa oleifera* plant

***Moringa oleifera***

*Moringa oleifera* Lam. (called Drumstick or Horse radish tree) is a tropical deciduous, perennial and monogenous plant which belong to *Moringaceae* family (Figure 8). It originated from India in the southern Asia, and widely naturalized globally due to its multipurpose use and widespread application. It has a silver grey bark with tripinnate compound elliptic leaves and grow to about 10

to 12 metre in height (Figure 8). The fruit is dehiscent, capsulated lengthly with three lobes and usually produce during the summer. This plant species is considered underutilized because it potential is not fully exploited (Gandji *et al.*, 2018; Singh *et al.*, 2020). *Moringa oleifera* is called Geligeji in Igala and Zogale among the Hausa language in Nigeria. The plant has tremendous nutritional

and medicinal benefits. Every part of the plant is endowed with several macro- and micro-nutrients as well as other bioactive compounds which play an essential role in and preventing several diseases and normal body function. Almost all parts of *Moringa* plant including the leaves, seeds, pods and even the flowers are edible, with huge medicinal benefits including antioxidant, anti-diabetic, anti-ulcer, anticancer and antimicrobial properties. Recent studies *Moringa* majorly proposed that its leaf should be used as an ingredient in formulating a functional food (Islam *et al.*, 2021). *Moringa* leaf possesses different types of micro-nutrients, which make it a higher natural source of minerals and vitamins (Figure 8). The leaf is rich in minerals such as potassium, calcium, zinc, copper, iron and magnesium. Vitamins such as vitamin A, vitamin B-group such as folic acid (B<sub>9</sub>), pyridoxine (B<sub>6</sub>) and nicotinic acid (B<sub>3</sub>) as well as vitamin C, D and E are also present in *Moringa* in appreciable amount. Phytochemicals including tannins, flavonoids, sterols, terpenoids, alkaloids, saponins, and reducing sugar are present alongside anti-cancer agents such as isothiocyanates, glucose inolates, glycerol-1-9-octadecanoate and glycoside compounds. (Gopalakrishnan *et al.*, 2016).

### **Moringa protein**

*Moringa oleifera* seeds contain a significant amount of protein, which represents the second major macro-nutrient component of the seeds after lipids. It was reported that its protein content varied between 19 to 37 % and is greatly influenced by processing, as analysis of the defatted seed revealed a protein composition ranging from 32 % to 63. Treatments such as fermentation and germination increased all the amino acids. However, the protein composition of the seeds entailed only the required essential amino acids for humans (tyrosine, histidine, phenylalanine, leucine, isoleucine, threonine) others like lysine, valine, methionine, and tryptophan are limiting amino acids in the seed. Hence, the nutritional attributes of *Moringa* seed can be increased by complementing it with other food rich in lysine and sulphur-containing amino acids. In this case, the seed can be combined with legumes like soybean or cereals such as millet, sorghum, corn and rice to produce complementary food with balanced protein (Saa *et al.*, 2019).

### **Moringa vitamins**

Vitamins play an important role in the process of energy production in the human body. Vitamins, such as vitamin A precursor ( $\beta$ -carotene), vitamin B-group (folic acid, pyridoxine, and nicotinic acid), vitamin C, D, and E, are all found in appreciable amount in various parts of *Moringa oleifera*. *Moringa oleifera* seeds contain

provitamin A (2.04 %). In addition, vitamin E in the forms of  $\alpha$ -tocopherol,  $\gamma$ -tocopherol, and  $\delta$ -tocopherol have also been reported in its seed oil (Saa *et al.*, 2019; Meireles *et al.*, 2020).

### **Moringa minerals**

*Moringa oleifera* contains a lot of minerals, which are essential for physiological growth and development (Table 6). Among the minerals, calcium is considered one of the important minerals for human growth. While 8 ounces (226.8 g) of milk can provide 300 - 400 mg of calcium, *Moringa* leaves can provide 1000 mg while its powder can provide more than 4000 mg. *Moringa* powder can be used as a substitute for iron tablets for the treatment of anaemia. It was also reported to contain more iron than spinach. *Moringa oleifera* leaves contain about 25.5 - 31.03 mg of zinc/kg. A good dietary intake of zinc is essential for proper growth of sperm cells and is also necessary for the synthesis of DNA and RNA (Gopalakrishnan *et al.*, 2016). *Moringa oleifera* seeds are rich in minerals of which potassium, phosphorus and iron are the principal minerals (Table 6). It was revealed that *Moringa oleifera* seeds exhibited a Calcium/Phosphorus ratio greater than one while the Na/K ratio is greater than the recommended value of 0.60. Nevertheless, the mineral composition of seeds differs significantly from one region of the world to another (Ijarotimi *et al.*, 2013).

### **Moringa health benefits**

*Moringa oleifera* is also known as the miracle tree, which for centuries has been indicated for traditional medicine without any reports of side effects in doses achievable by ingestion. Different parts of *Moringa oleifera* are considered as important elements with diverse medicinal value, used as natural medicine to treat several conditions, such as malnutrition, diabetes, blindness, anaemia, hypertension, skin, arthritis, joints and kidney stones disease. The plant also showed capacity in preventing cardiovascular diseases, regulating blood-glucose levels and providing antioxidant, anti-inflammatory and anti-cancer effects (Meireles *et al.*, 2020). *Moringa* as a rich source of vitamins plays a significant role in the prevention and treatment of common vitamin deficiency diseases such as scurvy, beriberi and rickets. For instance, Vitamin A plays a key role in vision and possesses antioxidant properties in the form of  $\beta$ -carotene which limit the oxidation of other biomolecules. *Moringa* leaves also have a low calorific value and can be used in the diet of the obese to manage or prevent obesity. The pods are fibrous and are valuable to treat digestive complications and thwart colon cancer (Gopalakrishnan *et al.*, 2016). Polyunsaturated fatty acids such as linoleic acid, linolenic acid and oleic acid are capable of reducing

**Table 6:** Selected nutrient composition of *Moringa* leaves, leaf powder, seeds and pods (per 100 g).

Nutrients	Fresh leaves	Dry leaves	Leaf powder	Seed	Pods
Calories (kcal)	92	329	205	-	26
Protein (g)	6.7	29.4	27.1	35	2.5
Fat (g)	1.7	5.2	2.3	38.7	0.1
Carbohydrate (g)	12.5	41.2	38.2	8.7	3.7
Fibre (g)	0.9	12.5	19.2	2.9	4.8
<b>Vitamins (mg)</b>					
Vitamin (B <sub>1</sub> )	0.06	2.02	2.64	0.05	0.05
Vitamin (B <sub>2</sub> )	0.05	21.3	20.5	0.06	0.07
Vitamin (B <sub>3</sub> )	0.8	7.6	8.2	0.2	0.2
Vitamin C	220	15.8	17.3	4.5	120
Vitamin E	448	10.8	113	751.7	-
<b>Minerals (mg)</b>					
Calcium (mg)	440	2185	2003	45	30
Magnesium (mg)	42	448	368	635	24
Phosphorus (mg)	70	252	204	75	110
Potassium (mg)	259	1236	1324	-	259
Copper (mg)	0.07	0.49	0.57	5.2	3.1
Iron (mg)	0.85	25.6	28.2	-	5.3
Sulphur (mg)	-	-	870	0.05	137

Source: (Gopalakrishnan *et al.*, 2016).

**Table 7:** Antioxidant composition of *Moringa oleifera* leaf extract.

Parameters	Amount (mg/100g)
Total antioxidant capacity (ascorbic acid equivalent.)	1701.8
Total flavonoids (quercetin equivalent)	257.0
Total phenols (gallic acid equivalent)	785.5

Source: (Islam *et al.*, 2021).

**Table 8:** Medicinal uses, nutritive and bioactive properties of parts of *Moringa* plant.

Medicinal uses	Nutritive and bioactive properties
<b>Leaves</b>	
Treatment of asthma, heart burn, syphilis, pneumonia, hyperglycemia, diarrhea, scurvy, skin diseases. It also reduces, blood pressure and cholesterol and acts as an antioxidant, anticancer, antimicrobial, anti-atherosclerotic and antidiabetic agents.	It contains protein, and several minerals, vitamins, essential amino acids. Phytochemicals, including tannins, flavanoids like quercetin, isoquercetin, other phenolics and isothiocyanates.
<b>Seeds</b>	
Treatment of hyperthyroidism, Crohn's disease, virus arthritis, rheumatism, cramp, epilepsy and sexually transmitted diseases, and also can act as antimicrobial and anti-inflammatory agents.	It contains fats, fiber, protein, several minerals, vitamins, essential fatty acids. Phytochemicals including tannins, flavonoids, other phenolics, saponin, terpenoids and antibiotic pterygosperrin.
<b>Root bark</b>	
It can be used as a cardiac stimulant, anti-ulcer and anti-inflammatory agent.	Alkaloids like morphine, moriginine, minerals like calcium, magnesium and sodium.
<b>Pods</b>	
It can be used to treat diarrhea, liver, spleen problems and joint pain.	It is rich in fiber, non-structural carbohydrate, protein, ash and polyunsaturated fatty acids.

Source: (Gopalakrishnan *et al.*, 2016).

cholesterol. It was reported that *Moringa* seed oil contains around 76% polyunsaturated fatty acids, making it ideal product for reducing cholesterol and use as a substitute for olive oil (Mbikay, 2012).

### Antioxidant

*Moringa* plant can be considered as a great source of antioxidants, both *in-vivo* and *in-vitro* as a result of its flavonoids and other phenolic compounds (Tables 7 and

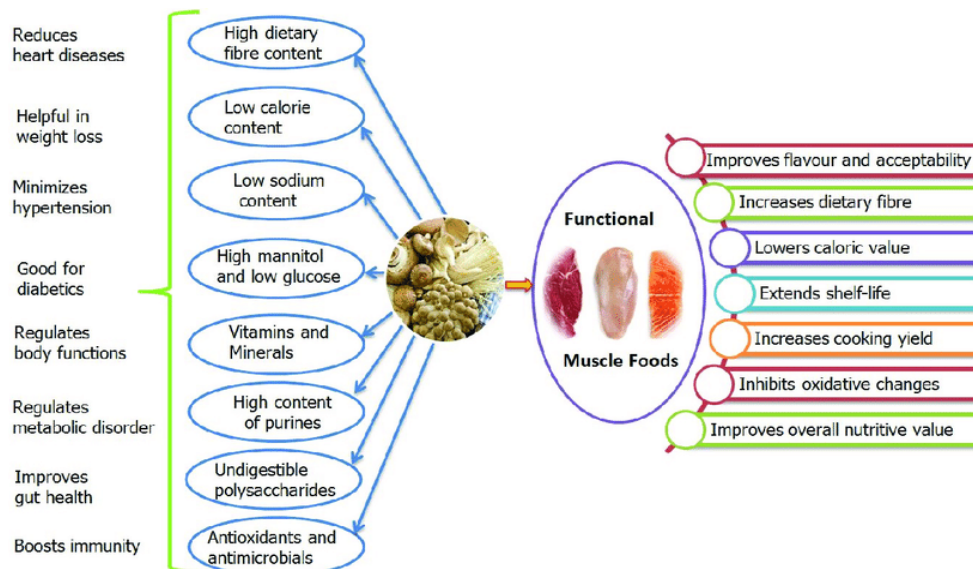
8). Furthermore, the presence of vitamin A, E and C in different parts of the plant in high proportion affirmed its capacity as a source of natural antioxidant and anti-inflammatory plant compared to other conventional plant sources (Islam *et al.*, 2021).

### Edible mushroom

Edible mushrooms are important food source which are consumed not only for their natural taste and flavour, but



**Figure 9:** (A) *Lentinusedodes* (shiitake mushroom) and (B) *Pleurotus* (oyster mushroom) (Valverde *et al.*, 2015).



**Figure 10:** Schematic diagram showing the influence of mushroom nutrients on quality attributes of muscle food with regard to human health effects (Das *et al.*, 2021).

also for their important nutritional value (Figure 9). They are popularly known as “vegetable meat” in many cultures. Botanically, they are the fruiting bodies of macroscopic filamentous saprophytic fungi that grow above ground and rotten wood (Das *et al.*, 2021). Mushrooms are popular valuable food because they are low in calories, carbohydrate, fat and sodium. The nutrient of mushrooms varies from one species to another, and also depends on their growth requirement. On the average, it contains 56 % carbohydrate, 30 % protein, 2 % fat and 10 % ash on dry weight basis. Besides, mushrooms provide essential nutrients,

including potassium, riboflavin, niacin, vitamin D and fiber. The crude fat contains all classes of lipid compounds such as free fatty acids, glycerides, sterols, and phospholipids. Among the existing fatty acids, linoleic acid constitutes higher proportion. They can be successfully used as dietary supplements to promote human health, as an appetizer and also as ingredient in soups, sauces, salads, stuffing and meat dishes. Together with an existing history as food source, mushrooms are considered important for their healing and properties in traditional medicine. Many nutraceutical properties are ascribed to mushrooms (Abebaw, 2020).

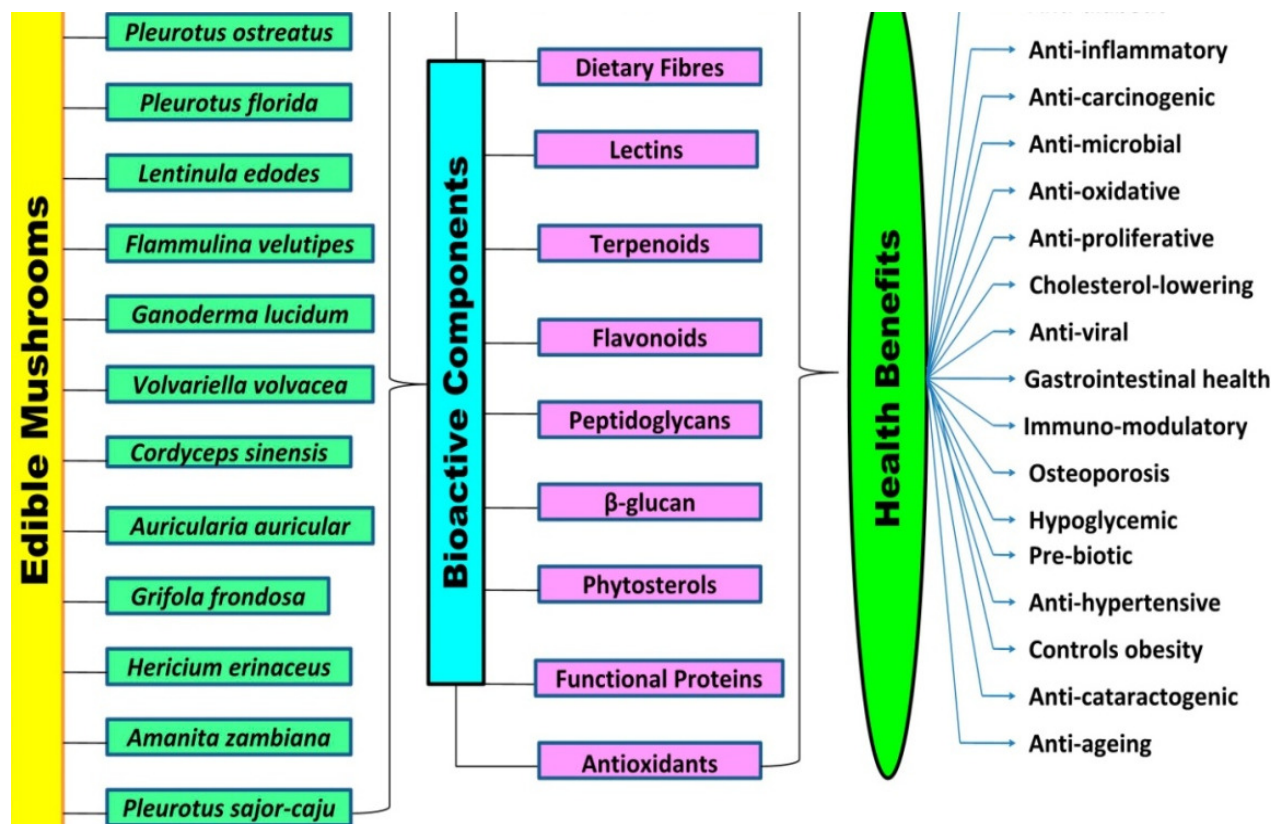


Figure 11: Edible mushrooms, bioactive components, and health benefits (Kumar *et al.*, 2021).

### Edible mushroom protein

Mushrooms are good source of quality protein. They contains 20 - 35 % protein on dry weight basis, which is higher than vegetables and fruits. Mushroom protein possessed all the essential amino acids and is particularly rich in lysine, which is limiting amino acids in most staple cereal food (Figure 10). It is also called white vegetables or “boneless vegetarian meat”. Protein is an important constituent of dry matter of mushrooms. However, its content in mushrooms depend on the composition of the substratum, size of pileus, species of mushrooms and harvest time (Kakon *et al.*, 2012).

### Edible mushroom vitamins and minerals

Mushrooms are one of the best sources of vitamins especially the vitamin B-group (Figure 10). Mushrooms were reported to be an excellent source of nicotinic acid, riboflavin, pantothenic acid and ascorbic acid. They were reported to contain valuable and high assimilated mineral elements such as iron, potassium, phosphorus, calcium and copper with potassium alone forms 45 % of its total ash content (Kakon *et al.*, 2012; Abebaw, 2020).

### Edible mushrooms health benefits

Edible mushrooms contains bioactive compounds which possess diverse biological functions in their polysaccharides cell wall. The various forms of bioactive compounds produced by edible mushrooms include phenolic compounds, lectins, terpenoids and glucans with several health benefits, including antioxidant, immune-stimulation, hypoglycemic effects and anti-tumour, (Kumar *et al.*, 2021). The absence of starch in mushrooms makes it an ideal food for diabetic individual who wants to reduce excess fat (Figure 11). They can also be used to formulate high protein and low caloric diet, hence, can be recommended for patients with heart problem. The low total fat content and high quantity of polyunsaturated fatty acids (72–85%) in relative to its fatty acids significantly contributed to the health value of mushrooms (Singh, 2017).

#### Antioxidant

Edible mushrooms which exist in their wild natural form or cultivated, contains appreciable bioactive compounds

such as phenolic compounds, vitamins and carotenoids with high antioxidant property. It also contained polysaccharides in the form of cellulose, which together with the bioactive compounds accounts their health-promoting effects and benefits. Dietary supplementation of edible mushrooms can reduce oxidative stress by increasing antioxidant defence (Kumar *et al.*, 2021).

### Cholesterol lowering effects

Hypercholesterolemia, oxidized LDL cholesterol, and atherosclerosis are the pathogenic cause of cardiovascular disorders. As a result, the regulation of cholesterol concentration is essential in other to prevent as well as treat high cholesterol and cardiovascular related disorders. In addition, the high fibre contents of edible mushrooms alongside their low fat could make them an alternative and natural food source for preventing cardiovascular disorders. Food products supplemented with edible mushrooms function as a natural hypocholesteromic diet which are often suggested in oriental traditional treatment. Report showed that *Termitomy cesmircarpus* mushrooms significantly reduced serum LDL-cholesterol, total cholesterol, triglycerides as well as the occurrence of high blood lipids related disorders. This effect was attributed to the large fibre quantity in edible mushroom (Nabubuya *et al.*, 2010).

### CONCLUSION

Soybean, *Spirulina*, *Moringa olifera* and edible mushrooms and their products are some important non-conventional food sources of plant origin which commonly used to add variety and nutritional value to daily diet due to their exceptional nutrient content. They are rich source of macro- and micro-nutrients with high quality protein, with well-balanced essential amino acids, vitamins and minerals. Their protein qualities are superior to several other plant protein, and have no limiting factor to their amino acid assimilation. They also contain essential fatty acid and several bioactive compounds with appreciable antioxidants properties which made them useful ingredients in functional food formulation. In addition, the processed forms of these food sources have been proven to have acceptable organoleptic properties without any record of either acute or chronic toxicities, making it safe for human consumption. Nutritional supplements could be consumed for different reasons; either to compensate for an insufficient energy, macro-nutrient or micro nutrient intake, with the objective of preventing or reversing nutrient deficiency diseases. However, protein, vitamins and minerals deficiencies are the renowned cause of malnutrition and many nutritional disorders.

Food fortification practice is aimed at improving the nutritional quality of food and tackle specific health conditions resulting from nutrient deficiency. Hence, the formulation of functional food using natural staple food and non-conventional food sources can be considered as a major strategy to meet the nutritional demands of the growing population. It also enhance the nutritional composition and health benefit of major staple food.

### Conflict of interest

The authors have not declared any conflict of interest.

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