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Study on the health benefit and utilization of sprouted grains for development of value-added food products: A review

Ankesh Pathak◆ and Sury Pratap Singh

Department of Food Technology, Parul University, Vadodara-390001, Gujarat, India

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Abstract

Sprouting is a process which starts with the uptake of water by the seed and ends with the appearance of a radicle. It is a process which is known to increase the nutrient content of whole grains along with improved flavour. Sprouting also reduces the level of phytate content of the grain, increasing the absorption of vitamins and minerals. Depending on the seed and seed type, different grains show different results after sprouting but all of them show increased levels of proteins, fats, carbohydrates, vitamins and minerals and decreased levels of enzymatic action and antinutrients. It can be consumed by diabetics, is easily digestible, boosts immunity and has anticancer properties. Sprouted grains have a low glycaemic index and are completely "organic". Sprouted grains are one of the most convenient food ingredients with minimum to no processing required and it requires no machinery equipment which results in lower chances of contamination and is additive free. In recent years, there is an increasing awareness of the advantages of sprouting and multiple products like cookies, snacks, tortillas, *etc*., have been developed. In this review, we discussed the potential of sprouted grains and their flour along with their nutritional attributes in the development of value added products.

1. Introduction

The term "sprouted grains" as defined by the American Association of Cereal Chemists (AACC) "malted or sprouted grains containing all of the original bran, germ, and endosperm shall be considered whole grains as long as sprout growth does not exceed kernel length and nutrient values have not diminished. These grains should be labelled as malted or sprouted whole grain" (Anonymous, 2008). These above mentioned grains are generally rich sources of carbohydrates, proteins, and fats. These are also abundant in B-complex vitamins like thiamine, riboflavin, niacin, *etc.*, and they also are a good source of minerals like iron, calcium, and phosphorous which provide structure to our body. The endosperm is generally rich in starches, while the bran holds most of the fibre and vitamins which are mostly lost during processing. The use of sprouted grains as food ingredients is prevalent for many years because of the belief that they provide improved nutritional flavour and textural benefits (Kodicek and Young, 1969).They were consumed by people on sea voyages to combat scurvy is one example of the nutritional benefits sprouted grains have to offer (Kodicek and Young, 1969). Although, sprouted grains have indeed added benefits, there are some contradictory reports on whether sprouted grains provide enough ascorbic acid to prevent scurvy on these voyages (Kodicek and Young, 1969). Sprouted grains are generally seed grains whose radicle has just started to be visible. They are obtained by soaking seed grains in cold water for days or weeks depending on the grain type and variations. There is increased acceptability for sprouted grains in recent years because they are considered "natural", have "better taste", are "healthier" and "more nutritious" (Mattucci, 2015). In addition, sprouted grains are also organic, vegan, genetically modified organisms free and whole grains (Mattucci, 2015). The process of sprouting comprises three phases. During Phase I, the seed is impregnated with water and the cell material and cell matrices absorb all the water, also known as the imbibition phase. In Phase II, there is a limited water uptake with more emphasis on metabolism activation which will be required for the initiation of the radicle in the following phases. At the end of this phase, the radicle starts to emerge. In the last phase, *i.e.*, Phase III, there is a major mobilization of all reserve materials with a further uptake of water coupled with seedling growth (Mattucci, 2015).

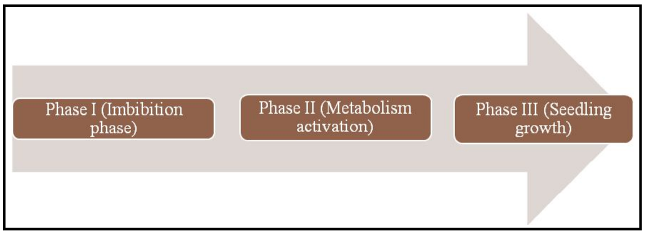

Figure 1: Phases of sprouting.

2. Soybean sprouts

Since soybean (*Glycine max* L.) is one of the primary food sources for both nutritional purposes, it has gained relevance in agriculture (Suman and Neelam, 2018). Soybean (*G. max*) is a year-round vegetable suitable for sprout production and human consumption. Although, its exact origin is unknown, it is a part of the typical diet of Korean people due to the high amount of protein, oil and other

Corresponding author: Mr. Ankesh Pathak

Department of Food Technology, Parul University, Vadodara-390001, Gujarat, India

E-mail: ankeshpathak17@gmail.com

Tel.: +91-8369464363

components. Soybean is a high source of protein, carbohydrates, fats, vitamins and minerals. Additionally, they contain isoflavones, phytic acid (phytate) and saponins which affect the nutrient availability of soybean (Liu, 1999). The nutrient composition of soybean depends on a variety of factors like seed variety, soil type and its composition, climate, water availability, *etc*. There is a plethora of products that one can get from soybean like soymilk, soy sprouts, vegetable soybean, soy sauce (a fermented soybean product), soy paste, *etc*.

2.1 Nutritional significance of soybean sprouts

Research has shown various benefits of sprouting soybean, including reduced risk of cardiovascular disease and cancer as it contains several phytochemicals with high antioxidizing properties (Prakash *et al*., 2007). High levels of sodium, zinc, potassium, copper, iron, magnesium and manganese are present in soybean sprouts specifically hypocotyls and cotyledons (Plaza *et al*., 2003;Youn *et al*., 2011). Anti-nutritional factors like hemagglutinin, trypsin inhibitors and lipoxygenase also decrease after sprouting increasing the nutritional aspects of soybean (Shi *et al*., 2010). Thus, soybean sprouting is an important process which enhances the nutritional aspects of soybean.

2.2 Amino acid and protein content

Soybean is a rich source of protein, sprouting only further enhances its protein content by up to 46 per cent (Bau *et al*., 1997) with varying levels. Different results have been reported by Lee and Chung (1982) and (Choi *et al*., 2000b), the former reporting increase in protein levels and later reported a decrease in protein content levels after 5 days of sprouting. Soybean seeds from Japan, the United States and China were taken which contained 437.2 mg, 452.2 mg and 367.2 mg/100 g of free amino acids and increased up to 12,768.8 mg, 10,845.9 mg and 11,931 mg/100 g dry weight (Mizuno and Yamada, 2006). Asparagine contents increase significantly (Byun *et al*., 1977; Lee *et al*., 2004). Asparagine, which is known to have detoxifying effects, was reported to be around 25 per cent of dry weight after 15 days of sprouting from 42.9 mg/100 g to and 7423.3 mg/100 g (Byun *et al*., 1977). Other than asparagine, there is also a significant increase in glutamate, histidine, alanine, proline, lysine, valine and isoleucine during sprouting (Friedman and Brandon, 2001; Martinez-Villaluenga *et al*., 2006).

Table 1: Free amino acid content in different seed types before and after sprouting

Seed type	Free amino acids before sprouting (mg/100 g)	Free amino acids after sprouting (mg/100 g)
Japan	437.2	12,768.8
United states	452.2	10,845.9
China	367.2	11931

Source: Mizuno and Yamada (2006).

2.3 Oil and fatty acid content

Soybean oil is a commercial soybean product made by extracting oil from its seed. Sprouting the seed has a negative effect (Kim, 1981) on the oil content of the seed, *i.e.*, from 15 per cent to 10 per cent (Shi *et al*., 2010). There are also a few changes in the fatty acid composition of the soybean seeds as a result of sprouting. The levels of palmitic, stearic and oleic acid are slightly increased, whereas the opposite is observed in the levels of linoleic acid (LA) and alpha-linolenic acid (ALA) during sprouting (Mizuno and Yamada, 2006). Different results are obtained depending on the number of days the seed is sprouted. Some contrary reports suggest a decrease in ALA content but increase in LA content in 5 days old sprouts (Lee *et al*., 2002). Thus, the fatty acid composition of soybean sprouts depends on the cultivar and also other factors like days of sprouting (Dhakal *et al*., 2009) and the growth environment (Yang, 1981).

2.4 Isoflavone content

Phytoestrogens are plant-derived compounds which possess a wide range of biological activities (Shi *et al*., 2010). Isoflavones are a class of phytoestrogens which are available in soybean lentils, beans, peas, onion and apples (Dixon and Sumner, 2003). Its consumption has proven to reduce the risk of cardiovascular disease, menopausal symptoms, protection from cancers and bone resorption (Messina, 2000; Allred *et al*., 2004; Prakash *et al*., 2007). It ranges from 0.05 per cent to 0.5 per cent of the dry weight in the seed (Khattak *et al*., 2007). Soybean seed after sprouting has shown to increase the isoflavone content (Kim *et al*., 2003; Kim *et al*., 2004; Kim *et al*., 2006. Also, during sprouting, light caused an increase the concentration of isoflavones (Chi *et al*., 2005).

2.5 Vitamin content

Soybean seeds contain vitamins A, B_1, C and E (Collins and Sanders, 1976). It was observed that there was a significant amount of increase in vitamin C (4-20 times during 4-5 days of sprouting) (Plaza *et al*., 2003). Apart from these, (Lee *et al*., 2013) observed an increase in levels of vitamins, lutein and beta-carotene. A 20, 24 fold increase in lutein levels and an 8, 17 fold increase in beta-carotene levels were observed.

2.6 Saponin

Depending on regional tastes, soybean is eaten in a variety of food products, thus it is critical to comprehend how different processing techniques affect the medicinal component's availability (Shiwani *et al*., 2012). Saponins have several health advantages, including lowering blood glucose and kidney disease risk (Tanaka, 2006; Percival, 1921), as well as lowering blood cholesterol levels (Lee *et al*., 2005). According to Oh *et al*. (2003), the cultivar Eunhakong (Shin *et al*., 1993) had a crude saponin content increase from 4.59 mg/g in the seeds to 5.33 mg/g in sprouts that were 6 days old. According to (Fenwick and Oakenfull, 1983), soybean seeds' saponin content makes up roughly 0.5 per cent of their total dry weight and can range from 0.6 per cent to 6.5 per cent of dry weight (Tsukamoto *et al*., 1995).

2.7 Sugar content

In soybean seeds, the carbohydrates are up to 33 per cent, out of which around 16 per centare soluble sugars (Hyomwitz and Collins, 1974). Sucrose, raffinose, and stachyose, which range from 41.3 per cent to 67.5 per cent, 5.2 per cent to 15.8 per cent, and 12.1 per cent to 35.2 per cent, make up the majority of the soluble sugar fraction (Yazdi-Samadi *et al*., 1977; Eldridge *et al.*, 1979). Due to their sweetness and ease of digestion, glucose, fructose, and sucrose are regarded as desirable sugars, whereas stachyose and raffinose are unfavourable sugars that are indigestible and induce gas and diarrhoea (Wang *et al.*, 2014). During the sprouting phase, the soybean seed's sugar content is reduced. According to (Shi *et al*., 2010), the sugar content of soybean seeds was 19.9 per cent at the time of sowing but dropped to 14 per cent after 7 days of sprouting.

2.8 Minerals

Minerals essential for human nutrition, including Zn, Na, Fe, and calcium, are found in soybean sprouts. During sprouting, the contents of Zn, Ca, Na, Mn, K, and Cu considerably rose whereas Fe declined. The raw seed had a Fe content of 48.87 (µg/g dry weight), while it was 35.29 (µg/g dry weight) for 4-day-old sprouts (Plaza *et al.*, 2003).

3. Lentil sprouts

According to Shrivastava and Vasishtha (2012) lentils (*Lens culinaris* Medic) are a type of legume with high nutritional content, bioactive ingredients, antioxidants, and other phytochemicals that have beneficial effects on health. Thus, regular consumption of lentils can improve human nutrition while also preventing and reducing the occurrence of chronic diseases like cancer, heart disease, metabolic diseases, diabetes and obesity (Bouchenak and Lamri-Senhadji, 2013). According to Haminiuk *et al*. (2012), the presence of phenols, a class of chemicals with antioxidant, antitumour, and anti-inflammatory properties determines the pro-health effects of lentil sprouts and other plants. Therefore, lentils are essential to improving human nutrition, especially in underdeveloped nations. However, their usage is occasionally limited by the presence of various saponins, which are antinutritional components, and are natural substances with surface activity properties found in pulses (Ayet *et al.*, 1997). High saponin levels decrease the bioavailability of micronutrients, but also have a few positive benefits on human health that have been noted in the literature (Liener, 1994).

3.1 Chemical composition

The moisture content increased significantly as a result of sprouting. With longer sprouting times, this rise grew gradually and considerably. Dry legumes hydrate quickly, as a result of the legume's structure. The seed's ability to absorb more water over time is a result of an increase in the number of hydrated cells (Nonogaki *et al*., 2010). Lentils had a 25.63 per cent protein content when they were raw. Protein content rose significantly as a result of sprouting. In sprouted lentil seeds, these increases in protein content varied from 7.33 to 12.60 per cent. The decrease in dry weight, notably from the respiration of carbohydrates during germination, was related to the rise in protein content (Mahmoud and Anany, 2014; Uppal and Bains, 2012). Raw lentil seed oil content was 1.2 per cent. Compared to raw seeds, sprouted seeds had less oil. Sprouting causes a substantial drop in oil content. Oil content considerably decreased from 2.2 (g/100 g) in the raw samples to 1.32, 1.24, 1.15, and 0.90 (g/100 g), respectively, in the samples that underwent 3, 4, 5, and 6-day germination. The increased activity of lipolytic enzymes during germination, which degraded the fats into fatty acids and glycerol, may be responsible for these decreases in oil content (Uvere and Orji, 2002). The sprouting process significantly increased the ash contents of lentil seeds. These increases could be due to an increase in phytase enzyme activity during germination. The amount of crude fibre in sprouted seeds was higher than that of raw seeds. The sprouting process significantly increases the content of crude fibre. Fibre content changes could be caused by a portion of the seed fibre that may be enzymatically solubilized during seed germination (Elmaki *et al*., 1999).The reductions in oil and carbohydrates could be attributed to their use as energy sources in the sprouting process. The acceleration of breathing during germination causes the energy to be released from the destruction of carbon-based compounds. Germination transforms carbohydrates through the hydrolysis of macromolecules and the conversion of insoluble nutrients to soluble nutrients in the cotyledons (Enujiugha *et al.*, 2003).

Table 2: Oil content in lentils before and after sprouting

Seed	Oil content (g/100 g)
Raw	2.2
3-day germinated	1.32
4-day germinated	1.24
5-day germinated	1.15
6-day germinated	0.90

Source: Uvere and Orji (2002).

3.2 Total sugars

At the end of the sprouting phase, the total reducing and non-reducing sugars in sprouted seeds were approximately 2.89, 3.10, and 2.80 times higher than those in raw seeds. This increase in sugar content could be a result of the polysaccharides' mobilization and hydrolysis during the soaking and germination phases (Hooda and Jood, 2003). Due to the growing plant's demand for energy, germination saw a decrease in stored carbohydrates and an increase in total soluble and reducing sugars (Colmenares *et al.*, 1990). Earlier studies have noted a similar trend in the amount of sugar present during germination (Ch *et al.*, 2012; Shakuntala *et al.*, 2011).

3.3 Amino acids

Free amino acids function as nitrogen transporters, crucial for cellular biosynthesis, and homeostasis (Mapelli *et al.*, 2001). The amount of free amino acids is 1.86 mg/g DW in raw lentil seeds. Unbound amino acids in sprouted seeds had a higher content than in unprocessed seeds. Free amino acid levels significantly increased during the sprouting process. The qualities of solubility are influenced by things like awell as sourcing, processing settings, pH, strength and the inclusion of other components (Elkhalifa and Bernhardt, 2010).The improvement in protein solubility is significant due to the process of sprouting. This increase is gradual and noticeable as sporting time rose. Lentil seeds sprouted after 3, 4, 5 and 6 days had protein solubilities that were, respectively, 1.40, 1.62, 1.65 and 1.68 times higher than those of unsprouted seeds. These increases could be the result of the increased proteolytic activity that occurs during germination, which will cause the storage proteins to be hydrolysed, increasing the solubility of the proteins (Afify *et al*., 2012). The nutritional quality of a protein is principally governed by its amino acid composition. Total essential amino acids of lentil seeds protein formed 38.10 per cent of the total amino acid content. Linseed protein was abundant in essential amino acids, including isoleucine, compared to the (WHO, 1991) reference for leucine, lysine, total aromatic amino acids, and tryptophan. The protein from lentil seeds was somewhat deficient in total sulphur amino acids and threonine. Nonessential amino acids made up 61.90 per cent of the total amino acid composition in total. The primary non-essential amino acids in lentil seeds protein were discovered to be glutamic, aspartic, and arginine acids at 21.40, 13.70 and 7.60 per cent, respectively. Similar findings with similar values were provided by several other authors (Carbonaro *et al*., 1997; Kavas and El, 1992; Mahmoud and Anany, 2014; Rozan *et al*., 2001; Porres *et al*., 2002). The essential amino acid content of lentil seeds is enhanced by the germination process. Leucine, lysine, phenylalanine and valine content all increased significantly as a result of the sprouting process. The amount of tyrosine, threonine, and tryptophan in lentil seeds, as well as the total sulphur amino acids, significantly decreased during the sprouting process. In several pieces of research, the necessary amino acids, with the exception of histidine and sulphur amino acids, were found to be greatly elevated during germination (Afify *et al*., 2012; Elemo *et al*., 2011). It has been demonstrated that the germination of cereals and legumes is generally favourable since it enhances their nutritional value and amino acid bioavailability (Correia *et al*., 2008; Egli *et al*., 2004; Gernah *et al.*, 2011; Mubarak, 2005). Changes in the amino acid concentration during the first 72 h of germination may be caused by protein hydrolysis, synthesis, and reorganisation (Taraseviciene *et al.*, 2009). According to Rodriguez *et al*. (2008), the germination of seeds entails the mobilisation of the cotyledons' protein reserves along with the synthesis of fresh proteins that are essential for the formation of sprouts.

3.4 Antinutritional factors

Antinutrients, which are frequently found in plant food, have both harmful consequences and positive health effects. An example is a phytic acid, which when combined with calcium, zinc, iron, and copper, creates insoluble complexes. Another type of antinutrients which are highly prevalent is a class of polyphenolic chemicals called flavonoids,which also includes phenolic compounds (tannins) enzyme (amylase and protease) inhibitors and saponins (Ryden and Selvendran, 1993). On a dry weight basis, raw seeds contained 466.10 mg/100 g of tannins and 233.04 mg/100 g of phytic acid, respectively. The tannin and phytic acid content were significantly reduced during the sprouting phase. With longer sprouting times, these declines rise progressively and considerably. Lentil seeds included high levels of phytic acid (45.85-73.76 per cent) and tannins (47.86-59.40 percent). The sprouting process significantly reduced the amount (Ghavidel and Prakash, 2007; Prakash *et al.*, 2007). According to Shimelis and Rakshit (2007), tannins in water may have leached into germinated seeds, causing a drop in their tannincontent. Another explanation is due to polyphenols' binding with other chemical compounds such as protein or carbs (Saharan *et al*., 2002; Saxena *et al*., 2003; Khandelwal *et al*., 2010) showed that the enzyme polyphenol oxidase may be active during the period of soaking before germination, resulting in degradation and subsequent losses of polyphenols. The decrease of phytate content in various legume seeds after germination is probably due to a significant increase in phytase activity (El-Adawy, 2002; Khattak *et al*., 2007; Shimelis and Rakshit, 2007). A decrease in phytic acid was expected because germination is primarily a catabolic process that hydrolyses reserve resources to provide vital nutrients to the growing plant (Colmenares *et al*., 1990).

3.5 Antioxidant activity

3.5.1 Total phenolic content

Ungerminated lentil seeds had a phenol level of 1341.13 mg/100 g dry weight basis. The germination process considerably enhanced the total phenolic content. When lentil seeds were raw, their phenol content was 1341.13 mg/100 g dry weight; after 3, 4, 5, and 6 days of germination, it was 1411.50, 1463.00, 1630.20, and 1510.10 mg/100 g dry weight, respectively. According to Randhir *et al*. (2004), these increases may be caused by the biosynthesis and bioaccumulation of phenolic compounds as a defensive mechanism to survive environmental stresses like exposure to cold as well as the degradation to polymerized polyphenols, particularly hydrolysable tannins and other glycosylated flavonoids (Monagas *et al*., 2005). The lentil seeds that had been allowed to germinate for five days had the highest level of phenolic content. However, on the sixth day of germination, these gains decreased. This decrease was caused by the mobilisation of phenolic compounds that have been accumulated by the activation of enzymes such as polyphenol oxidase during sprouting (Vadivel and Biesalski, 2012).

Table 3: Total phenolic contentof lentil seeds on sprouting

Seed	Total phenolic content (TPC) (mg/100 g)
Raw	1341.13
3-day germinated	1411.50
4-day germinated	1463.00
5-day germinated	1630.20
6-day germinated	1510.10

Source: Randhir et al. (2004).

3.5.2 Flavonoids

Plants contain a class of naturally occurring chemicals called flavonoids, which have varying phenolic structures (Quattrocchio *et al*., 2006). They are common in grains, seeds, flowers, fruits, and vegetables (Amic *et al*., 2007). Lentil seeds that were ungerminated or raw had 398.33 mg of flavonoids per 100 g DW. Raw lentil seed has a substantially lower flavonoid concentration than sprouted seed. The sprouting procedure was found to significantly boost the lentil seeds' overall flavonoid content. The content of flavonoids gradually increased over the length of the germination days.

3.5.3 Antioxidant activity

By using the DPPH radical scavenging method, the antioxidant properties of raw and sprouted lentil seeds were determined. Raw and sprouted lentil seeds' DPPH radical-scavenging activity was measured in per cent inhibition and ranged from 40.76 to 62.19 per cent. Compared to raw seeds, sprouted seeds demonstrated a significantly increased capacity to absorb DPPH radicals. In particular, polyphenols in phytochemicals have significant free radical scavenging action, which lowers the risk of cancer, age-related neuronal degeneration, and chronic illnesses (Lako *et al*., 2007; Picchi *et al*., 2012;Teow *et al*., 2007). One of the numerous metabolic changes that occur as a result of seed sprouting is an increase in antioxidant activity, which is primarily caused by an increase in the activity of endogenous hydrolytic enzymes. There was an improved digestibility of protein and starch, an increase in sugar and B vitamin content and lower phytate and protease inhibitor concentrations (Chavan *et al*., 1989; Alvarez-Jubete *et al*., 2009). This rise may possibly be related to the production of substances like vitamin C and tocopherols, which have antioxidant properties (Sharma and Gujral, 2010). Thus, it can be stated that the total antioxidant activity of lentils increases on sprouting.

4. Sprouted barley

Due to their high quantity of macronutrients and dietary fibre, slow digestion, and low sugar release, millets are known as grains that are beneficial to diabetics. In addition, millets have a low glycemic index when compared to other cereals (Mounika and Hymavathi, 2021).The ancient grain known as barley (*Hordeum vulgare* L.) has long been used for animal feed and as a primary ingredient in the manufacture of malt (Madakemohekar *et al*., 2018). Although, barley was likely used as food for humans at first, it evolved primarily into a feed, malting, and brewing grain as a result of the growth in popularity of wheat and rice. Approximately, two-thirds of the barley harvest has been utilised recently for just over 2 per cent is used for food directly, and one-third is used for malting. However, it has remained a significant food source for most of its history for several ethnic groups, primarily in northern Africa and Asia (Newman and Newman, 2006). Early on, it was understood that barley was a hearty tasting and high energy food. Roman gladiators, for instance, were referred to as “hordearii.” or “barley men” for consuming barley to increase their strength and endurance (Parmeswaran and Sadasivam, 1982). Depending on whether, the hull is tightly attached to the grain or not, barley is categorised as spring or winter kinds, two-row or six-row, hulled or hulless, and depending on whether it will be used for malting or feeding. Depending upon grain composition, it is further divided into normal, waxy, high lysine, high beta-glucan and proanthocyanidin free amylose starch varieties. Different types of barley frequently have a wide range of physical and chemical traits, which affects their processing qualities and end-use quality. Beta-glucan, protein, phenolic compounds and other essential biochemical components are present in barley grains, particularly hulless barley, making them a significant food ingredient (Arendt and Zannini, 2013). Numerous health advantages of beta-glucan have been documented in various works of literature, including decreased glycaemic index (Jenkins *et al*., 2002), activity against colon cancer, decreased serum cholesterol, increased stool bulk and elimination of harmful substances (Ahmad *et al*., 2012). According to Arendt and Zannini (2013). Burkus and Ternelli (2000), the technological advantages of beta-glucan include its use as a stabilising, thickening, gelatin and emulsifier in functional beverages, bread and snack foods. In the following section, we review the changes in the nutritional composition of barley after sprouting.

4.1 Nutritional significance of barley sprouts

According to the findings of earlier research (Rakcejeva, 2006), the quantity of fibre, vitamin B_2, E, calcium and B_3 during the germination of grains rise, and vitamin C is produced. During protein hydrolysis, vital compounds are produced due to grain activation resulting in the production of amino acids. Compared to rye and wheat, glucosamine concentration rises the fastest in sprouted hull-less barley after sprouting. Glucosamine is a crucial physiologically active substance that preventively boosts the body’s resilience, particularly the immune system’s phagocytic activity, while secreting the immunological mediator cytokinin, which encourages the body’s immune response to continue to develop (Slesarev *et al*., 1998; Ermolaev, 2002). A natural flavonoid called saponarin renowned for its hepatoprotective and antioxidant properties, is the main substance of barley sprouts, constituting 72 per cent of the total amount of polyphenols (Seo *et al*., 2014). Barley flours typically absorb more water due to their higher content of soluble fibre than wheat flours (Holtekjolen *et al*., 2008).

4.2 Fatty acids

Compared to non-germinated grain, barley sprouts’ fat levels were considerably lower and this reduction had a linear time-dependent pattern. A decrease in fat may be linked to depletion of the stored fat that is involved in grain catabolic activities essential for protein synthesis in the growing plant. Additionally, the amount of saturated, unsaturated, monounsaturated, and polyunsaturated fatty acids in germinated barley was assessed. These chemicals were present at quantities comparable to non-germinated barley grain in barley that germinated in a shorter amount of time and at lower temperatures. Unsaturated fatty acids behaved in the opposite way to saturated fatty acids during sprouting, reaching levels close to 37 per cent at longer durations of germination. In comparison to control barley, polyunsaturated acids did not exhibit any appreciable changes. At higher temperatures and longer germination durations, the results ranged from 59 per cent to 63 per cent showing an insignificant decrease. According to the findings, lipases hydrolyse triglycerides, which are the primary lipid storage form in cereals, into diglycerides, monoglycerides, and finally glycerol and fatty acids (Krist *et al*., 2005). As a result, it appears that alpha-oxidation plays a lesser role when grains are sprouted, whereas beta-oxidation,which is aided byoxidase, plays a major role in producing power for metabolic processes (Copeland and McDonald, 2001).

4.3 Protein

Regardless of the germination conditions utilised, protein content was found to have significantly increased following germination in all barley sprouts. The increased protein content in seed sprouts may be explained by the respiration related loss of carbs, which results in an apparent gain in other nutrients like protein (Gomez-Favela *et al*., 2017). A bigger reduction in the sprout’s dry weight and a more substantial increase in protein levels would result from a higher temperature and a longer cooking time. Additionally, imbibition reawakens protein synthesis (Chavarin-Martinez *et al*., 2019), which could possibly contribute to the increased protein concentrationin barley sprouts. Again, only the germination period had any effect on the protein increase and a linear effect was seen.

4.4 Vitamins

Regardless of the vitamin under study, vitamin concentration rose in barley after germination and showed alinear relationship with respect to temperature and time. Greater levels of water-soluble vitamins (B_1, B_2, and C) were observed at longer germination periods and higher temperatures. While vitamin B_2 levels in sprouted barley increased sixfold, vitamin B_1 and C contents in longer germinated barley practically tripled. As a result of the biosynthesis occurring in the grain, various writers have documented an increase in vitamin content during chickpea and barley germination (Bibi *et al*., 2008; Arora *et al*., 2010).

4.5 Beta-glucan

The amount of beta-glucan in raw and germinated barley was measured. The study showed that the concentrations of beta-glucan in barley grains were close to 5 g/100 g dry matter and decreased to a minor extent during germination for short times (reductions of 14 to 22 per cent with respect to the initial content after 84-86 h of germination), but longer germination times cause greater losses. At lower temperatures, the effect of germination time on beta-glucan levels was more noticeable. According to studies, germination increases the activity of the main enzymes that break down the cell walls of wheat endosperm during germination, decreasing levels of betaglucan (Marconi *et al*., 2014; Betts *et al*., 2017).

4.6 GABA

GABA (c-aminobutyric acid) levels in non-sprouted barley were around 54 mg/100 g dry matter, but they considerably rose after germination to between 81 and 186 mg/100 g dry matter. The partial breakdown of storage proteins into oligopeptides and free amino acids during germination, followed by the activation of the glutamate decarboxylase enzyme that converts glutamic acid to GABA, leads to the increase in GABA content in barley sprouts (Caceres *et al*., 2017; Chu *et al*., 2019).

4.7 Total phenolic content, phenolic compounds and antioxidant activity

The ability of boosting the antioxidant qualities of grains by raising phenolics contents is one of the key benefits of controlled germination. Regardless of the settings used during the process, the total phenolic contents (TPCs) of the barley significantly increased after germination compared to the controlled. Particularly at higher temperatures, germination time had a large linear impact on TPC content. The TPC levels in raw barley were consistent with those noted by Zhao *et al*. (2008) who noted amounts ranging from 3.07 to 4.48 mol GA equivalent/g dry matter in several types of barley. The majority of the free phenolic fraction was made up of flavanols like hydroxycinnamic acids, such as ferulic acid, and catechin, as well as procyanidin B, a dimeric form of catechin, among bonded phenols, 4-coumaric acid and caffeic acid were the most prevalent. Sprouting further only enhances the levels of TPCs and other phenolic compounds which was previously also reported by Carvalho *et al*. (2015) and Gangopadhyay *et al*. (2016). The study of many antioxidant indicators was conducted as a thorough assessment of total antioxidant activity. The sprouts formed at longer germination times had the highest antioxidant activities, indicating that the germination process increased antioxidant activity, which was primarily time-dependent.

4.8 Glycaemic index

The GI indicates the rate at which 50 g of carbohydrate in a particular food is absorbed into the bloodstream as blood sugar and ranges from 1 to 100. Glucose is ranked as a reference food. According to Bastidas *et al*. (2016), foods can be categorized by their GI as follows: I high foods with a GI of greater than 70, medium or low between 56 and 69, and less than 55. The release of reducing sugars caused GI in barley to rise considerably as germination progressed. In fact, research on brown rice and barley indicated that decreasing sugar levels while germination is caused by the hydrolysis of starch by the enzymes alpha-amylase and beta-amylase (Farzaneh *et al*., 2017; Charoenthaikij *et al*., 2012).

5. Sprouted millets

The term millets refer to any of the several small-seeded grasses which can be found throughout the year. These grasses are of huge importance in Asia and Africa. Some of the common millets consumed are *Setaria italica, Peninisetum typhoideum* or *Pennisetum glaucum* (pearl millet), *Eleusine coracan* (finger millet), *Echinocloa frumentacea* (barnyard millet) and *Pannicum miliaceum* (proso millet) (Lorenz, 1983).

5.1 Carbohydrates

From 0 to 96 h, starch declined gradually from 71.3 per cent to 35.1 per cent. Maltose and sucrose levels grew from 3.1 per cent to 17.5 per cent and 1.8 per cent to 12.8 per cent, respectively, through out the same time frame. During an 8-day germination period, the starch content of *Setaria italica* fell from 51.0 to 13.4 per cent (Parmeswaran and Sadasivam, 1982). Reducing sugars increased from 0.3 to 10.1 per cent in the same research. A large amount of the soluble carbohydrates in the dried seeds may be used for respiratory activity in the early stages of germination (Nomura and Akazawa, 1969). A large amount of alpha amylase has not yet been generated at this early stage. During sprouting, it has been discovered that amylase inhibitory activity diminishes over time (Mulamani and Supriya, 1993).

Table 4: Carbohydrates change after sprouting for 96 h

Carbohydrate	Per cent before sprouting	Per cent after sprouting
Maltose	3.1	17.5
Sucrose	1.8	12.8
Starch	71.3	35.1
Reducing sugars	0.3	10.1

Source: Parmeswaran and Sadasivam (1982).

5.2 Protein

Protein content increased slightly but significantly throughout each sample period, rising from 6.1 per cent in ungerminated seeds to 7.9 per cent over the 96 h sprouting period. Overall, this represented a growth of 29.5 per cent (Opuku *et al*., 1981). Similar results have been published (Parmeswaran and Sadasivam, 1982) when changes in millet protein levels varied from 14 to 40 per cent. These increases have been linked to the respiration induced loss of dry matter, particularly carbohydrates, which has led to an apparent rise in other nutrients like protein. According to a study, there was a drop in millet's tannin content. The amount of tannin in the raw sample was 0.27 mg for every 100 g of dry material. This lessened progressively until it became negligible at 60 h. Tannins have been found to prevent the activity of digestive enzymes and nutritional digestibility, especially for protein (Maxon *et al.*, 1973). It has been determined that the reported decrease in tannin content in germinated seeds is not the result of tannins actually being lost or degraded per se, but rather the creation of hydrophobic interactions of tannins with seed proteins and enzymes (Butler *et al.*, 1984). Leaching in the sprouting medium (Veerabhadrappa *et al.*, 1978) and increased activity of polyphenol oxidase and other catabolic enzymes, as seen by Kruger (1976) in wheat, have both been linked to a decrease in the tannin content of sorghum.

5.3 Minerals and other trace elements

Sprouting effectively increased the minerals' capacity to be extracted with HCl. There was a significant increase in calcium and iron extractability increasing to 90.2 and 37.3 per cent, respectively, from 76.9 and 18.1 per cent in the raw grain. After 96 h of germination, the extractability of Zn increased from 65.3 to 85.8 per cent. Phytate concentration per 100 g of dry matter reduced from 0.36 to 0.02 g. In 0.03 mol/l HCl, phytates and minerals form insoluble complexes that are impossible to separate. The observed decrease in phytate content may be the reason for these increases in the HCl extractability of minerals.These findings were similar to that obtained in the case of fava beans (Eskin and Wiebe, 1983).

Table 5: Change in extractability of minerals due to sprouting

Mineral	Extractability before sprouting (per cent)	Extractability after sprouting (per cent)
Calcium	76.9	90.2
Iron	18.1	37.3
Zinc	65.3	85.8

Source: Eskin and Wiebe (1983).

6. Conclusion

Thus, sprouting of grains not only increases its nutritive value, but also increases its nutrient availability. It also decreases the anti-nutrient content of the grains which further enhance nutrient availability.These sprouted grains contain high amounts of anti-inflammatory, anticarcinogenic, antidiabetic, *etc.*, components which normal grains lack. Sprouting of different grains offer different results and hence each of these grains can be incorporated in making of bakery products. Products like loaf breads, cookies, cakes and biscuits can be made by incorporating the flour obtained from these sprouted grains in varied proportions. Sprouted grains contains high amount of beta glucan, isoflavones, flavonoids, saponins and gamma aminobutyric acids (GABA). Thus, the advantages of consuming sprouted grains over unsprouted grains are that they are processing free, low GI, healthy, organic, taste better and also offer wide range of health benefits.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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