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Seed sprouts and microbial safety

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SUMMARY : Sprouts are one of the most complete and nutritional of all foods tested. Sprouts are real-life vitamins, minerals, proteins and enzymes. Their nutritional value was discovered thousands of years ago. Recently, numerous scientific studies in India as well as in the world suggest the importance of sprouts in a healthy diet. Because sprouts are predigested food, they have a higher biological efficiency value than whole seeds, raw or cooked. Also, sprouts have a regenerating effect on the human body. The chemical changes that occur in the sprouting seed activate a powerful enzyme factory, never to be surpassed in later stage growth of any legumes. The rich enzyme concentration can lead heightened enzyme activity in your metabolism, leading to regeneration of the bloodstream. Sprouts are the ideal supplement- The food of the future. They are economical, ecological, low in calories/fat, easy to store, fast and easy to grow, tasty and versatile to eat. This paper presents wide-ranging research and the latest developments in this emerging sprout processing technology.

KEY WORDS : Seed sprouts, Germination, Nutritional profile, Microbiological properties, Safety issues

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In many countries worldwide, including the India, the consumption of seed sprouts has increased in recent decades with the advent of neutraceuticals, phyto-chemicals (Shetty *et al.,* 2003) and the shift of consumer preference toward health foods (Rosario, 2003; Pandrangi *et al.,*2003). Seed sprouts are one of the most common vegetables consumed in the India due to availability and nutritional value. The sprouts, locally known as *Ankorit Dals*, are available in markets all year round and contain high-quality proteins comparable to those obtained from expensive animal and marine sources. However, the nutritional quality and the sprouting methods employed by local sprout growers make the commodity susceptible to microbial contamination and therefore, compromise the safety and quality of the sprouts. Unlike many developed countries where seed sprouts are produced in large industrial scales that allot enough capital for the procurement of appropriate sprouting equipment and facilities, sprouting in our country is most commonly done on a micro scale as a part of the growing backyard industry. With capital limited for the procurement of raw materials and simple sprouting equipment, other necessities required in assuring sprout safety are often not available.

Sprouts are very nutritious because they contain all elements a plant needs for life and growth. The endosperm of the seed is the storehouse of carbohydrates, protein, and oil. When the seed germinates, these become predigested amino acids and natural sugars upon which the plant embryo feeds as it grows to maturity. When used as food, the life force is released and supplies the energy which is capable of generating healthy cells in the body and supplying us with new vigour and life. Used as an adjunct to the diet, sprouts can retard the aging process, since they contain ample amounts of male and female hormones, available in their most assimilable form. Processed foods often lack the vitamins and minerals necessary to a balanced diet. Research shows that, in sprouts, one finds one of the foods highest in vitamin and mineral content (Shipard, 2005). Sprouts should, therefore, occupy a prominent place in the diet. Among their other virtues is the fact that the seeds are low in cost, can be stored safely for longer duration, and are easy to grow and when sprouted, increase their nutritional value many times. Germinated seeds are recommended to cure scurvy. Malic and oxalic acids collected

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from green leaves are prescribed for intestinal disorders. Soaked grain and husk are fed to horses and cattle as concentrate and roughage, respectively.

Around the world, studies have been and are being conducted on the use of germinated seeds as a low-cost, highly nutritive source of human food. It is well-established that when legumes are properly soaked and germinated, their nutritive value increases greatly, usually to levels equal to or exceeding those of the cooked bean. The increase in nutritive value in the raw sprouted seed is due to an explosion of enzyme activity, which breaks down the storage-protein and starch in the seed into amino acids, peptides, and simpler carbohydrates needed for the seed to grow. The seed is literally digesting its own protein and starch and creating amino acids in the process. Because of this process, sprouted seeds are essentially a predigested food. At the same time, the anti-nutritional factors such as enzyme inhibitors and other anti-nutrients are greatly decreased to insignificant levels.

Sprouts provide a good supply of vitamins A, E and C plus B complex. Like enzymes, vitamins serve as bioactive catalysts to assist in the digestion and metabolism of feeds and the release of energy. They are also essential for the healing and repair of cells. However, vitamins are very perishable, and in general, the fresher the feeds eaten, the higher the vitamin content. The vitamin content of some seeds can increase by up to 20 times their original value within several days of sprouting. Mung bean sprouts have B vitamin increases, compared to the dry seeds, of - B1 up 285 per cent, B2 up 515 per cent, B3 up 256 per cent. Even soaking seeds overnight in water yields greatly increased amounts of B vitamins, as well as vitamin C. Compared with mature plants; sprouts can yield vitamin contents 30 times higher (Shipard, 2005).

Seed sprouts can be stored for long periods of time and can be easily obtained by germinating the seeds in the dark for up to four days. This process has been used by the Asian countries for centuries. Sprouting does not require soil or solar radiation and is not limited to seasonal growth. Large amounts of sprouts can be obtained in a relatively short time. Sprouts are a cheap source of certain vitamins in the diet and some vitamins are synthesized in the germinating seeds. The sprouting process results in an improvement in the vitamin content (Magaram *et al.,* 1985). Though it is easy to grow sprouts but the main drawbacks are shortage of time for sprouting as in most of the families both husband and wife are working. In western countries, china etc sprouts are grown commercially and made available to consumers. But in India the same trend has been started with the opening of food/ vegetable malls. Sprouts are highly perishable in nature and get spoiled if not stored properly. Due to a short shelf-life, sprouts are susceptible to get spoiled during distribution or in supermarket. One of the primary causes of spoilage is visible mold growth and/or musty smell from the sprouts. Spoilage occurs sooner and more frequent when sprouts are not refrigerated in the supermarket and/or during distribution. Sprout can be easily bruised and readily infected with various bacteria, mould and yeast during handling and transportation. Sprouts cannot be stored for longer time under ambient conditions. So, a method to increase the shelf life of sprout would be advantageous to producers as well as to the consumers.

The most common sprouts often solds in Indian markets are moong sprouts, chickpea sprouts, pigeonpeas and soybean sprouts. Another common sprout is the alfalfa sprout and the barley sprout.

Other seeds that can be sprouted include adzuki bean, almond, amaranth, annatto seed, anise seed, basil, lima bean, broccoli, buckwheat, cabbage, canola seed, cauliflower, celery, dill, fennel, fenugreek, flax seed, garlic, hemp seed, green lentils, pearl millet, mizuna, mustard, oats, onion, black-eyed peas, green peas, peanut, psyllium, pumpkin, radish, rye, sesame, sunflower, triticale and wheat berries.

However, many sprouts are in fact toxic when eaten, like kidney beans. Some sprouts can be cooked to remove the toxin, while others will be toxic either way and should be avoided. With all seeds, care should be taken that they are intended for sprouting or human consumption rather than sowing. Seeds intended for sowing may be treated with chemical dressings. Some varieties of edible seed be heat-treated, thus making them unfit to sprout.

Many varieties of nuts, such as almonds and peanuts, can also be started in their growth cycle by soaking and sprouting, although because the sprouts are generally still very tiny when eaten, they are usually called “soaks.”

Sprout history :

Medicinally and nutritionally, sprouts have a long history. It has been written that the Ancient Chinese physicians recognized and prescribed sprouts for curing many disorders over 5,000 years ago. Sprouts have continued to be a main staple in the diets of Americans of Oriental descent. Although accounts of sprouting appear in the Bible in the Book of Daniel, it took centuries for the West to fully realize its nutrition merits. In the 1700’s, sailors were riddled by scurvy (lack of Vitamin C) and suffered heavy casualties during their two to three year voyages. From 1772-1775, Captain James Cook had his sailors eat limes, lemons and varieties of sprouts; all abundant holders of vitamin C. These plus other fresh fruits and vegetables and a continuous program of growing and eating sprouts were credited with the breakthrough, thus solving the mariners’ greatest casualty problem (Sanderson, 2009).

Sprouts processing :

Sprouting is the practice of soaking, draining and then rinsing seeds at regular intervals until they germinate, or sprout.

This can be a semi-automated or fully automated process when done on a large scale for commercial use.

Basic steps in sprouting :

– Measure out appropriate amount of seed, visually inspect and remove stones, sticks, weed seed, broken seeds, etc.
– Rinse seed.
– Soak seed in water for appropriate time.
– Rinse soaked seed, put in sprouting environment for appropriate time.
– When ready, rinse seeds. Store in refrigerator, in sprouting environment or in other suitable container until ready to use. If not used within 12 hours, seeds should be serviced (rinsed) every 24 hours in refrigerator.

Moisture, warmth, and in most cases, indirect sunlight are necessary for sprouting. Some sprouts, such as mung beans, can be grown in the dark. Little time, effort or space is needed to make sprouts.

To sprout seeds, the seeds are moistened, and then left at room temperature (between 13 and 21 ^{0}C) in a sprouting vessel. Many different types of vessels can be used. One type is a simple glass jar with a piece of cloth secured over its rim. 'Tiered' clear plastic sprouters are commercially available, allowing a number of "seeds" to be sprouted simultaneously (Fig. 1). By staggering sowings, a constant supply of young sprouts can be ensured. Any vessel used for sprouting must allow water to drain from it, because sprouts that sit in water will rot quickly. The seeds will swell and begin germinating within a day or two.

Sprouts are rinsed as little as twice a day, but possibly three or four times a day in hotter climates, to prevent them from souring. Each seed has its own ideal sprouting time. Depending on which seed is used, after three to five days they will have grown to two or three inches in length and will be suitable for consumption. If left longer they will begin to develop leaves, and are then known as baby greens. A popular baby green is sunflower after 7-10 days. The growth process of any sprout can be slowed or halted by refrigerating until needed.

Common causes for sprouts to become inedible :

– Seeds are allowed to dry out
– Seeds are left in standing water
– Temperature is high or too low
– Insufficient rinsing
– Dirty equipment
– Insufficient air flow
– Contaminated source of water
– Poor rate of germination of seed

Seeds can be sprouted either in light or dark conditions. Those sprouted in the dark will be crisper in texture and whiter, but these have less nutritional content than those grown in partial sunlight. Growing in full sunlight is not recommended, because of overheat or dry out of seeds. A very effective way to sprout beans like lentils or adzuki is in colanders. Soak the beans in hot water for about 8 hours then place in the colander. Wash twice a day. The sprouted beans can be eaten raw or cooked.

Sprouting methods :

Jars :

Wide-mouth, glass jars are available in different sizes. Jars with screen lids - cut pieces of different (plastic) mesh screens, or some of the special plastic screen lids design is suitable for sprouting. Sprouting in jars is quite easy. Seeds were filled in jar, and soaked in water with lid on. When soaking is over, invert jar and drain water, then rinse again. Then prop jar up at 45 degree angle for water to drain. Keep out of direct sunlight. Rinse seed in jar 2-3 times per day until ready, keeping it angled for drainage

Cloth :

Soak seed in flat-bottom containers, in shallow water. When soak done, empty seed into strainer and rinse. Then take flat-bottom bowl or saucer, line bottom with wet 100 per cent cotton washcloth, spread seed on wet cloth. Wrap wet seeds with wet cloths on top. Can add additional water to washcloths 12 hours later by a) sprinkling on top, or b) if very dry, remove seed from cloth, rinse, re-wet cloth, and put seed back between wet cloths. Cloths used should be 100 per cent cotton (terrycloth) or linen, used exclusively for sprouting, and of light colors. Cheap cotton washcloths (and cheap plastic bowls) work well and will last a long time. General scheme for seed sprout production is shown in Fig. 1

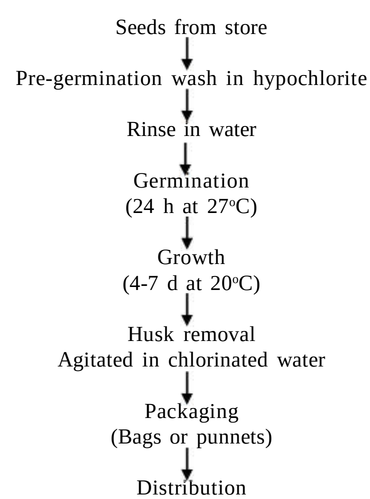

Fig. 1 : General scheme for seed sprout production

Other methods of sprouting :

– Plastic tube - variation on jar method; opens at both ends - easier to remove long sprouts like greens from tube than from jar.

- Sprouting bags - cotton or linen; also plastic mesh. Soak seed in bag in water, then hang up inside plastic bag (forms a little greenhouse).
- Trays: very good for growing greens. Might need drainage system.
- Clay saucer: used for mucilaginous seeds like flax, psyllium, etc.
- Commercial sprouters: wide variety available. Often fairly expensive; most don't work as well as cloth/jar methods.

Packaging of seed sprouts :

Another intervention method that may improve the microbial quality of sprouts is alteration of the packaging conditions. Packaging alterations would be acceptable not only to the traditional sprout producer, but also to the organic producer who does not add chemicals to reduce microbial loads during production. Sprout producers use a variety of different packaging materials including heat-sealed or twist tie-sealed plastic bags, Ziplock bags, heat-sealed cellophane bags, plastic boxes/ cups with a film seal, clamshell packages and produce boxes (Yam and Lee, 1995). Many of these packaging systems include perforated packaging (PP) to allow for respiration, while others utilize non-permeable films. Modified atmosphere packaging (MAP), where the atmosphere surrounding the product contains a reduced O_2 concentration and elevated CO_2 concentration, has helped to maintain the fresh produce quality and to extend the shelf-life of fresh produce (Zagory and Kader, 1988; Brackett *et al.,* 1993; Nguyen-the and Carlin, 1994; Yam and Lee, 1995). Carrots, tomatoes (Beuchat and Brackett, 1991), and lettuce (Beuchat and Brackett, 1990) all benefited from an extended shelf-life due to MAP, even though the total microorganisms were not impacted by MAP. As with other vegetables, MAP may have an impact on the microbial quality of seed sprouts.

Another one of the common packaging methods in the food industry is vacuum and partial vacuum packaging. However, vacuum packaging (VP) may not be appropriate for fruit and vegetable products because it accelerates the deterioration of quality of some fruits and vegetables (Ponka *et al.,* 1995). Additionally, the equipment needed for vacuum packaging as well as MAP may be too costly for a small sprout producer to purchase. Despite the added costs, mold growth appears to significantly contribute to microbial spoilage of sprouts, and reducing the amount of oxygen using either MAP or VP may reduce or eliminate the spoilage problems caused by molds and yeast. Additionally, PP may allow for more environmental contamination of the sprouts while non-permeable packaging used for VP and MAP may serve as a physical barrier to mold and bacterial contamination. On the other hand, altering packaging conditions are likely to alter the microbial profile on the sprouts. Altered profiles may have a beneficial or detrimental impact on spoilage micro-organisms.

Maturity indices for seed sprouts :

Sprouts, plant seedlings consumed shortly after germination, are produced from many vegetable and agronomic plant seeds. Harvest maturity is highly regulated by germination (sprouting) conditions. The desired sprout length is the primary maturity index and harvesting is done at a relatively fixed number of days following radicle (root) emergence. Depending on seed type, harvest generally occurs 3 to 8 days after germination (Ex. alfalfa and sunflower, respectively). Examples of typical desired sprout lengths are given below in Table 1.

Table 1: Typical desired seed sprout lengths

Sr. No.	Type	Harvest maturity (mm)
1.	Adzuki	14 to 26
2.	Alfalfa	26 to 38
3.	Bean	26 to 38
4.	Buckwheat	10 to 15
5.	*Brassica* spp. (broccoli, etc)	16 to 26
6.	Chickpea	26 to 36
7.	Mung Bean	26 to 76
8.	Radish	16 to 26
9	Wheat	10 to 15

Source: *Suslow and Cantwell, 2002*

Quality indices for seed sprouts :

Sprouts should be clean, brightly colored for the type and free of damage, debris and decay. Bean sprouts should be etiolated (lacking noticeable green chlorophyll) with white root tips (none to very limited browning). Sprouts are typically harvested and washed free of seed coats and non-germinated seed. If germinated in a solid medium rather than in hydro-phonic culture, sprouts are thoroughly washed to remove adhering materials. (Suslow and Cantwell, 2002).

Optimum temperature and relative humidity for storage of seed sprouts :

Optimum temperature and RH per cent for storage of seed sprouts are 32^0F (0^0C) and 95-100 per cent, respectively. Rapid cooling is essential to achieve the full storage potential of seed sprouts. Under these conditions most sprouts may be expected to maintain acceptable quality for 5 to 9 days. Shelf-life at 36^0F (2.5^0C) is less than 5 days, at 41^0F (5^0C) and at 50^0F (10^0C) is less than 2 days. The high respiration rates and perishable nature demand distribution and short-term storage at 32^0F (0^0C). Although industry experiences with mung bean suggest the potential for damage, no symptoms of chilling injury have been unequivocally linked to this temperature regime

(Suslow and Cantwell, 2002). Rate of respiration and ethylene production is given in Table 2.

Table 2 : Rate of respiration and ethylene production of mung bean sprouts

Temperature	0°C	5°C	10°C
Rates of Respiration (ml CO_2/kg·hr)	9 - 11	19 - 21	42 – 45
Ethylene Production (ml/kg·hr)	0.15	0.24	0.9

Source: (*Suslow and Cantwell, 2002*)

Responses to ethylene and controlled atmospheres (CA) :

Ethylene effects are low to medium sensitivity and not considered to be a significant factor in the optimal handling and distribution regimes for sprouts. Packing sprouts in plastic "clamshells" with limited venting or in perforated film pouches helps maintain quality. One report on mung bean sprouts (CA) demonstrated that 5% O_2 + 15%CO_2 extended keeping quality. (Suslow and Cantwell, 2002)

Physiological disorders :

Freeze injury sprouts are susceptible to freeze injury but sensitivity varies widely. Shoots become water-soaked and turn black. Roots appear water-soaked and glassy. Roots become soft quickly on warming and darken rapidly.

Pathological disorders :

Bacterial decay is a common problem in many sprout types and will develop very rapidly in production systems as well as in post-harvest storage, at warmer than optimum temperatures. High quality seed, proper pre-germination, seed treatments and post-harvest refrigeration are the primary controls but washing sprouts in chlorinated or ozonated water (or other effective and approved disinfectant) will help control this decay and spoilage.

Microbial food safety and sanitation :

Several types of seed sprouts have been clinically linked to several notable outbreaks of bacterial pathogens, especially in recent years. Multi-state incidents of highly virulent Salmonella and enterohemorrhagic *E. coli* O157:H7 have been traced to the consumption of alfalfa, Mung bean, and possibly radish sprouts. Seed contamination has been positively identified as, at least, one confirmed source of contamination in several cases.

Microbiological spoilage :

The term "spoilage" is defined as "any change that occurs in a food whereby the food is made unacceptable for human consumption" (Andrews *et al.*, 1979). Due to a short shelf-life, seed sprout producers report economic losses from product that becomes spoiled during distribution or in the supermarket. One of the primary causes of spoilage is visible mold growth and/or a musty smell from the sprouts. Preliminary data collected in our laboratory indicated that lactic acid bacteria and molds predominate the microflora of the spoiled sprouts. Producers report seasonal differences in spoilage, with peak losses occurring in the summer months. Spoilage also occurs sooner and more frequently when sprouts are not refrigerated in the supermarket and/or during distribution. In addition to spoilage issues, pathogens could be introduced into sprouts from the seeds, in water used during production and improper sanitation during production and marketing (Patterson and Woodburn, 1980). Seed sprouts have recently become a vehicle for many foodborne illness outbreaks.

In 1995, an outbreak of *Salmonella stanley* and *Salmonella anatum* infections occurred because of consumption of contaminated alfalfa sprouts (Jaquette *et al.*, 1996). Outbreaks of food poisoning caused by *Escherichia coli* O157:H7 and infection by other *Salmonella* spp. have also been associated with the consumption of raw seed sprouts (O'Mahoney *et al.*, 1990; Ponka *et al.*, 1995).

Intervention methods that improve the shelf-life of seed sprouts may also improve the safety of the sprouts by reducing pathogen loads. Chlorine treatment of seeds or sprouts at various stages of production has been suggested as an intervention method to reduce the total populations or to kill micro-organisms such as *Salmonella* without adversely affecting the germination (Park and Sanders 1990; Brackett 1993; Jaquette *et al.*, 1996; Beuchat 1996 and 1997).

Reduction of total micro-organisms using a chlorine treatment may possibly have the added benefit of extending the shelf-life of the sprouts. Soaking seeds in chlorinated water is an inexpensive, readily available intervention that can be utilized by traditional sprout producers if effective in improving the microbial quality and extending shelf-life.

Microbiological safety evaluations and recommendations on sprouted seeds :

Sprouts have been identified as a special problem because of the potential for pathogen growth during the sprouting process. If pathogens are present on or in the seed, sprouting conditions may favour their proliferation. There is no inherent step in the production of raw sprouts to reduce or eliminate pathogens. Contaminated seed is the likely source for most reported sprout-associated outbreaks. Research has been initiated on methods to reduce or eliminate pathogenic bacteria on seeds and sprouts and some treatments show promise. However, to date, no single treatment has been shown to completely eliminate pathogens under experimental conditions used. Finally, the Committee found that, at the time of the charge, there was a lack of fundamental food safety knowledge along the continuum from seed production through sprout consumption. More recently, many have become aware of the potential for this food to be a vehicle for food-borne illness and the need for appropriate controls: however, such awareness is not universal. Although seed appears to be the most likely source of contamination in sprout associated outbreaks, practices and conditions at the sprouting facility may also impact on the safety of the finished product. In recent sprout-associated outbreak investigations, facilities associated with outbreaks did not consistently apply seed disinfection treatments prior to sprouting. Conversely, facilities that used seed from the same lot as an implicated facility, but had not been associated with reported illnesses, appear to have been consistently using seed disinfection treatments, such as 20,000 ppm calcium hypochlorite, to disinfect seed prior to sprouting.

Keeping in view, the number of specific recommendations has developed, including :

- The knowledge of all interested parties pertaining to the microbiological safety of sprouted seeds must be enhanced; government and industry should develop education programes for seed and sprout producers on basic principles for microbiological food safety, good agricultural practices, good manufacturing practices, and hazard analysis and critical control point (HACCP) systems.
- Good agricultural practices should be systematically implemented to reduce the potential for microbial contamination of seeds for sprout production.
- Seed cleaning, storage, and handling practices that minimize the potential for microbial contamination should be developed and implemented.
- Seeds should be treated with one or more treatments that have been shown to reduce pathogenic bacteria that may be present. Intervention strategies that deliver less than a given reduction (at this time, 5-log) in levels of *Salmonella* spp. and enterohemorrhagic *Escherichia coli* O:157 should be coupled with a microbiological testing programme.
- Establish good manufacturing practices and food safety systems, including regulatory oversight, microbial testing, adoption of HACCP and improved traceback, that systematically look for means to prevent seeds from serving as the vehicle for food-borne disease (Table 3) .

Table 3: Critical control point analysis of seed sprout production

Control point	Hazard	Control measure
Raw materials:	Mould or bacterial growth due to damp storage conditions	Dry storage/ humidity and moisture control of beans
dried	Contamination by birds, rodents or insects	Pest control programme
seeds/beans	High microbial loading	Use of approved suppliers
	Contamination by foreign matter	Inspection, sieving and washing
	Contamination by pesticides	Discard seeds
Packaging	Contamination by birds, rodents or insects	Pest control programme
materials	Contamination by dirt	Clean storage environment
Soaking and	Growth of surface microbial contamination	Surface decontamination of seeds
germination of	Contamination from dirty growth containers	Cleaning and disinfection of recycled germination containers
seeds	Contamination from water supply	Disinfection of water supply
Growth of	Excessive microbial proliferation	Use of disinfected irrigation water
bean sprouts	Contamination from dirty growth containers	Cleaning and disinfection of recycled germination containers
	Contamination from water supply	Disinfection of water supply
Harvesting/	High microbial levels on the harvested sprouts	Application of control measures before harvesting
washing	Contamination from wash water	Chlorination of wash water
Sprouts	Proliferation of micro-organisms in wash tank water	Chilling and chlorination of wash tank water
	Proliferation of micro-organisms in wash tank water	Chilling and chlorination of wash tank water
	Contamination of wash tank surfaces	Cleaning and disinfecting wash tank system daily at the end of production
	Collection bin contamination	Clean/disinfect collection bins
Packing	Contamination from unsanitary handling practices	Personnel hygiene control, cleaning and sanitation of equipment
	Cross-contamination from raw material, germination and growing areas	Well designed factory layout and drainage system. Controlled movement of staff and equipment
	Metal fragments in product	Use metal detector
Storage	Microbial growth	Store at 5^0C± 2. Limited shelf life.
Distribution	Microbial growth	Distribution chill chains at 5^0C ±2.
	Use of out of date product	Date label and stock rotation control
Consumer	Storage abuse of product leading to microbial growth	Clear instructions to the consumer on storage, shelf-life and product preparation.

Source: Belton (1999)

– Conduct research related to the microbiological safety of sprouted seeds, particularly in the areas of pathogen reduction or elimination, sources of contamination and its prevention, and preventing or retarding pathogen growth during sprouting.

Nutritional information :

Sprouts are rich in digestible energy, bio-available vitamins, minerals, amino acids, proteins, beneficial enzymes and phyto-chemicals, as these are necessary for a germinating plant to grow. These nutrients are essential for human health. The desirable nutritional changes that occur during sprouting are mainly due to the breakdown of complex compounds into a more simple form, transformation into essential constituents and breakdown of nutritionally undesirable constituents. The metabolic activity of resting seeds increases as soon as they are hydrated during soaking. Complex biochemical changes occur during hydration and subsequent sprouting.

The reserve chemical constituents, such as protein, starch and lipids, are broken down by enzymes into simple compounds that are used to make new compounds. Sprouting grains causes increased activities of hydrolytic enzymes, improvements in the contents of total proteins, fat, certain essential amino acids, total sugars, B-group vitamins, and a decrease in dry matter, starch and anti-nutrients. The increased contents of protein, fat, fiber and total ash are only apparent and attributable to the disappearance of starch. (Chavan and Kadam, 1989). Summary of nutritional benefits upon sprouting is given in Table 4.

Increase in plant enzyme content :

Sprouts are a tremendous source of (plant) digestive enzymes. Enzymes act as biological catalysts needed for the complete digestion of protein, carbohydrates and fats. The physiology of vitamins, minerals and trace elements is also dependent on enzyme activity. Being eaten whilst extremely young, "alive" and rapidly developing, sprouts have been acclaimed as the "most enzyme-rich food on the planet". Estimates suggest there can be up to 100 times more enzymes in sprouts than in fruit and vegetables, depending on the particular type of enzyme and the variety of seed being sprouted. The period of greatest enzyme activity in sprouts is generally between germination and 7 days of age.

Grains and legume seeds of all plants contain abundant enzymes. However, while grains and seeds are dry, enzymes are largely inactive, due to enzyme inhibitors, until given moisture to activate germination. It is these inhibitors that enable many seeds to last for years in soil without deteriorating, whilst waiting for moisture. Enzyme inhibitors in some grains and legume seeds (for example trypsin inhibitors in raw soybeans and certain other beans and peas) need to be inactivated by heating or other processes, before they can be safely fed. However, heating, cooking and grinding processes can also inactivate certain digestive enzymes within grains and seeds. Fortunately, during germination and sprouting of grains and seeds, many enzyme inhibitors are effectively neutralized, whilst at the same time the activity of beneficial plant digestive enzymes is greatly enhanced (Shipard, 2005).

Increase in crude protein content :

The protein content of sprouts increased from the time of germination, as shown below. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves, thus increasing crude protein levels. Crude protein contents of seed and 4, 6 and 8-day old barley grass mats (Morgan *et al.*, 1992)

I*ncrease in protein quality* :

Very complex qualitative changes are reported to occur during soaking and sprouting of seeds. The conversion of storage proteins of cereal grains into albumins and globulins during sprouting may improve the quality of cereal proteins. Many studies have shown an increase in the content of the amino acid lysine with sprouting. An increase in proteolytic activity during sprouting is desirable for nutritional improvement of cereals because it leads to hydrolysis of prolamins and the liberated amino acids such as glutamic and

Table 4: Summary of nutritional benefits upon sprouting

- When seeds are sprouted, the hydrolytic enzymes breakdown grain storage compounds into more simple and digestible fractions

Starch simple	→	Sugars and soluble carbohydrates
Protein	→	Soluble proteins and free amino acids
Fats	→	Essential fatty acids

Minerals chelate (*i.e.*, merge with a protein molecule) in a way that increases their bioavailability.

- Sprouting grains results in –

↑	Protein and starch digestibility	↑	Total sugars	↑	Crude fibre %
↑	Protein % and protein quality	↑	Lysine %	↑	B-group Vitamins Vitamin-E and Vitamin-A

Anti-Nutritional compounds such as phytates and protease inhibitors

All these actions greatly enhance the digestibility and nutrient value of sprouted grains, well above the original grain or seed.

Source: Shipard (2005)

proline are converted to limiting amino acids such as lysine (Chavan and Kadam, 1989).

Increase in crude fibre content :

In sprouted barley, crude fibre, a major constituent of cell walls, increases both in percentage and real terms, with the synthesis of structural carbohydrates, such as cellulose and hemicellulose (Cuddeford, 1989). Chung *et al*. (1989) found that the fibre content increased from 3.75 per cent in un-sprouted barley seed to 6 per cent in 5-day sprouts (Table 5).

Table 5 : Crude protein and crude fibre changes in barley sprouted over a 7-day period

Days	Crude protein (% of DM)	Crude fibre (% of DM)
1.	12.7%	5.6%
2.	13.0%	2 5.9%
3.	13.6%	5.8%
4.	13.4%	7.4%
5.	13.9%	9.7%
6.	14.0%	10.8%
7.	15.5%	14.1%
Original seed	12.7%	5.4%

Source: Cuddeford (1989)

Increase in essential fatty acids :

An increase in lipase activity has been reported in barley by MacLeod and White (1962), as cited by Chavan and Kadam (1989). Increased lipolytic activity during germination and sprouting causes hydrolysis of triacylglycerols to glycerol and constituent fatty acids.

Increase in vitamin content :

Sprouting treatment of cereal grains generally improves their vitamin value, especially the B-group vitamins (Chavan and Kadam, 1989). Certain vitamins such as á-tocopherol (Vitamin-E) and β-carotene (Vitamin-A precursor) are produced during the growth process (Cuddeford, 1989).

Sprouts provide a good supply of vitamins A, E and C plus, B complex. Like enzymes, vitamins serve as bioactive catalysts to assist in the digestion and metabolism of feeds and the release of energy. They are also essential for the healing and repair of cells. However, vitamins are very perishable and in general, the fresher the feeds eaten, the higher the vitamin content. The vitamin content of some seeds can increase by up to 20 times their original value within several days of sprouting. Mung bean sprouts have B vitamin increases, compared to the dry seeds, of - B1 up 285 per cent, B2 up 515 per cent, B3 up 256 perb cent. Even soaking seeds overnight in water yields greatly increased amounts of B vitamins, as well as vitamin C. Compared with mature plants, sprouts can yield vitamin contents 30 times higher. (Shipard, 2005).

Health concerns: risks and anti- nutritional factors :

Raw sprouts have been associated with dozens of food borne illness outbreaks since 1995. FDA and other public health officials are working with industry to identify and implement production practices that will assure that seed and sprouted seed are produced under safe conditions. While these efforts have improved food safety awareness within the industry and have led to a significantly better understanding of the microbial ecology of sprout-associated food-borne illness, not all industry segments have been reached and outbreaks continue to occur.

Consequently, FDA released a guidance document, entitled “Guidance for industry: reducing microbial food safety hazards for sprouted seed” (the “sprout guidance”). The sprout guidance identifies a number of areas, from the farm to the sprout facility, where FDA believes immediate steps should be taken to reduce the risk of sprouts serving as a vehicle for food-borne illness and to ensure that sprouts are not adulterated under the Food, Drug and Cosmetic Act (the act). Specific recommendations in the sprout guidance include: development and implementation of good agricultural practices and good manufacturing practices in the production and handling of seeds and sprouts, seed disinfection treatments and microbial testing before product enters the food supply. The agency will closely monitor the safety of sprouts and the adoption of enhanced prevention practices as set out in the sprout guidance. FDA plans to send investigators to sprouting facilities to test water used to grow sprouts (*i.e.*, spent irrigation water) and assess the adoption of preventive controls. Failure to adopt effective preventive controls can be considered in-sanitary conditions which may render food injurious to health. FDA will consider enforcement actions against any party who does not have effective preventive controls in place, in particular, effective microbial testing.

Some legumes can contain toxins or anti-nutritional factors, which can be reduced by soaking, sprouting and cooking shouldn’t eat large quantities of raw legume sprouts on a regular basis, no more than about 550g daily. However, not all legume sprouts contain these anti-nutritional factors and many have beneficial properties so it is recommended that the advice of a qualified nutritionist is sought before making any decisions about what to include or eliminate from a diet. However, in our country no such guidelines are prepared for seed sprouts.

Reduction of anti-nutritional factors :

Phytic acid occurs primarily in the seed coats and germ of plant seeds. It forms insoluble or nearly insoluble compounds with minerals including calcium, iron, magnesium and zinc, such that they cannot be effectively absorbed into the blood. Diets high in phytic acid and poor in these minerals produce mineral deficiency symptoms in experimental animals (Chavan and Kadam, 1989). The latter authors state that the sprouting of cereals has been reported to decrease levels of phytic acid. Similarly, Shipard (2005) states that enzymes of germination and sprouting have the ability to eliminate detrimental substances such as phytic acid.

Buckwheat sprouts contain fagopyrin, a naturally occurring substance in the buckwheat plant. When ingested in sufficient quantity, fagopyrin is known to cause the skin of animals and people to become phototoxic, which is to say hypersensitive to sunlight, particularly if juiced or eaten in large quantities. Due to the growing popularity of sprouts in general, and a widespread ignorance as to the toxic dangers posed by buckwheat sprouts specifically, many people are today suffering unnecessarily. Also, sprouted grains, nuts and seeds should not be consumed by anyone sensitive to mono sodium glutamate, as sprouting naturally converts any glutamate to its free form, which immediately enters in the blood stream and causes reactions.

Sprouting and the living foods diet :

Advocates of a raw food diet promote the use of sprouting as an effective way to increase vitamin content and digestibility. Sprouts are believed by many to be the most nutrient rich food on earth. This, however, is a misinterpretation which seems to stem from the way nutritional content is presented. Companies that sell seeds and sprouting products compare the vitamin content of the seeds to that of the sprouts which has been shown to increase significantly. The increase is due to seeds having very little vitamin content not sprouts containing large amounts. Additionally, when sprouts are compared to commonly eaten vegetables the overall vitamin content of sprouts is shown to be substantially lower. This is not to say that eating sprouts is not nutritious or healthy, but rather, to show that there is no scientific evidence that sprouts are superior to other edible plants.

Many raw food dietitians avoid un-sprouted grains, nuts and seeds. While raw and un-sprouted grains, nuts and seeds contain enzyme deactivators that harm the stomach, and cooking them denatures their fats and oils, soaked or sprouted grains, nuts and seeds have natural oils and active enzymes at the same time.

Unlike most cooked foods, there are very few commercial avenues for purchasing such foods. Most "raw foods bars" are raw but not sprouted (and therefore, do not have active enzymes) because the bars would not keep as long on the shelf. The same is true of most nut and seed butters. The fact that sprouts have a limited shelf-life is seen as a nutritional asset, as it shows that the nutrients in sprouts are easily assimilated by the digestive system.

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