Arvind Kumar Jaiswal[1], Dharmendra Kumar[2], Som Dutt[2] and Brajesh Singh[2]*

Potato: A Key Crop for Global Food and Nutritional Security

Potato (*Solanum tuberosum* L.) is one of the most important food crops in the world and a major source of food and nutritional security. It is widely grown, low in cost, easy to prepare, and valued for its ability to provide quick energy and useful nutrients. Although it is mainly known as a starch-rich food, potato tubers also contain proteins, dietary fibre, vitamins, minerals, phenolics, anthocyanins, carotenoids, and other bioactive compounds that support human health. Potatoes are also a good source of resistant starch and high-quality protein, and they contribute important amounts of vitamin C, vitamin B6, potassium, and iron to the diet. Coloured and biofortified potatoes are especially rich in health-promoting compounds and may help reduce the risk of chronic diseases such as diabetes, obesity, and cardiovascular disorders. In addition, potato proteins and phenolic compounds show antioxidant, anti-inflammatory, and cholesterol-lowering properties. Value-added potato products, including cookies, halwa premix, semolina, porridge, gulab-jamun, jalebi, muffins, and other convenient foods, increase the use of potato in healthy and consumer-friendly forms. Overall, potato is not only a staple crop but also a versatile and nutritious food with strong potential to improve public health and support future food security.

Keywords: Bioactive elements; Indoor farming; Microgreens; Novel culinary element

POTATO (*Solanum tuberosum* L.) is one of the most important food crops in the world, ranking after rice and wheat. It originated in the Andes Mountains and has been cultivated for more than 8,000 years. From its early use in the pre-Columbian period, when it was processed into products like chuno, the potato has spread to over 160 countries. Today, it serves as a staple food for more than one billion people worldwide. Recognizing its global importance, the year 2008 was declared the "International Year of the Potato." Potatoes play a key role in meeting the energy and nutritional needs of populations in both developing and developed countries. They are widely consumed because of their low cost, easy availability, and versatility in cooking. Their mild taste allows them to be used in a variety of dishes and combined with many other foods. Due to these advantages, potatoes contribute significantly to global food security and have the potential to help reduce malnutrition.

Although potatoes are often viewed as foods high in carbohydrates and calories, their nutritional value is frequently underestimated. Many people wrongly associate potato consumption with obesity and diabetes, while ignoring their health benefits. In reality, potatoes are a rich source of essential nutrients such as vitamin C, vitamin B3, vitamin B6, dietary fibre, potassium, phosphorus, and good-quality protein. They also contain several bioactive compounds that promote health. Coloured potatoes, such as yellow- and purple-fleshed varieties, are especially rich in beneficial compounds. Yellow-fleshed potatoes contain carotenoids, while purple potatoes are rich in anthocyanins. These compounds are known for their antioxidant properties and their role in reducing the risk of chronic diseases, including cancer, diabetes, and age-related disorders. In addition, potato protein peptides have shown potential in managing conditions such as hypertension, obesity, hyperlipidaemia, and certain microbial infections.

Potatoes also contain small amounts of antinutritional compounds such as glycoalkaloids, proteinase inhibitors, and lectins. However, when present within safe limits, these compounds may also provide health benefits. Scientific studies, including laboratory experiments, animal studies, and human clinical trials, have demonstrated the positive effects of potato consumption on health. These studies highlight the anticancer, anti-inflammatory, anti-diabetic, and cholesterol-lowering properties of potato components. Several studies have primarily focused on the characterization of nutrients and bioactive compounds, including carotenoids, phenolics, anthocyanins, vitamins, proteins, and minerals, in both

raw and processed potatoes. Recent investigations have further addressed the bio-accessibility of these compounds. Although coloured potato varieties have received considerable attention, conventional cream- and yellow-fleshed potatoes also possess substantial levels of health-promoting constituents. This article emphasizes the phytonutrient profile and possibilities of value- addition in potatoes and elucidates their role in human health promotion.

Potato is wholesome and nutrient-dense food

The nutritional importance of any crop depends on its metabolic composition, and potato holds a unique position in this regard. It is considered a nutrient-rich food due to the presence of several health-promoting components. Starch is the major constituent of potato and serves as a significant source of dietary carbohydrates. In addition to starch, potato tubers contain proteins, vitamins, minerals, bioactive compounds, phytochemicals, phenolics, anthocyanins, and carotenoids, all of which contribute positively to human health. Due to its high consumption, potato is also one of the major contributors of total phenolic intake among fruits and vegetables. Furthermore, potatoes are highly efficient in energy production, yielding more calories per unit area (216 MJ ha^{-1} day^{-1}) compared to crops such as maize (159 MJ ha^{-1} day^{-1}) and rice (121 MJ ha^{-1} day^{-1}).

Nutritional profile of the potatoes from different database is provided in table 1. In general, potatoes consist of about 80% water and 20% dry matter, which includes carbohydrates (about 15 g), proteins (about 2 g), and small amounts of other components that vary among cultivars. Potato starch, which accounts for 65–85% of the dry matter, is mainly composed of amylose and amylopectin. Cooked potatoes are generally classified as high glycaemic index foods due to rapid starch digestion. However, raw potatoes contain resistant starch, which is not easily digested and offers several health benefits. Resistant starch has been associated with improved glucose tolerance and insulin sensitivity, reduced cholesterol and triglyceride levels, enhanced satiety, and protection against colon cancer. Although potatoes contain relatively low protein, their protein quality is high, with a biological value of approximately 90–100, comparable to that of whole egg protein. Potato proteins have a well-balanced amino acid profile and are particularly rich in essential amino acids, including lysine, which is often limited in plant-based foods.

From a dietary perspective, 100 g of potato can provide about 4% of daily energy requirements, 6% of carbohydrates, 9% of dietary fibre, 4% of protein, 33% of vitamin C, 15% of vitamin B6, and 12% of potassium. Because potatoes are consumed regularly and in significant quantities, they make a meaningful contribution to daily nutrient intake. Their versatility and wide acceptability further enhance their importance, as they can be consumed in fresh or processed forms in a variety of food preparations.

Table 1. Nutritional profile of potato

Constituents	Constituents/ 100 g tuber fresh weight	Recommended Dietary Allowances (RDA)	% RDA fulfilled by 100 g potato
Carbohydrates (g)	14.89	130	11.5
Protein (g)	1.54	54	2.9
Dietary fibre (g)	1.71	40	4.3
Energy (kcal)	69.7	2710	2.6
Calcium (mg)	9.52	1000	1.0
Iron (mg)	0.57	19	3.0
Zinc (mg)	0.28	17	1.6
Sodium (mg)	4.11	2000	0.2
Potassium (mg)	541	3500	15.5
Phosphorus (mg)	43.42	1000	4.3
Vitamin C (mg)	23.15	80	28.9
Thiamin (mg)	0.06	1.8	3.3
Riboflavin (mg)	0.01	2.5	0.4
Niacin (mg)	1.04	18	5.8
Pantothenic acid (mg)	0.38	5	7.6
Vitamin B6 (mg)	0.1	2.4	4.2
Biotin (µg)	1.35	30	4.5
Folate, total (µg)	17	300	5.7

Source: ICMR-NIN Expert Group (2020); Recommended dietary allowances and estimated average requirements for Indians: A short report; National Institute of Nutrition; and USDA Reference Legacy database 170032

Potato: A rich source of health promoting compounds

While often viewed primarily as a staple carbohydrate source, the potato is a complex matrix of bioactive compounds with significant therapeutic potential. Recent nutritional research has shifted focus from the potato's basic macronutrient profile to its diverse array of secondary metabolites. These include glycoalkaloids, polyphenols, anthocyanins, carotenoids, vitamins, and specialized proteins. Collectively, these compounds contribute to various health benefits, including anti-cancer, anti-diabetic, anti-inflammatory, and anti-hyperlipidemic effects, while also supporting gastrointestinal health.

Glycoalkaloids: Natural defense with therapeutic potential: Glycoalkaloids are nitrogen-containing steroid glycosides found naturally in potatoes. The two primary types, alpha-solanine and alpha-chaconine, account for roughly 95% of the total glycoalkaloid content. While these compounds can be toxic at high levels (above 20 mg/100g of fresh weight), they offer remarkable health benefits when consumed within safe limits.

Anticancer and anti-inflammatory properties: Research indicates that alpha-solanine can trigger programmed cell death (apoptosis) in human liver and colon cancer cells. Specifically, at a concentration of 30 µM, it has been shown to reduce the formation of cancer colonies without damaging healthy cells. In animal studies, low doses (5 mg/kg body weight) have led to a visible reduction in the size and incidence of breast and prostate tumors.

Alpha-chaconine is noted for its ability to inhibit the spread (metastasis) of cancer. It achieves this by suppressing specific signalling pathways (PI3K/Akt/NF-κB) and reducing proteins responsible for cancer cell invasion. Beyond oncology, these glycoalkaloids act as anti-inflammatory agents by reducing the production of pro-inflammatory cytokines in the body's immune cells.

Antioxidant compounds: Phenolics and pigments: Potatoes are a rich source of antioxidants, including phenolic acids, carotenoids, and Vitamin C. The most prominent polyphenol in potatoes is chlorogenic acid, which is highly effective at preventing the proliferation of colon and prostate cancer cells. The variety of the potato significantly influences its antioxidant capacity. Purple and red varieties are particularly dense in anthocyanins. Extracts from these colored potatoes have demonstrated the ability to suppress the growth of stomach cancer cells, eliminate cancer stem cells in the colon and improve metabolic markers in diabetic subjects by lowering blood glucose and increasing glucose tolerance. Furthermore, human studies show that consuming approximately 150g of purple potatoes daily for six weeks can significantly lower C-reactive protein levels, which is a key marker of systemic inflammation.

Dietary fiber and resistant starch: The dietary fiber and resistant starch found in potatoes play a vital role in weight management and digestive health. The amount of resistant starch is largely determined by the amylose content of the potato variety.

Gut health and prebiotic effects: ***Bacterial modulation***: In both human and animal studies, potato-derived resistant starch has been shown to increase populations of *Bifidobacteria* and *Lactobacilli*. Simultaneously, it reduces harmful bacteria like *Clostridium*, which are often associated with gut dysbiosis and disease.

- *Short-Chain Fatty Acids (SCFAs):* As bacteria ferment potato fiber, they produce butyrate. Butyric acid is the preferred energy source for the cells lining the colon. It strengthens the gut barrier, reducing 'leaky gut' symptoms, and has been shown to accumulate inside cancer cells, leading to their destruction by suppressing histone deacetylase.

Proteins and bioactive peptides: Potato proteins are more than just a source of amino acids; they contain bioactive peptides that target metabolic and cardiovascular health.

- *Metabolic and Cholesterol Management:* Potato protein hydrolysates (proteins broken down by enzymes) have shown the ability to protect against complications of diabetes by supporting muscle synthesis even under high-glucose conditions. Additionally, they exhibit antihyperlipidemic effects by reducing total serum cholesterol and increasing the excretion of bile acids. Studies on rats fed with cooked, unpeeled potatoes showed significant decreases in liver and plasma cholesterol.
- *Satiety and Weight Control:* Potatoes contain specific 'trypsin inhibitors' that stimulate the release of cholecystokinin (CCK), a hormone responsible for signalling fullness to the brain. This explains why individuals often report feeling more satisfied and fuller after a meal containing potatoes compared to meals containing rice or pasta.

Enzyme inhibitors and blood sugar regulation: Potatoes contain natural inhibitors of enzymes like α-amylase and α-glucosidase. These enzymes are responsible for breaking down starches into sugars. By slowing this process, potato extracts help prevent sharp spikes in blood sugar after meals. Red and purple varieties are especially effective, with inhibitory properties that can reduce blood glucose levels by 18% to 30%.

Other specialized compounds: Beyond the well-known vitamins and minerals, potatoes contain 'niche' compounds with specific medical applications.

- ***Biguanides*:** These compounds, found in higher concentrations in the potato peel, are natural analogues to modern diabetes medications. They help lower glucose production in the liver.
- ***Kukoamines*:** Originally discovered in expensive wolfberries (Goji berries), kukoamines have also been identified in potatoes. These molecules are known for their ability to naturally lower blood pressure, making the potato a potential dietary ally for hypertensive patients.
- ***Insulin-like antigens*:** Found especially in sprouted potatoes, these antigens provide a fascinating area for future research into how plant-based molecules can mimic human hormones to regulate metabolism.

The 'healthfulness' of a potato is not a fixed value; it is highly dependent on how the tuber is handled from farm to fork. Consumers looking for maximum antioxidant density should prioritize purple, red, or deep-yellow varieties. These contain significantly higher levels of anthocyanins

and carotenoids than standard white or russet potatoes. Furthermore, how a potato is prepared matters. Boiling can result in the loss of water-soluble vitamins, whereas baking or steaming preserves more of the bioactive profile. Interestingly, processing methods like spray-drying potato juice can actually concentrate its cytotoxic (cancer-killing) properties against intestinal cancer cells. Then the storage also affects the chemical composition of a potato. Proper storage can actually lead to an increase in certain phenolic compounds, though excessive light should be avoided to prevent glycoalkaloids from reaching toxic levels.

Safety considerations and balanced consumption: It is important to address the 'anti-nutrients' in potatoes. Glycoalkaloids, lectins, and proteinase inhibitors are often labelled as 'bad' because they are the plant's defence system. However, as the evidence shows, in controlled amounts, these are the very compounds that provide anticancer and satiety benefits. The key is moderation and proper preparation–removing green skin and sprouts ensures that glycoalkaloids remain in the therapeutic range rather than the toxic range.

Efforts towards further enriching potatoes nutritionally

The development of bio-fortified crop varieties is a critical strategy for addressing nutritional deficiencies in the human diet. The ICAR-Central Potato Research Institute (CPRI) in Shimla has successfully developed several potato cultivars that are enriched with essential minerals, antioxidants, and vitamins. These varieties, including *Kufri Manik*, *Kufri Neelkanth*, and *Kufri Jamunia*, offer significantly higher nutritional value compared to standard white-coloured potato varieties.

Kufri Manik: Mineral and anthocyanin enrichment: *Kufri Manik* is a specialized variety recognized for its high mineral content and deep pigmentation (Fig. 1a). This variety was formally notified in the Gazette on April 1, 2021.

- *Nutritional Profile*: This variety contains 33 ppm of Zinc and 30 ppm of Iron. In contrast, standard white potatoes typically contain only 0.5–4.6 ppm of Zinc and 3–23 ppm of Iron.
- *Antioxidants*: It is also rich in anthocyanin, providing 68 mg/100g, while standard varieties often contain only 0–5 mg/100g.
- *Yield and Maturity*: The variety produces an average yield of 23–25 t/ha and reaches maturity within 75–90 days.
- *Adaptation*: It is specifically suited for the Eastern plains, including regions such as Bihar, Orissa, West Bengal, Assam, and Eastern Uttar Pradesh.

Kufri Neelkanth: High antioxidants and carotenoids: *Kufri Neelkanth* is designed for the North Indian plains and is notable for its high concentration of beneficial plant pigments (Fig. 1b). This variety was notified in the Gazette on February 5, 2019.

- Nutritional Profile: This variety is rich in antioxidants, specifically containing 11 mg/100g of anthocyanin and 292 µg/100g (fresh weight) of carotenoids. Whereas normal white potatoes have significantly lower levels, typically ranging from 0–5 mg/100g for anthocyanin and 27–74 µg/100g for carotenoids.
- Yield and Maturity: It offers a high average yield of 36–38 t/ha with a maturity period of 90–100 days.
- Adaptation: The variety is well-adapted to Punjab, Haryana, Uttar Pradesh, Uttarakhand (plains), Bihar, Madhya Pradesh, and Chhattisgarh.

Fig. 1: Fresh tubers of: (a) *Kufri Manik*, (b) *Kufri Neelkanth*, (c) *Kufri Jamunia* biofortified varieties of potato developed by ICAR-CPRI, Shimla

c) Kufri Jamunia: Vitamin C and anthocyanin rich specialty table purpose variety

Kufri Jamunia serves the specialty table potato segment and provides a broad range of vitamins and antioxidants (Fig. 1c). Its Gazette notification was issued on November 13, 2024

- Nutritional Profile: It contains 32.36 mg/100g of anthocyanin, 51.52 mg/100g of Vitamin C, and 163.04 µg/100g of carotenoids. Compared to the standard 11–30 mg/100g of Vitamin C found in white potatoes, *Kufri Jamunia* provides a superior source of this essential vitamin.
- Yield and Maturity: It yields approximately 32–35 t/ha and matures in 90–100 days.
- Adaptation: This variety has broad adaptation across the Northern, Central, and Eastern plains, covering states like Gujarat, Rajasthan, and West Bengal.

The bio-fortified varieties developed by ICAR-CPRI represent a significant advancement in agricultural

Table 2: Potato based value added products

Category	Products	Suitable type potatoes	Speciality
	Potato cheeselings	All types, normal sugar	Gluten-free, high fiber
	Potato Murukku	All types, normal sugar	Gluten-free, high fiber
	Potato boondi	All types, normal sugar	Gluten-free, high fiber
	Potato jalebi	All types, normal sugar	Ready-to-reconstitute, gluten-free, high fiber, fasting friendly
Baked	Potato-Fruit-butter cookies	All types, normal sugar	Gluten-free, high fiber, fasting friendly, low sodium
	Potato-Kodo millet cookies	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-Finger millet cookies	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-Sorghum cookies	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-Pearl millet cookies	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-Chickpea cookies	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-Barnyard cookies	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-coconut cookies	All types, normal sugar	Gluten-free, high fiber, low sodium, fasting friendly
	Potato-tapioca cookies	All types, normal sugar	Gluten-free, high fiber, low sodium, fasting friendly
	Potato-water chest nut cookies	All types, normal sugar	Gluten-free, high fiber, low sodium, fasting friendly
	Potato-finger millet dry cake	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato-corn dry cake	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato muffins	All types, normal sugar	Gluten-free, high fiber, low sodium
	Potato pastry	All types, normal sugar	Gluten-free, high fiber, low sodium
Dehydrated	Potato porridge	All types, normal sugar	Gluten-free, high fiber, fasting friendly
	Potato semolina	All types, normal sugar	Gluten-free, high fiber, fasting friendly
	Potato cubes	High dry matter, low sugar	Ready-to-reconstitute
	Potato shreds	High dry matter, low sugar	Ready-to-reconstitute
	Potato chips	High dry matter, low sugar	Gluten-free, high fiber, fasting friendly
	Potato sticks	High dry matter, low sugar	Gluten-free, high fiber, fasting friendly
	Potato flour	All types, normal sugar	Gluten-free, high fiber, fasting friendly
Premix	Gulab jamun premix	All types, normal sugar	Gluten-free, high fiber, fasting friendly
	Jalebi premix	All types, normal sugar	Gluten-free, high fiber, fasting friendly
	Halwa premix	All types with high sugar	Gluten-free, instant, high fiber, fasting friendly
	Idli premix	All types, normal sugar	Gluten-free, high fiber, fasting friendly
Sweets	Potato preserve	Low dry matter, high sugar, undersize, oversize	Fasting friendly
	Potato burfi	All types, high sugar	Lactose free, high fiber, fasting friendly
	Frozen gulab jamun	All types, high sugar	Gluten-free, high fiber, fasting friendly
	Potato ice-cream	All types, high sugar, coloured	Gluten-free, high fiber, fasting friendly, anthocyanin rich

Normal sugar -<300 mg/100g Fresh Weight (FW), Low sugar <150 mg/100g FW, High sugar->300 mg/100g FW ; High dry matter≥ 20%, Low dry matter ≤17 %

Fig. 2: Innovative value-added products developed by ICAR-CPRI

nutrition. By providing higher levels of Zinc, Iron, Vitamin C, and antioxidants, these potatoes serve as more than a basic starch source; they are a functional food capable of improving public health across various regions of India.

Innovative value-added potato-based products

With advancements in technology and increasing market demand, the sector of potato processing is experiencing substantial growth. As per prevailing culinary preferences and dietary habits of the Indian populace, the ICAR-Central Potato Research Institute has innovatively developed a variety of novel value-added potato products tailored to meet the needs of a broader segment of the Indian population. A variety of innovative potato-based products including potato cookies, millet potato cookies, halwa premix, semolina, porridge, gulab jamun, jalebi, muffins, and numerous others (Table-2, Fig. 2) has been created with consideration of the dietary inclinations of the Indian populace. All of which are enriched with dietary fibre, protein, vitamin C, and potassium. The low sodium concentration and gluten-free nature of these products render them appropriate for individuals with celiac disease, wheat allergies, and hypertension. A particularly significant characteristic of these products is their versatility, as they can be produced from potatoes of diverse shapes, sizes, colors, and dry matter content, even post-storage. This adaptability not only enhances the culinary experience but also ensures minimal waste, allowing for a wider range of dishes that cater to both traditional and contemporary tastes.

SUMMARY

From a humble tuber grown to fill stomachs, potato is steadily transforming into a 'smart food' that can nourish, protect and empower people across all age groups. It not only delivers quick energy, but also offers good quality protein, fibre, vitamins, minerals and a rich mix of protective plant compounds that support heart health, blood sugar control, healthy cholesterol levels and a strong gut. Coloured and bio-fortified varieties such as *Kufri Manik, Kufri Neelkanth* and *Kufri Jamunia* add a new chapter to this story by providing extra iron, zinc, vitamin C and antioxidants, turning an everyday vegetable into a powerful tool against hidden hunger and lifestyle diseases. At the same time, long-standing doubts about antinutritional factors are being addressed through better varieties, proper storage and simple kitchen practices, so that consumers can confidently enjoy potatoes in safe and wholesome forms. Parallel to this nutritional progress, potato-based value-added products–ranging from gluten-free cookies and premixes to dehydrated snacks and traditional sweets are opening new avenues for farmers, women entrepreneurs, food processors and health-conscious consumers alike. Looking ahead, the real opportunity lies in bringing these scientific gains from lab and field to the common plate: promoting bio-fortified and coloured potatoes, refining processing methods that retain sensitive nutrients, and spreading clear, practical messages on how to select, cook and store potatoes for maximum benefit. If integrated thoughtfully into nutrition programmes, school meals and public health campaigns, potatoes can help tackle undernutrition and non-communicable diseases in an affordable and culturally acceptable way. With continued research on genetics and processing, active participation of farmers and industry, and growing public awareness of 'food as medicine,' the potato is well placed to move beyond its image as mere starch and claim its role as one of nature's most effective, farmer-friendly health foods.

For futher correspondence, contact:
[1]ICAR-Central Potato Research Institute, Regional station, Jalandhar 144 003, Punjab, India; [2]Dr. Brajesh Singh, Director, ICAR-Central Potato Research Institute, Shimla 171 001, Himachal Pradesh, India. Email: brajesh.singh@icar.org.in; birju16@gmail.com