PLANT SCIENCE TODAY
Vol 13(1): 1-13
https://doi.org/10.14719/pst.9072

eISSN 2348-1900

REVIEW ARTICLE

Biochemical constituents and health-promoting properties of garden pea (*Pisum sativum* L.) - A review

D K Upadhyay[1]*, Ajay Tripathi[2], Kuldeep Pandey[3], Priti Upadhyay[4], Aastik Jha[1], C N Ram[1], Ashish Kumar Singh[1], Anil Kumar[1], Sanjeev Singh[1], M K Maurya[1] & P K Dalal[1]

[1]Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya 224 229,Uttar Pradesh, India
[2]Department of Agriculture Biochemistry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya 224 229, Uttar Pradesh, India
[3]Department of Fruit Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya 224 229, Uttar Pradesh, India
[4]Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, New Delhi, India

*Correspondence email - dhananjay.gpb2011@gmail.com

Received: 24 April 2025; Accepted: 16 October 2025; Available online: Version 1.0: 06 January 2026; Version 2.0: 19 January 2026

Cite this article: Upadhyay DK, Ajay T, Kuldeep P, Priti U, Aastik J, Ram CN, Ashish KS, Anil K, Sanjeev S, Maurya MK, Dalal PK. Biochemical constituents and health-promoting properties of garden pea (*Pisum sativum* L.) - A review. Plant Science Today. 2026; 13(1): 1-13. https://doi.org/10.14719/pst.9072

Abstract

Pulses, including peas, have long been essential to the human diet due to their high carbohydrate, protein and other nutrient content. Recently, there has been a lot of interest in pulse consumption's health benefits beyond nutrition. The systematic review focuses on the established and potential health benefits of eating peas, *Pisum sativum* L. and specifically green and yellow cotyledon dry peas, often known as smooth peas or field peas. Thus, the review regarding biochemical composition, nutritional aspects and health advantages of pea will be beneficial for new researchers. The outer pod comprises around 35-40 % of the pea's weight. Globally, considerable amounts of pea residue are generated, the vast majority of which is used as animal feed. Pea pods not only offer an appropriate quality of dietary fibre, but also supply a significant amount of proteins, carbohydrates and minerals. The pea pods contain significant amounts of polyphenols, including phenolic acids such as 5-caffeoylquinic acid and flavanols such as catechin and epicatechin. Pea pods provide pharmacological advantages, including antidiabetic, hepatoprotective, Reno protective, reproductive-protective, antimicrobial and α-amylase inhibitory action. The trend towards a healthier lifestyle has raised concerns about a fibre-rich diet. The review concludes that pea pods have the potential for usage in the bakery and ready-to-eat product industries. When pea pod powder is added to food products, it has been shown to improve nutritional value and structural integrity. Additionally, suggestions for improving pea use aregiven in order to support the grain's growth into a useful and sustainable crop. Peas and their constituent parts can be improved further toprovide more value and nourishing food materials. This study summarises the relevant literature and available data on the nutritional profile, pharmacological advantages and application in functional meals. Pea pods' prospective applications outside of the food industry have also been detailed. Despite extensive studies on the nutritional profile of garden peas, comprehensive evaluations linking specific biochemical constituents to their health-promoting effects remain limited. Further research is needed to identify bioactive compounds and elucidate their mechanisms for functional food and nutraceutical applications.

Keywords: dietary fibre; human health; nutritional composition; peas; *Pisum sativum* L.; protein

Introduction

The FAO defines pulses as legumes harvested only for seed, which is consumed directly. The FAO list contains eleven basic pulses, including peas, but excludes oilseed legumes and immature vegetables. In terms of production, India is the second-largest producer of green peas after China and ranks tenth among vegetable crops. The global yearly output of green and dry pea seeds is roughly 14.5 Mt and 22 Mt, respectively (1-3). Peas have long been known as a low-cost, easily accessible source of protein, complex carbs, vitamins and minerals. Peas are an important food product due to their high nutrient density, which can cover the dietary needs of an estimated 1000 million undernourished people worldwide. Only 7.9 % of adults in the US ingest the required amount of dried beans or peas daily. Many studies have found that pulses, particularly peas, can provide health advantages in addition to meeting basic dietary requirements. Bioactive components and nutrients in peas are directly linked to their biological activity and health advantages (4).

Peas are considered to be medium to low glycemic index foods because their glycemic index ranges from 55 to 60. Garden pea (*Pisum sativum* L.) is a widely consumed legume known for its rich nutritional and bioactive profile. While several studies have reported its protein, carbohydrate, vitamin, mineral and polyphenol contents, there is a lack of integrated information linking these biochemical constituents to specific health benefits such as antioxidant, anti-diabetic and cardio-protective effects. A comprehensive review is therefore needed to synthesise current knowledge on its bioactive compounds and health-promoting properties, identify research gaps and provide guidance for future studies and the development of functional foods and nutraceuticals. The objective of this paper is to give a complete assessment of the proven and potential health advantages of eating. The nutrient composition and phytochemical elements of peas are explained in order to contextualise the putative pathways for pea consumption's health advantages.

Biochemical components and their importance in garden pea

Protein

Peas are a good source of protein and are employed as functional ingredients in various food sectors. A kind of field pea includes 14.5-28.5 % protein; most varieties fall within the range ranging up to 24.4-27.4 % (5-8). Pea protein is described as a non -allergic food ingredient with astonishing nutritional value which do not require changes in its genetic composition (9). Primarily, Pea protein is divided into four categories: globulin, albumin, prolamin and glutelin. Globulin and albumin are the key storage proteins, accounting for 55-65 % and 18-25 % respectively and play a role in seed germination (Table 1). Globulin has been divided into two types: legumin (hexameric protein, 320-400 kDa) and vicilin (trimeric protein, 150-180 kDa). Prolamin and glutelin are found in minor quantities (Table 1), around 3-5 % each (10). The crude protein of pea contains 10-15 % non-protein nitrogen-containing compounds and the rest are hormones, enzymes, enzyme inhibitors, storage proteins and a few non-storage proteins which account for 70-80 % of crude protein. The solubility and modification of pea protein have been described utilising industrial-scale microfluidization, which will encourage the food industry to employ pea protein without introducing exogenous substances (11).

Carbohydrates

Unlike tuber starch or cereals, pea carbohydrate is uniquely stable to high range viscosity and temperature (12). Pea carbohydrates contain glucose, galactose and arabinose, with stachyose and tetra saccharides being the most prevalent polysaccharides. Polysaccharide extraction from peapods has also been shown to contain galactose, xylose and arabinose as monosaccharides (13). Glucose is produced from starch polymers like amylose and amylopectin, which are chains of glucose units linked by α-1,4 and α-1,6 bonds. Through enzymatic hydrolysis (using amylases and glucoamylases) or acid hydrolysis, these polymers are broken down into simpler sugars and finally into glucose. This process is essential for producing sweeteners, bioethanol and other industrial products. Cellulose accounts for the majority of carbohydrates, whereas additional pectic polysaccharide derivatives include rhamnose, arabinose, galactose and uronic acids. Peas contain 3.73 % total oligosaccharides in total solids (14).

Table 1. Nutritional composition of pea (44)

Nutritional components	Composition (%)	References
Total carbohydrate	17-22	(17, 28, 35, 36)
Starch (g/100g)	20-50	
Dietary fibre (g/100 g)		
Total dietary fibre	14-26	(25, 37, 38, 39, 40)
Insoluble fibre	10-15	
Soluble fibre	2-9	
Protein (%)	20.5-22.6	
Globulin (%)	55-65	
Albumin (%)	18-25	(6, 10, 12, 20, 41)
Prolamin (%)	4-5	
Glutelin (%)	3-4	
Crude Fat (%)	2-3	
Ash (%)	3.2 ± 0.004	(28, 42)
Lipid (%)	1.75 ± 0.001	
Fibre (%)	2.5 ± 0.003	
Minerals (mg/100g)		
Potassium	98 ± 0.021	
Calcium	9.5 ± 0.033	(6, 28, 43)
Sodium	3.5 ± 0.001	
Magnesium	5.5 ± 0.005	
Vitamins (mg/kg)		
Thiamine (B_1)	5.3 ± 0.8	(26)
Riboflavin (B_2)	0.7 ± 0.1	
Folate (B_9)	0.54 ± 0.16	

Starch is classified into three types based on the digestion and absorption of glucose into the gastrointestinal systemnamely quickly digestible (RDS), slow digestible (SDS) and resistant starch (RS) (15, 16). After ingestion, there is a fast increase in blood glucose levels due to the presence of the RDS fraction, which ranges from 9.2 % to 10.7 % and the SDS fraction, which ranges from 23.3 % to 26.5 % and is digested completely but slowly in the small intestine. RS portion changes phase by fermenting in the large intestine, while 10.1 % to 14.7 % is not digested in the small intestine (4, 16). The percentages of starch digested in the small intestine result in a low glycemic index, which directly influences the metabolic rate of digestion (17). Starch is likewise made up of a linear glucan chain of amylose and a highly branched molecular chain of amylopectin. The ratio of the two determines digestion and postprandial glucose response. Pea contains 38.2 % ± 0.2 % apparent amylase (18), resulting in limited digestibility and minimal glucose release, leading to a low glycemic index.

A spontaneous mutation in pea seeds enhances starch synthesis and glucose regulation (19). Pea contains α-galactosides, an oligosaccharide that may be difficult to digest in the gastrointestinal tract. The high fermentability of these oligosaccharides produces gas, which causes stomach pain. These non-digestible oligosaccharide dietary components have the potential to be identified as prebiotic agents with beneficial effects on consumer health. The amount of essential amino acids and their bioavailability define the nutritional profile of protein processed by the organism. Pea seeds contain threonine, cysteine, methionine, lysine, glycine, alanine, leucine and phenylalanine amino acids (20). The protein content of pea seeds is high in lysine, leucine and phenylalanine, but low in sulfur-containing amino acids such as methionine and cysteine (10, 21). Protein content is positively correlated with total α-galactosidase, verbascose, arginine, glutamic and carotenoid pigment levels (8). One of the proteins found in legumes, known as lectins or phytohemagglutinins, can agglutinate the red blood cells found in peas (20). A recent study found that pea protein hydrolysates can suppress nitric oxide, a metabolic by-product that can cause severe cell damage (10). Pasta-like sheets were created utilising protein and dietary fibre fractions from yellow pea (22). Pea protein isolates produced mixed sumiri gels by partially substituting myofibrillar proteins (23). Fermentation with co-cultured LAB and yeast may ameliorate sensory deficiencies in pea protein-based products (24).

Vitamins and minerals

Peas and their peels are high in vitamins and minerals, providing several health benefits (25, 26). Potassium is the most prominent mineral element, accounting for 1.04 % of the dry and dehulled weight of peas, followed by phosphorus, magnesium and calcium at 0.39 %, 0.10 % and 0.08 %, respectively and is particularly high in vitamin B (4, 6). Extractions were used to isolate various vitamins and minerals. The E group of vitamins is made up entirely of β and γ tocopherols (27). Field or garden pea seeds included ranges of potassium (97-99 mg/100g), calcium (9-11 mg/100g), magnesium (5-7 mg/100g), salt (3-4 mg/100g) and trace amounts of copper, nickel, selenium, folate and boron (6, 28). Selenium and folate, for example, could be utilised to prevent deficiency illnesses, making them health-promoting minerals (29).

Low phytate lines have recently been created to minimise phytate concentrations, which aid in mineral absorption (30). Biofortification improves the nutritional profile of pulse crops that lack micro-nutrients, including iron, zinc, folic acid, β-carotene, carotenoids, folates, iodine and more by genetic engineering, agronomic intervention and plant breeding. Thus, peas are high in iron, zinc and manganese and have naturally low phytic groups, making them suitable for biofortification and a potential solution to nutrient-deficiency hunger (30, 31). Pea seeds have been reported to be used as zinc biofortification combined with selenium, which improves bioavailability in food products (26, 32, 33), whereas phosphorus biofortification has been done to increase the soil microbiome in nutrients for higher pea production to combat micronutrient malnutrition (34).

Dietary fibres

Dietary fibres (DF) are nondigestible carbohydrates that inhibit enzymatic digestion (hydrolysis). They are divided into soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) depending on their water solubility (Table 1). IDF consists of lignin, cellulose and certain hemicelluloses, while SDF includes β-glucans, galactomannans, pectin, inulin and other non-starch polysaccharides (6, 13, 39). Soluble fibre has good prebiotic and enhancer qualities that have the potential to reduce glucose absorption in the small intestine and cholesterol levels, but insoluble fibre increases faecal volume, water absorption and intestinal control. Physiologically, water absorption is more significant in the body because it improves laxative effects and peristalsis. Insoluble fibre is primarily produced from grains, whereas soluble fibre can be found in fruits and vegetables that have been dissolved in water and fermented in the colon (45, 46).

Colonic bacteria fully break down pectin, a plentiful partly methylated polysaccharide that is soluble in water. Due to its gelling quality, pectin may slow down the emptying of the stomach by affecting the small intestine's transit times, indicating its hypoglycemic characteristics (47, 48). Pea contains 1.2-1.7 % pectin, 2.4 % cellulose, 1.0 % hemicellulose and 2.5 % lignin (49). The dietary fibre in peapods is extracted using the Association of Official Analytical Chemists (AOAC) enzymatic-gravimetric hydrolysis techniques. The latter are plentiful in xylose and glucose, as demonstrated by high-performance liquid chromatography (HPLC) processing of the soluble sugars, which produced glucose as a major component. Pea pods have a ferric reducing antioxidant power of 25.9 μmol Trolox equivalents/g and can scavenge 2,2-diphenyl-1-picrylhydrazyl radical at a rate of 16.0 mg/mL (42).

Functional foods provide significant economic and health benefits. Dietary fibres have an exceptional ability to thrive in the fibre-rich market. To meet this demand, numerous sources have been found and efforts to extract it from fruits, vegetables and wastes are currently underway. There have been several research methods utilised in the past, such as dry processing, alkali wet milling, conventional wet milling, enzymatic-gravimetric, non-enzymatic gravimetric, microbial and chemical treatments, but there is no standardised protocol for fibre extraction (39). The most common procedures for TDF, SDF and IDF are the enzymatic-gravimetric approach and the ultrasound-assisted alkali extraction method (50). Other methods for extracting soluble dietary fibre include acidic extraction and cellulose-assisted alkaline extraction, which is further improved using the Response Surface Methodology (RSM) (51).

Polyphenols

Total phenolic content: Phenolics are considered one of the most essential bioactive components in peas. Peas contain both free and bound polyphenols. A recent study found that the concentration of free phenolics (90.4-112 mg GAE/100 g DW) in three pea genotypes was higher than that of bound phenolics (58.5-83.9 mg GAE/100 g DW) (52). Furthermore, the total polyphenols of 22 different pea genotypes, including maturities, flower colours, seed coat colours and seed morphologies, were comprehensively studied. The total phenolic content (TPC) of peas varied across 22 genotypes, ranging from 12.6 to 128.6 mg GAE/100 g FW and was found to be substantially linked with seed coat colour and shape (53). The genotypes with greenish orange seed coats had the highest TPC (128.6 mg GAE/100 g FW) of all genotypes. However, genotypes with dimpled and round seed coats had significantly higher TPC (≥24.0 mg GAE/100 g FW) than those with wrinkled seed coats (53). Furthermore, dark-colored seeds had higher TPC than light-colored seeds (54). Furthermore, the coloured hulls of pea seeds contained phenolic chemicals (55). *In vitro* digestion revealed that the red hulls of peas generated more TPC (31.54 ± 0.69 mg GAE/g DW) than the yellow hulls (14.88 ± 0.27 mg GAE/g DW). Furthermore, TPC in pea sprouts increased from 584.32 to 910.69 mg GAE/100 g DW after seven days of germination, indicating that germination can increase polyphenol content in peas (56).

Flavonoids: Various flavonoids, including flavonols, flavones, isoflavones, flavanones, flavanols/flavan-3-ols and anthocyanins (Table 2), have been determined in different parts of peas using multiple techniques, such as liquid chromatography (LC), LC coupled with mass spectrometry (LC-MS), LC coupled with electrospray ionization-tandem mass spectrometry (LC-ESI-MS/MS) and ultra-HPLC coupled with quadrupole orbitrap high-resolution mass spectrometers (UHPLC-Q the total flavonoid concentration (TFC) in peas ranged from 4.61 to 45.84 mg CE/100 g FW, with a nearly tenfold variance (53). Furthermore, soluble flavonoids (52.2-60.3 mg CE/100 g DW) are more abundant than bound flavonoids (8.42-20.3 mg CE/100 g DW) in pea seeds (52). Interestingly, TFC levels in pea seeds were found to be substantially linked with seed coat colour and shape (53). The genotypes with dimpled and spherical seed coats had a higher TFC (≥9 mg CE/100 g FW), while those with greenish-orange seed coats had the highest TFC among all evaluated genotypes (53). Pea seeds with darker colours were found to have more TFC than pea seeds with lighter colours (54). Furthermore, the

Table 2. Bioactive compounds isolated from different pea raw materials and derived products, together with their identification methodology (67)

Family	Compounds	Plant parts	Methods	References
Flavonols	Isorhamnetin 3-rutinoside, isorhamnetin glycoside, quercetin, quercetin 3-galattoside, rutin, quercetin triglucoside, quercetin diglucoside, kaempferol triglucoside, quercetin caffeoyl triglucoside, quercetin coumaroyl triglucoside, quercetin sinapoy ltriglucoside, quercetin feruloyl triglucoside, isorhamnetin glycoside, kaempferol glucoside, kaempferol coumaroyl, kaempferol, dihydromyricetin, kaempferol 3-O-rutinoside-40-glucoside ($C_{33}H_{40}O_{20}$), dihydroquercetin, myricetin 3-O-rhamnoside, kaempferol 3-O-glucoside, kaempferolhexoside, kaempferol-7-O-glucoside, kaempferol-7-O-rutinoside, kaempferol-3-O-rhamnoside, kaempferol dihexoside, isorhamnetin, dihydrokaempferol, kaempferol 3-O-glucopyranoside, fisetin, kaempferol 3-O-neohesperidoside, kaempferol 3-O-sophorotrioside, kaempferol 3-O-(6'''-O-trans-p-coumaroyl)-sophorotrioside, galangin, morin, quercetin 3-O-D-glucopyranoside, quercetin 3-O-sophorotrioside, quercetin, 3-O-(6'''-O-trans-p-coumaroyl)-sophorotrioside, quercetin, 3-O-(6'''-O-trans-caffeoyl)-sophorotrioside, quercetin, 3-O-(6'''-O-trans-feruloyl)-sophorotrioside, quercetin, 3-O-(6'''-O-trans-sinapoyl)-sophorotrioside, quercetin, 3-O-(6'''-O-(4-hydroxy)-trans-cinnamoyl) sophorotrioside, Pisumflflavonoside II [quercetin 3-O-(6'''-O-trans-p-coumaroyl)-sophorotrio-side 7-O-D-glucopyranoside], Pisumflflavonoside II [quercetin 3-O-(6'''-O-trans-p-coumaroyl)-sophorotrioside 7-O-D-glucopyranoside]	Seed, seed coat, pod, sprout, leaf	LC-MS, LC-ESI-MS, LC-ESI-MS/MS, UHPLC-MS, UHPLC-LTQ-MS, UHPLC-Q-HRMS	(28, 57-66)
Flavones	Phloretin, apigenin, luteolin-7-O-glucoside, eriodictyolglycoside, apigenin-7-O-glucoside, luteolin, luteolin, 80-O-glucoside, vitexin, luteolin 30,7-di-O-glucoside, apigenin-6.8-di-C-glucoside, luteolin-80-C-glucoside, tricin	Seed, seed coat, pod	LC-MS, LC-ESI-MS, LC-ESI-MS/MS, UHPLC-MS	(28, 57-59, 61, 62, 64)
Flavanols	Catechin, (epi) catechin, gallocatechin, (epi) gallocatechin, fisetin, catechin gallate	Seed, seed coat, pod, sprout	LC-MS, LC-ESI-MS/MS, UHPLC-MS, UHPLC-LTQ-MS, UHPLC-Q-HRMS	(28, 57, 58, 60, 62-65)
Flavanones	Eriodictyol, naringenin, naringin, hesperidin, melitidin, pinocembrin, liquiritigenin, hesperetin	Seed, seed coat, pod, sprout	LC-MS, LC-ESI-MS, UHPLC-MS, UHPLC-Q-HRMS, UHPLC-LTQ-MS	(57, 59, 61-65)
Isoflavones	Genistein, daidzein, cirsiliol, prunetin, afrormosina, formononetin, isoformononetin, pseudobaptigenina, sayanedin,	Seed, seed coat, pod, sprout	LC-ESI-MS, UHPLC-MS, UHPLC-LTQ-MS	(57, 58, 61, 62, 65)
Anthocyanins	Cyanidin 3-sambubioside-5-glucoside, cyanidin3-sophoroside-5-glucoside, delphinidin, 3-sambubioside-5-glucoside, delphinidin, 3-sophoroside-5-glucoside, delphinidin 3-O-(2-O-β-D-xylopyranosyl-β-D-galactopyranoside)-5-O-dglucopyranoside ($C_{32}H_{39}O^{+}_{24}$), Delphinidin 3-O-(2-O-β-D-xylopyranosyl-D-galactopyranoside)-5-O-(6-O-acetyl)-β-D-glucopyranoside, pelargonadin 3-glucoside, cyanidin 3,5-di-O-glucoside, malvidine-3-O-glucoside,	Seed, seed coat, pod	LC-MS, UHPLC-MS	(57, 62, 64)
Phenolic acids	Gallic acid, vanillin, syringic acid, quinic acid, protocatechuic acid, chlorogenic acid, 4-o-caffeoylquinic acid, p-coumaric acid,trans-ferulic acid, trans-cinnamic acid, p-hydroxybenzoic acid, dicaffeoylquinic acid, caffeic acid, 3,4-dihydroxybenzoic acid, 4-hydroxybenzoic acid, vanillin acid, ferulic acid, coumaroylquinic acid, 5-feruloylquinic acid, vanillic acid-4-β-D-glucoside, cinnamic acid, o-coumaric acid, 2,3-dihydroxybenzoic acid, 3,4-dihydroxybenzoic acid, ferulic acid, gentisic acid, m-hydroxybenzoic acid, p-hydroxybenzoic acid, 4-hydroxy-3-methoxybenzoicacid, p-hydroxyphenylacetic acid, rosmarinic acid, salicylic acid, sinapic acid, tannic acid, veratric acid	Seed, seed coat, pod, sprout	LC-MS, LC-ESI-MS/MS, LC-ESI-MS, UHPLC-MS, UHPLC-LTQ-MS	(28, 56, 57, 61-64, 66)

ESI: electrospray ionization; HRMS: high-resolution mass spectrometry; LC: liquid chromatography; LTQ: linearion-trap quadrupole; MS: mass spectrometry; MS/MS: tandem mass spectrometry; Q: quadrupole; UHPLC: ultrahigh-performance liquid chromatography.

germination treatment increased the TFC in pea sprouts from 4.53 to 6.02 mg CE/100 g DW (56). Glycosylated flavonols are the primary phenolic chemicals in peas (57). Many new flavonoid compounds have also been identified in different parts of peas in recent years (Table 2). For instance, several new flavonols, such as quercetin 3-galattoside, quercetin diglucoside, quercetin triglucoside, quercetin caffeoyl triglucoside, quercetin coumaroyl triglucoside, quercetin sinapoyltriglucoside, quercetin feruloyl triglucoside, dihydrokaempferol, kaempferol-3-O-rhamnoside, kaempferol-7-O-glucoside, kaempferol-7-O-rutinoside, kaempferol triglucoside, kaempferol hexoside, kaempferol dihexoside, kaempferol coumaroyl, myricetin 3-O-rhamnoside, dihydromyricetin and isorhamnetin 3-rutinoside, have been discovered in pea seeds, seed coats, pods, sprouts and leaves by several different techniques, such as LC-MS, UHPLC-MS, UHPLC-Q-HRMS and UHPLC-linear ion-trap quadrupole (LTQ)-OrbiTrap-MS analysis (UPLC-LTQ-MS) (58-60). Several novel flavones have also been identified in pea seeds and seed coats, including apigenin-7-O-glucoside, luteolin 80-O-glucoside, luteolin 30,7-di-O-glucoside and luteolin-80-C-glucoside (61-63). Pea seeds and seed coats include three novel flavanones: naringin, melitidin and eriodictyol (60-62). Flavan-3-ols (e.g., epigallocatechin and gallocatechin) and flavonols (e.g., myricetin-3-O-rhamnoside and quercetin-3-O-rhamnoside) were found in significantly higher concentrations (1300-6100 times) in seed coats of the purple flower pea line than in the white flower pea line (63). Some isoflavones, including genistein, myricetin, prunetin, isoformononetin and daidzein, have also been identified from pea pods, seeds and seed coats (57, 58, 63). Furthermore, three novel anthocyanins, pelargonadin 3-glucoside, cyanidin 3,5-di-O-glucoside and malvidine-3-O-glucoside, have been discovered in pea seeds and pods (28, 63). However, further precise structural information on numerous glycosylated flavonols is needed.

Phenolic acids: Phenolic acids are the second largest type of polyphenols in peas, behind flavonoids (57). The coloured pea seed coats had a higher phenolic acid content (78.53 g/g DW) than the corresponding white pea seed coats (17.17 g/g DW), with the coloured seed coats primarily containing vanillic acid, gentisic acid and protocatechuic acid and the white seed coats primarily containing ferulic acid and coumaric acid. Various new phenolic acids, such as vanillin acid, quinic acid, coumaroyl quinic acid, 5-feruloylquinic acid, 4-O-caffeoylquinic acid, trans-ferulic acid, trans-cinnamic acid, p-hydroxybenzoic acid and 4-hydroxybenzoic acid, have recently been identified in different parts of peas (28, 61-64), which are listed in Table 2. Syringic acid was discovered to be lacking in all of the seed coats; however, gallic acid and caffeic acid were present in the seed coats of purple flower lines (63). However, another study discovered syringic acid in yellow pea shells (64). The total amount of phenolic acids in the water-based extract of pea pods was 73.15 mg/100 g, with 5-caffeoylquinic acid having the greatest level in the extract, with a mean value of 59.87 mg/100 g (58). Furthermore, the levels of gallic acid, ferulic acid and syringic acid in pea seeds are reported to be significantly high during germination (56). In general, the types and concentrations of phenolic acids in peas varied depending on the plant section, colour and extraction process.

Phytochemicals and antioxidant properties

Antioxidants are bioactive chemicals that limit the damage induced by free radical reactive species (16, 61, 68). Many bioactive compounds, such as phenolics, antioxidants and other phytochemicals, are non-nutritive substances found in pea byproducts, but tannin has been identified as a vital natural antioxidant (Table 3). The metabolism of green pea hull phenolics, their absorption and *in vivo* antioxidant activity were also investigated (69). The concentration of phenolics in pea seed coats varies depending on the variety (57). Catechin, coumaric acids, caffeic acids, vanillic acids, ferulic, pisatin, protocatechuic, proanthocyanidin, steroid phytohormone and tannins are among the many active phytochemicals found in pea-like flavonoids, along with daidzein, genistein, asparaginase, apigenin, lectin, kaempferol and several phenolic compounds (70). Pea genotypes with varying maturity levels and seed coat colour exhibited significant levels of phenolics, total flavonoids and antioxidant activity (53, 54). The presence of techno-functional capabilities and phytochemical compositions in pea protein isolates suggests that they could be used as a value-added ingredient in prepared foods. Pea residues are thought to be a possible source of bioactive compounds that have been proven to improve human health (71). Exploration of pea germplasm with high polyphenol content benefits pea breeding cultivars (64).

Table 3. Phytochemicals and antioxidant content of pea and pea pod (44)

Phytochemical and antioxidant	Pea	Pea pod	References
TPC (mg GAE/g extract)	1.53	32 ± 1	
TFC (mg QE/g extract)	0.08	22 ± 1	
CT (µg CE/g extract)	0.26	48 ± 1	
DPPH (IC_{50} µg/mL)	0.91	1430 ± 10	
ABTS (IC_{50} µg/mL)	-	1700 ± 20	(28, 57, 82)
FRAP (µM TE/mg extract)	1.06	75 ± 5	
Phosphomolybdenum (µgAsA E/g extract)	-	45 ± 4	
Anti-AChE (%)	-	32 ± 1	
Inhibition of protein denaturation (%)	-	88 ± 3	

Antioxidative compounds with an active quenching effect against free radicals or their damage (Table 3) can reduce oxidative injury (72, 73). The antioxidant activities of tannin crude extract from the seed coat of pea were investigated using the phosphatidylcholine (PC) liposome method. The condensed tannins in the coloured seed coat of peas contained 1560 mg of catechin equivalent per 100 g. Legumes also include pro-anthocyanidines, which are condensed tannins found in seed coats (hulls). The sum of free phenolic acids extracted from soluble esters and glycosides of coloured seed coat and white seed coat was 78.53 and 17.17 g/g dry matter, respectively, indicating a significant difference. The white seed coat contained hydroxycinnamic acids, coumaric and ferulic acids, whilst the coloured seed coat contained phenolic acids such as vanillic, benzoic acids, protocatechuic and gentisic acids (74).

The seed coat of peas contains a significant concentration of glycosides, particularly luteolin, quercetin and apigenin, while the cotyledon contains hydroxycinnamic and hydroxybenzoic acids, both of which contain flavonol and flavone glycosides. Cotyledon contains conjugated malic acid molecules such as p-hydroxybenzoyl-malic acid and trans p-coumaroyl-malic acid, whereas the seed coat contains just stilbene trans-resveratrol-3-glucoside. Scientists studied the bioactive chemicals in many types of cool-season legumes, including pea, employing advanced technologies such as UAE (75-77). Phenols are an effective agent for chelating metal catalysts, removing free radicals, initiating antioxidant enzymes and inhibiting oxidases (78). TPC (Total polyphenol content) concentration varies with the colour of the pea; for example, the yellow pea had 0.85 to 1.14 mg of TPC, but the green pea had 0.65 to 0.99 mg. Flavonoids are known to be secondary metabolites of plants; hence, TFC (Total flavonoid content) in yellow pea and green pea were 0.09 to 0.17 mg and 0.05 to 0.15 mg, respectively (Table 3). Simple phenolics condensed to create tannins with varying molecular configurations, which then split into hydrolysable and condensed pro-anthocyanidins (polymers of flavan-3-ols). Yellow and green peas had nearly identical condensed tannin content (CTC) of 0.22 to 0.59 mg and 0.23 to 0.61 mg, respectively (Table 3).

Diphenylpicryhydrazyl (DPPH) free radical scavenging is a reliable approach for screening antioxidants, which are vital in preventing the harmful effects of free radicals involved in a variety of disorders, including cancer. The FRAP (Ferric reducing antioxidant power) analysis is used to determine the antioxidant properties that prevent cell damage induced by free radicals (77). Recent developments in nutrition, due to a rise in phytochemicals, allow for the enhancement of functional or designer foods that would aid in the prevention of a variety of ailments (79). Green pea pod polysaccharide (GPPP) was extracted using an acoustic extraction approach and demonstrated significant scavenging ability (91.03 %) against free radicals as measured by the DPPH assay (80). It has a reducing power of 63 % and a ferric reducing antioxidant power of 0.34 mmol/L, calculated from a total of 0.9 mg/mL. Different processing conditions may reduce the quantity of antioxidants such as trypsin inhibitors, phytic acid and saponins, hence improving the bioavailability of nutrients in peas (81).

Anti-nutritional factor

Anti-nutritional compounds (ANCs) are chemicals that inhibit digestion. ANCs are non-fibrous natural compounds that have a deleterious impact on human and animal health, affecting both growth and metabolic function. ANCs are further divided into two categories: protein-associated ANCs and non-protein-associated ANCs. Non-protein ANCs include alkaloids, phytic acid and phenolic compounds, while protein-associated ANCs include lectins, chymotrypsin inhibitors, trypsin inhibitors, antifungal peptides and ribosome-inactivating proteins. The proper ratio of anti-nutrients to nutrients can mitigate the detrimental effects on digestibility and play an important role in cellular function, including antioxidant and anti-inflammatory actions (6). Mild hydrothermal treatment reduces α-galactosides, trypsin inhibitors and phytic acid levels while improving pea protein digestion and utilisation (83).

Recent research has demonstrated that protein anti-nutritional substances found in pea seeds, such as lectins and protease inhibitors, can help prevent immunological insufficiency by delivering vitamins and minerals. Non-nutritional substances, such as angiotensin I-converting enzyme (ACE) inhibitors, relax the veins and arteries to lower blood pressure. Lectins have the potential to reduce the impact of certain types of malignancies by enhancing innate defence mechanisms and obesity. Trypsin and chymotrypsin, which are protease inhibitors, also demonstrated the highest results in avoiding various malignancies and have powerful anti-inflammatory effects. ACE inhibitors may also help reduce hypertension (84).

Other beneficial components

Peas include several useful chemicals, including β-carotene and zeaxanthin. A comparative investigation indicated that the concentrations of total carotenoids varied substantially in different pea varieties, ranging from 16.72 to 59.39 mg β-carotene/kg DW (85). In addition, the number of carotenoids in green cotyledons of peas was found to be 10-27 μg/g DW, which was slightly greater than that in yellow cotyledons (5-17 g/g DW). The average amounts of lutein, β-carotene, zeaxanthin and violaxanthin in 94 pea accessions were 11.2 μg/g, 0.5 μg/g, 0.3 μg/g and 0.3 μg/g, respectively (86).

Health benefits

Glycemic response, blood glucose and insulin resistance

The glycemic index (GI) is a grading system that compares the carbohydrate content in food models based on blood glucose levels. Carbohydrates with a lower GI rating (55 or less) digest and absorb more slowly. As a result of the slow metabolism, blood glucose absorption increases less, lowering insulin resistance. Pea is ranked lower on the glycemic index table, with a GI value of 22. There is a scientific link between blood sugar, insulin and glycemic index.

The two key enzymes involved in the breakdown of starch and intestinal glucose absorption are α-amylase and α-glucosidase, whose inhibition process has been recorded to slow down the transit period of carbohydrates that flow into the bloodstream (79). The fibre and protein elements of the pea aid in the process of delayed digestion, which reversibly helps to balance blood sugar levels after consumption. Excessive sugar consumption promotes a variety of ailments such as obesity, diabetes and other heart-related diseases and a recent study has linked harmful cholesterol and triglyceride levels. Soluble fibre in the diet decreases LDL cholesterol, generally known as bad cholesterol and keeps blood glucose levels stable (Table 4). It has been found that pea fibre supplementation reduces triglyceride levels in both plasma and liver. Starches in the pea with a low GI may be used as a favourable tool for well-being, particularly for the eradication of disorders related to insulin resistance (12). It has also been observed that pea polysaccharides have the capacity to reduce diabetes-induced pancreatic tissue injury (87).

Cardiovascular health

Cardiovascular disease (CVD) has recently emerged as a major cause of increased mortality in emerging countries. Hypertension is intimately linked to the progression of cardiovascular disease by increasing blood pressure (68). Obesity has been linked to a 72 % increased risk of coronary heart disease (CHD), which is especially prevalent among obese women. Hypercholesterolemia is a significant risk factor for CHD that can be avoided with lifestyle changes (92). Consuming more dietary fibre is connected with fewer cardiovascular illnesses (90). Experimental studies showed that increasing dietary fibre consumption may slow down the process of low-density lipoprotein cholesterol (LDL-C) absorption as well as fasting glucose concentration (91), lowering the risk of CHD (Table 3). Water-soluble dietary fibre, in particular, has been linked to a lower risk of cardiovascular disease (89). The average dietary fibre intake was determined to be approximately 29 g per day. People who consumed less than 29 g of DF per day had 38 % higher risks of hypercholesterolemia and a 43 % increase in LDL cholesterol when compared to those who consumed more than the usual DF consumption (93). Green peas are naturally high in flavonols, carotenoids, vitamin C and antioxidants, which reduce

Table 4. Studies related to the metabolic health benefits and functions of the pea

Study type	Pea constituents	Results	Reference
Glycaemic response, blood glucose and insulin resistance	Dietary fibres, carbohydrates	Enhance glucose tolerance, No change in glycaemic response, Lower PP insulin.	(4, 16, 28, 68)
Intestinal microflora and its fermentability	Pea proteins (glycated), dietary fibre	Help in homeostasis, improve gastrointestinal microbiota.	(88)
Cardiovascular health	Dietary fibres, proteins and polyphenols	Lessen cardiovascular diseases, reduce cholesterol level, improve serum lipid levels and reduce the incidence of chronic disease.	(16, 89, 90)
α-Galactosidic effect/α-Galactooligosaccharides	α-Galactosidase	Normalising bowel functions, increasing lactobacilli and bifidobacteria.	(16, 45)
Anti-acetylcholinesterase property (anti-AChE)	Anti-acetylcholinesterase, antioxidants	Anti-diabetic, antihyperlipidemic, reduce the risk of oxidative stress.	(28, 68)
Cancer prevention	Phenolic compound, isoflavin, dietary fibres	Anti-cancer activity, DNA repair and reducing inflammation	(16)
Weight management	Dietary fibres, resistant starch, phytochemicals, oligosaccharides and many more	Increased stool weight	(16, 91)

the risk of heart stroke by modifying cardiometabolic risks and various heart diseases due to their ability to protect cells from damage (94-96).

α-Galactosidic/α-Galacto-oligosaccharides effects

α-Galactosides, derived from sucrose, contain 1-3 galactose units conjugated by α-1,6 links. They exhibit the traits of high solubility and quick fermentation found in colonic microbiota (Table 3). They are regarded as the ultimate source of energy necessary to obtain from plants, but are not fully exploited throughout the germination process. Due to the high fermentability, a variety of gases (e.g., CO_2, H_2, CH_4) are generated, which causes digestive discomfort and flatulence caused by indigestible oligosaccharides. Prebiotics are non-digestible oligosaccharides that are soluble carbohydrates with a low molecular weight (90). The oligosaccharides are from the raffinose family, which has sparked interest in pulse research, where raffinose, stachyose and verbascose serve as a broad foundation for experiments. They are fermented in the colonic flora, which increases bifidobacteria, which have various health benefits, including a potential preservative action against colorectal cancer and infectious bowel illnesses. The results demonstrated improved carbohydrate and lipid metabolism, as oligofructosaccharides suppressed hepatic triacylglycerol levels. Some studies have reported on the formation of α-galactooligosaccharides (12, 97).

Anti-acetylcholinesterase (anti-AChE) and antioxidant properties

In vitro and *in vivo* research demonstrated that peapods contain 32 % antiacetylcholinesterase (anti-AChE). Some antioxidant and protein denaturing capabilities were tested *in vitro*, while antidiabetic, cytoprotective and antihyperlipidemic effects were tested in vivo. The pea pods are high in nutrients, with 24.34 % carbs, 13.37 % crude protein, 51 % fibre, 4.5 % fats and 4.5 % ash (Table 1). Oxidative stress is characterised as an imbalance of free radicals, which is closely connected with hyperlipidemia (98). The fatty acid (FA) profile of pea consists primarily of linoleic, linolenic and palmitic acids, which have shown a promising anti-hyperlipidaemic effect in lowering the risk of diabetes, including oxidative stress and preventing organ damage, specifically liver, kidney and testis (28, 68) (Table 4). These are necessary fatty acids for human consumption and should be included in diets.

Anti-inflammatory effect

Pea and its components have amazing anti-inflammatory properties. For example, a recent study found that polyphenols released from green pea hulls during *in vitro* digestion could reduce LPS-induced inflammation in Caco-2/RAW264.7 coculture cell models (82). Pea hull polyphenols can reduce the release of nitric oxide (NO), interleukin-6 (IL-6) and tumour necrosis factor α (TNF-α) from Caco-2/RAW264.7 coculture cells, as well as the mRNA expression of COX-2 and iNOS. In addition, pea protein hydrolysates from yellow field pea seeds also exhibited a remarkable *in vitro* anti-inflammatory effect, which could inhibit the secretion of NO, IL-6 and TNF-α from LPS/IFN-activated RAW264.7 macrophages (99). In animal studies, green pea flour supplementation could reduce the severity of dextran sulphate sodium (DSS)-induced colitis in C57BL/6J female mice, which was associated with inflammation suppression, mucin depletion and endoplasmic reticulum stress in the colon (100). Furthermore, polyphenols extracted from green pea hulls could improve colitis in C57BL/6 male mice by activating the Kelch-like ECH-associated protein 1 (Keap1)-NF-E2-related factor 2 (Nrf2)-antioxidant responsive element (ARE) signalling pathway, regulating gut microbiota and increasing short-chain fatty acid (SCFA) levels. UHPLC-LTQ-MS was used to identify the major components in the polyphenolic extract of green pea hulls as quercetin, kaempferol, catechin and their derivatives (64). Furthermore, albumin extracts from pea seeds show anti-inflammatory properties in DSS-induced colitis in C57BL/6J male mice (101). It was discovered that two pea seed albumin extracts, including pea seed extract (PSE) containing an albumin fraction and a non-starch polysaccharide fraction, as well as the albumin fraction from PSE, could reduce microscopic histological damage in comparison to untreated colitis mice and improve colonic mRNA expression of various pro-inflammatory markers. Overall, this research found that pea flours, polyphenols, proteins and non-starch polysaccharides have outstanding anti-inflammatory properties.

Regulation of metabolic syndrome

The metabolic syndrome (MS) is a collection of clinical conditions characterised by hypertension, dyslipidemia, obesity and hyperglycemia. Peptides produced from pea protein hydrolysates were discovered to have exceptional antihypertensive effects, as evidenced by suppressing the enzymatic activities of angiotensin converting enzyme (ACE) and renin (102-104). Furthermore, a tripeptide LRW (Leu-Arg-Trp) generated from the pea protein legumin was discovered to have antihypertensive properties by inhibiting angiotensin II-induced superoxide generation, inflammation and proliferation in vascular smooth muscle cells. Anti-hypertensive activity involves improving the ACE2-Ang-(1-7)-MasR axis and modulating the nuclear factor-kB (NF-kB) pathway (105). Furthermore, animal research revealed that pea protein hydrolysates have potential antihypertensive characteristics (102, 104). For example, long-term oral administration of pea protein hydrolysates (1 % casein substitution in the diet) in spontaneously hypertensive rats reduced systolic blood pressure by up to -36 mmHg after three weeks (104). Overall, our findings indicate that pea and pea protein hydrolysates can be turned into health products to prevent hypertension.

Pea and its bioactive components have hypolipidemic effects both *in vitro* and *in vivo*. It was discovered that eating peas regularly might considerably restore blood total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C), as well as ameliorate liver lesions in rats fed a high-fat diet (98). Furthermore, the effect of autoclaved extract (AE) of pea pods (mostly polyphenols and dietary fibre) on lipid profiles in rats with high-sucrose diet-induced hyperlipidemia was investigated (106). AE was observed to significantly reduce blood triglyceride (TG) and TC levels in rats on a high-sucrose diet. Furthermore, AE may greatly increase the proliferation of Bifidobacteria in the cecum. Furthermore, research found that pea protein isolates significantly reduced blood TC and TG levels in rats, which appeared to alter cellular lipid homeostasis by enhancing hepatic cholesterol absorption genes while lowering fatty acid synthesis genes (107). Peas can be combined to create health products that help avoid hyperlipidemia.

Obesity is a severe, obvious, but often overlooked global health issue. Promoting adipocyte differentiation may help to alleviate obesity-related metabolic problems. Recently, the effect of pea protein hydrolysates on adipocyte development was studied using 3T3-L1 murine pre-adipocytes (108). It was discovered that pea vicilin hydrolysate (PVH) might increase mRNA expression of the adipocyte fatty acid-binding protein while decreasing that of preadipocyte factor-1, hence encouraging adipocyte development. Furthermore, PVH has the potential to increase adiponectin and insulin-responsive glucose transporter 4 expression, as well as glucose uptake. Peroxisome proliferator-activated receptor gamma (PPAR) levels increased during adipocyte development. Overall, this study found that PVH could promote adipocyte differentiation by partially increasing PPAR expression and ligand activity (108). Furthermore, pea proteins and hydrolysates, as well as pea dietary fibre, are useful in the treatment of obesity. It was discovered that pea seed flours may reduce weight gain in diet-induced obese rats and pea dietary fibre and pea flours could significantly reduce the final % body fat compared to the control (109). On the other hand, pea dietary fibre may reduce the Firmicutes/Bacteroidetes ratio and the abundance of Clostridium leptum, which is higher in obese people. A 12-week clinic trial with 53 obese or overweight people was also conducted to further understand the effects of pea dietary fibre on the regulation of the microbiota-host metabolic axis in obesity (110). It was discovered that supplementing the diet with pea fibre could prevent negative changes in the metabolic profile, which could be due to a minor change in the gut microbial profile, resulting in changes in short-chain fatty acids (SCFAs), bile acids (BAs) and ketone bodies, which are key signalling molecules linked to obesity (110).

Antimicrobial effect

Several studies have shown that pea and its by-products have remarkable antimicrobial activities, such as pea peptides, pea lectins, polyphenols derived from pea peels and soluble polysaccharides derived from pea pods (13, 111-113). 11S pea globulin inhibits both Gram-positive and Gram-negative bacteria, with MICs ranging from 120 to 160 and 145 to 190 µg/mL, respectively. However, 11S pea globulin can significantly suppress the growth of fungi, with MICs ranging from 55 to 80 µg/mL (111). Pea lectins can suppress the growth of many bacteria, including *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*, with MICs ranging from 62.5 to 125 µg/mL (112). Furthermore, at a concentration of 50 mg/mL, soluble polysaccharides produced from pea pods showed clear inhibitory effects against Gram-negative and Gram-positive bacteria (13). Furthermore, the ethyl acetate extract of pea peels was found to be more effective than the methanolic and water extracts in inhibiting a variety of microorganisms (including *Staphylococcus aureus*, *Salmonella enterica*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus niger* and *Candida albicans*). For example, the aqueous extract of pea peels had no inhibitory impact on these bacteria (113). Finally, these investigations show that peas and their components have antibacterial properties and could be employed as antimicrobial agents in the food industry.

Anti-renal fibrosis effect

Renal fibrosis typically causes glomerulosclerosis and interstitial fibrosis, which can progress to long-term renal disease (114). The protein hydrolysate of green peas degraded by bromelain (PHGPB) was observed to stimulate the proliferation of SV40 MES 13 mesangial cells induced by high glucose levels (115). PHGPB has been shown to lower fibronectin (FN) and transforming growth factor-β 1 (TGF-1) levels in mesangial cell lines of diabetic glomerulosclerosis, indicating promise for antifibrosis in chronic kidney disease (115). Furthermore, a prior study found that PHGPB plays a role in TGF/SMAD signalling to prevent renal fibrosis (116). PHGPB was reported to reduce TGF-1 levels in high-glucose-induced SV40 MES 13 cells. Furthermore, PHGPB could reduce the expression of SMAD 2, SMAD 3 and SMAD 4 genes while increasing the expression of SMAD 7 (116). Peas have shown therapeutic results in the treatment of renal fibrosis, but the relevant research is still incomplete and future clinical investigations must cover the gaps.

Cancer prevention

The population's preference for a Western diet rich in fat, animal protein and refined carbohydrates effectively weakens their immune system and makes them more susceptible to carcinogenic consequences. Although nutrition is not thought to be a carcinogenic agent, it can trigger cancer-causing components (117). Pea extracts are both pharmacologically active and anticancer (70, 118). Peas are often high in biologically active compounds, which may have beneficial effects in lowering cancer risk when taken at specific amounts (119). In general, yellow peas are an excellent source of isoflavones, specifically genistein (dimerised) and daidzein (deoxydi-glycosidic), which are phytoestrogens with a variety of significant functions, including anti-carcinogenic properties. Genistein demonstrated anti-proliferative effects on cell growth driven by mitogens in breast cancer cells in people. This is a promising drug for reducing breast cancer (120). Furthermore, multiple pieces of data suggest that pulses high in dietary fibre may help to reduce the effects of certain types of cancer, particularly colon and rectal cancer (Table 5). Other bioactive

Table 5. Pea nutritional bioactive constituents and their effects on human health (44)

Nutritional components	Function	References
Carbohydrate	Resistant starch acts as a prebiotic. Increases faecal bulk, reduces colonic pH and reduces post-prandial glycaemic response	(16, 71)
Dietary fibre	Low glycaemic response and insulin resistance. Improve cardiovascular health, decrease blood pressure, enhance serum lipid levels and lower the indicator of inflammation	(4, 46)
Protein	Glycosylated protein may escape the small intestine, help in haemostasis and improve gastrointestinal microbiota	(88)
Phenolic compounds	Antioxidants protect against diseases such as cancer and various inflammatory conditions	(9, 28, 57, 121)
Isoflavin	Anti-cancer activity, DNA repair, induction of apoptosis, cell proliferation, migration and invasion	(70)
Lectin	Cytotoxic or tumour inhibition	(70)
Saponin	Bind cholesterol and bile acid, which may have hypocholesterolaemic effects	(121)
Oligosaccharide (α-galactosidase)	Normalising bowel function, increasing Lactobacilli and Bifidobacteria	(45)
Polyphenol	Antioxidants and reduce the incidence of chronic diseases	(45, 57)

chemicals found in pulses may have a cancer-fighting impact, including resistant starch, non-starch polysaccharides, oligosaccharides, folate, selenium, zinc, saponins and lectins (120). The presence of numerous bioactive micronutrients and phytochemicals in peas contributes to a balanced diet and reduces the risk of cancer.

Other beneficial effects

Pea and its bioactive components have additional health benefits. For example, the bioactive tripeptide LRW (Leu-Arg-Trp) derived from pea protein has been shown to positively regulate osteoblast activity via the Akt/Runx2 pathway, implying its potential for osteoporosis prevention (122). Furthermore, aqueous extracts from pea seed coatings showed cytotoxicity against several cancer cell lines, including LS174, MDAMB-453, A594 and K562 (123). Meanwhile, lectins from pea seeds showed clear inhibitory effects on Ehrlich ascites carcinoma cells *in vitro* and *in vivo*, halting the cell cycle during the G2/M phase (124). Furthermore, peptides derived from pea protein hydrolysates were found to have immunomodulatory effects *in vivo*, which could increase macrophage phagocytic activity, stimulate the gut mucosa immune response and increase IL-6 production via the simulation of toll-like receptor-2 (TLR2) and TLR4 (99). Furthermore, the anti-fatigue properties of pea peptides were investigated. Pea peptides have been shown to increase glycogen content in muscle and liver, reduce lactic acid build-up, suppress free radical oxidation in the body and promote immunological function (125).

Conclusion

The pea, which is virtually grown worldwide for its edible seeds, is nutritionally very rich. It is also high in dietary fibre, antioxidants, numerous important biomolecules and has a low glycaemic index, making it extremely useful in the treatment of diabetes, cardiovascular disease, certain cancers and many degenerative diseases. The current review discusses the nutritional value of peas and their underutilised by-products, particularly their pods, with an emphasis on their health benefits and varied functional qualities. Peas and their waste have desirable functionality, making them potentially appropriate for the food sector. Garden pea is a nutritionally rich legume with diverse biochemical constituents, including proteins, vitamins, minerals, polyphenols and other bioactive compounds. These compounds confer multiple health-promoting properties, such as antioxidant, anti-diabetic, anti-inflammatory and cardio-protective effects. Despite growing evidence of its functional benefits, further research is needed to clarify mechanisms of action, optimise bioavailability and explore its potential in functional foods and nutraceutical development. Overall, garden pea represents a valuable dietary resource with significant implications for human health and nutrition. Overall, the authors intended to provide current research information on peas and their by-products, which are thought to have enormous potential in terms of various nutrients and biomolecules with high credentials to support our various health -related diseases and alleviate them on a global scale.

Authors' contributions

DKU, AT and PU led the review process, conceptualised the study, drafted the manuscript, provided critical revisions, contributed to the study design and guided the methodology. KP provided critical revisions, contributed to the study design and guided the methodology. AJ, CNR, AKS, AK, SS, MKM and PKD supported the literature collection, assisted in data organisation and contributed to the refinement of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflicts of interest to declare.

Ethical issues: None

References

1. Food and Agriculture Organisation. FAOSTAT. Rome: Food and Agriculture Organisation; 2019. http://www.fao.org/faostat/en/#data/QC
2. Mondor M. Pea. In: Manickavasagan A, Thirunathan P, editors. Pulses. Cham: Springer; 2020. p. 245-73. https://doi.org/10.1007/978-3-030-41376-7_14
3. Senapati AK, Varshney AK, Sharma KV. Dehydration of green peas: A review. Int J Chem Stud. 2019;7(2):1088-91.
4. Dahl WJ, Foster LM, Tyler RT. Review of the health benefits of peas (*Pisum sativum* L.). Br J Nutr. 2012;108:S3-10. https://doi.org/10.1017/S0007114512000852
5. Santos CS, Carbas B, Castanho A, Vasconcelos MW, Vaz Patto MC, Domoney C et al. Variation in pea (*Pisum sativum* L.) seed quality traits defined by physicochemical functional properties. Foods. 2019;8(11):570. https://doi.org/10.3390/foods8110570
6. Millar KA, Gallagher E, Burke R, McCarthy S, Barry-Ryan C. Proximate composition and anti-nutritional factors of fava-bean (*Vicia faba*), green-pea and yellow-pea (*Pisum sativum* L.) flour. J Food Compos Anal. 2019;82:103233. https://doi.org/10.1016/j.jfca.2019.103233
7. Hood-Niefer SD, Warkentin TD, Chibbar RN, Vandenberg A, Tyler RT. Effect of genotype and environment on starch and protein concentration and physicochemical properties of starch from field pea and fababean. J Sci Food Agric. 2012;92(1):141-50. https://doi.org/10.1002/jsfa.4552
8. Reichert RD, MacKenzie SL. Composition of peas (*Pisum sativum*) varying widely in protein content. J Agric Food Chem. 1982;30(2):312-7. https://doi.org/10.1021/jf00110a024
9. Thakur V, Sharma P, Kumar P, Sharma P, Bhat SA, Sharma S et al. Quantifying impact of fermented liquid bioformulations, biofertilizers and organic amendments on horticultural and soil nutrient traits of garden pea (*Pisum sativum* L.). Int J Recycl Org Waste Agric. 2024;13(3):1-7.
10. Lu ZX, He JF, Zhang YC, Bing DJ. Composition and physicochemical properties of pea protein and its application in functional foods. Crit Rev Food Sci Nutr. 2020;60(15):2593-605. https://doi.org/10.1080/10408398.2019.1651248
11. He X, Chen J, He X, Feng Z, Li C, Liu W et al. Industry scale microfluidization to improve solubility and modify structure of pea protein. Innov Food Sci Emerg Technol. 2020;67:102582. https://doi.org/10.1016/j.ifset.2020.102582
12. Thakur V, Sharma P, Sharma P, Sharma S. Efficacy of biological waste on cropping traits and nutrient status of soil in garden pea under protected environment. Environ Eng Manage J. 2023;22

(12):1995-2002. https://doi.org/10.30638/eemj.2023.172

13. Belghith-Fendri L, Chaari F, Jeddou KB, Kallel F, Bouaziz F, Helbert CB et al. Polysaccharides extracted from pea pod by-products: identification and evaluation of biological and functional properties. Int J Biol Macromol. 2018;116:947-54. https://doi.org/10.1016/j.ijbiomac.2018.05.095
14. Tosh SM, Farnworth ER, Brummer Y, Duncan AM, Wright AJ, Boye JI et al. Nutritional profile and carbohydrate characterization of spray-dried lentil, pea and chickpea ingredients. Foods. 2013;2(3):338-49. https://doi.org/10.3390/foods2030338
15. Englyst HN, Quigley ME, Hudson GJ, Cummings JH. Determination of dietary fibre as non-starch polysaccharides by gas-liquid chromatography. Analyst. 1992;117(11):1707-14. https://doi.org/10.1039/AN9921701707
16. Singh B, Singh JP, Shevkani K, Singh N, Kaur A. Bioactive constituents in pulses and their health benefits. J Food Sci Technol. 2017;54(4):858-70. https://doi.org/10.1007/s13197-016-2391-9
17. Guillon F, Champ MM. Carbohydrate fractions of pea: uses in human nutrition and potential for health. Br J Nutr. 2002;88(S3):S293-306. https://doi.org/10.1079/BJN2002720
18. Chung HJ, Liu Q, Hoover R. Effect of hydrothermal treatments on crystalline structure, thermal properties and nutritional fractions of pea, lentil and navy bean starches. Food Res Int. 2010;43(2):501-8. https://doi.org/10.1016/j.foodres.2009.07.030
19. Petropoulou K, Salt LJ, Edwards CH, Warren FJ, Garcia-Perez I, Chambers ES, Frost GS. A natural mutation in *Pisum sativum* L. alters starch assembly and improves glucose homeostasis in humans. Nature Food. 2020;1(11):693-704. https://doi.org/10.1038/s43016-020-00159-8
20. Owusu-Ansah YJ, McCurdy SM. Pea proteins: chemistry, production technology and utilization. Food Rev Int. 1991;7(1):103-34. https://doi.org/10.1080/87559129109540903
21. Yi J, Gan C, Wen Z, Fan Y, Wu X. Pea protein-pectin colloidal particles for high internal phase pickering emulsions for β-carotene protection. Food Hydrocoll. 2021;113:106497. https://doi.org/10.1016/j.foodhyd.2020.106497
22. Muneer F, Johansson E, Hedenqvist MS, Plivelic TS, Markedal KE, Petersen IL et al. Protein and fibre rich fractions of yellow pea (*Pisum sativum* L.) and their impact on mechanical properties of pasta-like sheets. Food Res Int. 2018;106:607-18. https://doi.org/10.1016/j.foodres.2018.01.020
23. Borderías AJ, Tovar CA, Domínguez-Timón F, Díaz MT, Pedrosa MM, Moreno HM. Mixed surimi gels with pea protein isolates. Food Hydrocoll. 2020;107:105976. https://doi.org/10.1016/j.foodhyd.2020.105976
24. El Youssef C, Bonnarme P, Fraud S, Péron AC, Helinck S, Landaud S. Sensory improvement of a pea protein-based product using microbial co-cultures. Foods. 2020;9(3):349. https://doi.org/10.3390/foods9030349
25. Gawalko E, Garrett RG, Warkentin T, Wang N, Richter A. Trace elements in Canadian field peas. Food Addit Contam. 2009;26(7):1002-12. https://doi.org/10.1080/02652030902894389
26. Robinson GHJ, Balk J, Domoney C. Improving pulse crops as sources of protein, starch and micronutrients. Nutr Bull. 2019;44(3):202-15. https://doi.org/10.1111/nbu.12399
27. Boschin G, Arnoldi A. Legumes as sources of tocopherols. Food Chem. 2011;127(3):1199-203. https://doi.org/10.1016/j.foodchem.2011.01.124
28. Mejri F, Khoud HB, Njim L, Baati T, Selmi S, Martins A, Hosni K. *In vitro* and *in vivo* biological properties of pea pods (*Pisum sativum* L.). Food Biosci. 2019;32:100482. https://doi.org/10.1016/j.fbio.2019.100482
29. Han JY, Tyler RT. Determination of folate concentrations in pulses using a microbiological method with trienzyme extraction. J Agric Food Chem. 2003;51(18):5315-8. https://doi.org/10.1021/jf0211027
30. Jha AB, Warkentin TD. Biofortification of pulse crops: status and future perspectives. Plants. 2020;9(1):73. https://doi.org/10.3390/plants9010073
31. Amarakoon D, McPhee K, Thavarajah P. Iron-, zinc- and magnesium-rich field peas (*Pisum sativum* L.) with naturally low phytic acid. J Food Compos Anal. 2012;27(1):8-13. https://doi.org/10.1016/j.jfca.2012.05.007
32. Poblaciones MJ, Rengel Z. Soil and foliar zinc biofortification in field pea (*Pisum sativum* L.). Food Chem. 2016;212:427-33. https://doi.org/10.1016/j.foodchem.2016.05.189
33. Rehman HM, Cooper JW, Lam HM, Yang SH. Legume biofortification for combating hidden hunger. Plant Cell Environ. 2019;42(1):52-70. https://doi.org/10.1111/pce.13368
34. Powers SE, Thavarajah D. Field pea (*Pisum sativum* L.), sustainability and phosphorus use efficiency. Front Plant Sci. 2019;10:1489. https://doi.org/10.3389/fpls.2019.01489
35. Hanan E, Rudra SG, Sagar VR, Sharma V. Utilization of pea pod powder for instant pea soup formulation. J Food Process Preserv. 2020;44(11):e14888. https://doi.org/10.1111/jfpp.14888
36. Mateos-Aparicio I, Redondo-Cuenca A, Villanueva-Suárez MJ, Zapata-Revilla MA, Tenorio-Sanz MD. Pea pod, broad bean pod and okara as functional compound sources. LWT Food Sci Technol. 2010;43(9):1467-70. https://doi.org/10.1016/j.lwt.2010.05.008
37. Champ MMJ. Non-nutrient bioactive substances of pulses. Br J Nutr. 2002;88(S3):307-19. https://doi.org/10.1079/BJN2002721
38. Dalgetty DD, Baik BK. Isolation and characterization of cotyledon fibers from peas, lentils and chickpeas. Cereal Chem. 2003;80(3):310-5. https://doi.org/10.1094/CCHEM.2003.80.3.310
39. Maphosa Y, Jideani VA. Dietary fiber extraction for human nutrition. Food Rev Int. 2016;32(1):98-115. https://doi.org/10.1080/87559129.2015.1057840
40. Tosh SM, Yada S. Dietary fibres in pulses: characterization and functional attributes. Food Res Int. 2010;43(2):450-60. https://doi.org/10.1016/j.foodres.2009.09.005
41. Hall C, Hillen C, Garden Robinson J. Composition, nutritional value and health benefits of pulses. Cereal Chem. 2017;94(1):11-31. https://doi.org/10.1094/CCHEM-03-16-0069-FI
42. Mateos-Aparicio I, Redondo-Cuenca A, Villanueva-Suárez MJ. Fibre-rich ingredients from broad bean and pea by-products. J Sci Food Agric. 2012;92(3):697-703. https://doi.org/10.1002/jsfa.4633
43. Belghith-Fendri L, Chaari F, Kallel F, Zouari-Ellouzi S, Ghorbel R, Besbes S et al. Pea and broad bean pods as dietary fiber sources: effects on cake texture and sensory properties. J Food Sci. 2016;81(10):C2360-6. https://doi.org/10.1111/1750-3841.13448
44. Tapasya K, Sankar Chandra D. Potential health benefits of garden pea seeds and pods: a review. Legume Sci. 2021;3:e82. https://doi.org/10.1002/leg3.82
45. Roberfroid M, Slavin J. Nondigestible oligosaccharides. Crit Rev Food Sci Nutr. 2000;40(6):461-80. https://doi.org/10.1080/10408690091189239
46. Slavin J. Impact of proposed dietary fiber definition on nutrient databases. J Food Compos Anal. 2003;16(3):287-91. https://doi.org/10.1016/S0889-1575(03)00053-X
47. Bush RS, Jenkin RD, Allt WE, Beale FA, Bean H, Dembo AJ et al. Hypoxic cells influencing cure in cancer therapy. Br J Cancer Suppl. 1978;3:302.
48. Khan AR, Alam S, Ali S, Bibi S, Khalil IA. Dietary fiber profile of food legumes. Sarhad J Agric. 2007;23(3):763.
49. Dhingra D, Michael M, Rajput H, Patil RT. Dietary fibre in foods: a review. J Food Sci Technol. 2012;49(3):255-66. https://doi.org/10.1007/s13197-011-0365-5
50. Sun J, Zhang Z, Xiao F, Wei Q, Jing Z. Ultrasound-assisted alkali extraction of insoluble dietary fiber from soybean residues. Mater

Sci Eng. 2018;392(5):052005. https://doi.org/10.1088/1757-899X/392/5/052005

51. Hu H, Zhao Q. Extraction and functional properties of soluble dietary fibre from pineapple pomace. RSC Adv. 2018;8(72):41117-30. https://doi.org/10.1039/C8RA06928J

52. Gan RY, Wang MF, Lui WY, Wu K, Dai SH, Sui ZQ et al. Antioxidant capacity and phenolic content of 42 edible beans from China. Cereal Chem. 2017;94:291-7. https://doi.org/10.1094/CCHEM-03-16-0061-R

53. Devi J, Sanwal SK, Koley TK, Mishra GP, Karmakar P, Singh PM et al. Phenolics and antioxidant activities among garden pea (*Pisum sativum* L.) genotypes. Sci Hortic. 2019;244:141-50. https://doi.org/10.1016/j.scienta.2018.09.048

54. Zhao T, Su W, Qin Y, Wang L, Kang Y. Phenotypic diversity and antioxidant activity in pea (*Pisum sativum* L.) seeds. Cienc Rural. 2020;50(5):e20190196. https://doi.org/10.1590/0103-8478cr20190196

55. Ma Y, Gao J, Wei Z, Shahidi F. Effect of *in vitro* digestion on phenolics and antioxidant activity of red and yellow pea hulls. Food Chem. 2021;337:127606. https://doi.org/10.1016/j.foodchem.2020.127606

56. Borges-Martinez E, Gallardo-Velazquez T, Cardador-Martinez A, Moguel-Concha D, Osorio-Revilla G, Ruiz-Ruiz JC et al. Phenolic profile and antioxidant activity of pea (*Pisum sativum* L.) and black bean (*Phaseolus vulgaris* L.) sprouts. Food Sci Technol. 2022;42:e45920. https://doi.org/10.1590/fst.45920

57. Fahim JR, Attia EZ, Kamel MS. Phenolic profile of pea (*Pisum sativum*): overview. Phytochem Rev. 2019;18(1):173-98. https://doi.org/10.1007/s11101-018-9586-9

58. Castaldo L, Izzo L, Gaspari A, Lombardi S, Rodriguez-Carrasco Y, Narvaez A, Grosso M. Chemical composition of green pea (*Pisum sativum* L.) pod extracts and potential nutraceutical use. Antioxidants. 2022;11:105. https://doi.org/10.3390/antiox11010105

59. Abdelghffar EA, Obaid WA, Elgamal AM, Daoud R, Sobeh M, El Rae MA. Pea (*Pisum sativum*) peel extract attenuates Dox-induced oxidative myocardial injury. Biomed Pharmacother. 2021;143:112120. https://doi.org/10.1016/j.biopha.2021.112120

60. Guo FH, Tsao R, Li CY, Wang XY, Zhang H, Jiang L, et al. Green pea (*Pisum sativum* L.) hull polyphenol extracts ameliorate DSS-induced colitis through Keap1/Nrf2 pathway and gut microbiota modulation. Foods. 2021;10:2765. https://doi.org/10.3390/foods10112765

61. Jha AB, Purves RW, Elessawy FM, Zhang H, Vandenberg A, Warkentin TD. Polyphenolic profile of seed components of white and purple flower pea lines. Crop Sci. 2019;59:2711-19. https://doi.org/10.2135/cropsci2019.04.0279

62. Chahbani A, Fakhfakh N, Balti MA, Mabrouk M, El-Hatmi H, Zouari N. Microwave drying effects on drying kinetics, bioactive compounds and antioxidant activity of green peas (*Pisum sativum* L.). Food Biosci. 2018;25:32-8. https://doi.org/10.1016/j.fbio.2018.07.004

63. Elessawy FM, Bazghaleh N, Vandenberg A, Purves RW. Polyphenol profile comparisons of seed coats of five pulse crops using a semi-quantitative liquid chromatography-mass spectrometric method. Phytochem Anal. 2020;31:458-71. https://doi.org/10.1002/pca.2909

64. Guo FH, Tsao R, Wang XY, Jiang L, Sun Y, Xiong H. Phenolics of yellow pea (*Pisum sativum* L.) hulls, their plasma and urinary metabolites, organ distribution and *in vivo* antioxidant activities. J Agric Food Chem. 2021;69:5013-25. https://doi.org/10.1021/acs.jafc.1c00713

65. Carpentier J, Conforto E, Chaigneau C, Vendeville JE, Maugard T. Microencapsulation and controlled release of alpha-tocopherol by complex coacervation between pea protein and tragacanth gum. Innov Food Sci Emerg Technol. 2022;77:102951. https://doi.org/10.1016/j.ifset.2022.102951

66. Nazir N, Nisar M, Ahmad S, Wadood SF, Jan T, Zahoor M, et al. Characterization of phenolic compounds in two novel lines of *Pisum sativum* L. along with their *in vitro* antioxidant potential. Environ Sci Pollut Res. 2020;27:7639-46. https://doi.org/10.1007/s11356-019-07065-y

67. Wu DT, Li WX, Wan JJ, Hu YC, Gan RY, Zou L. A comprehensive review of pea (*Pisum sativum* L.): Chemical composition, processing, health benefits and food applications. Foods. 2023;12:2527. https://doi.org/10.3390/foods12132527

68. Ge J, Sun CX, Corke H, Gul K, Gan RY, Fang YP. The health benefits, functional properties, modifications and applications of pea (*Pisum sativum* L.) protein. Compr Rev Food Sci Food Saf. 2020;19:1835-76. https://doi.org/10.1111/1541-4337.12573

69. Guo F, Xiong H, Wang X, Jiang L, Yu N, Hu Z, et al. Phenolics of green pea (*Pisum sativum* L.) hulls, their plasma and urinary metabolites, bioavailability and *in vivo* antioxidant activities in a rat model. J Agric Food Chem. 2019;67:11955-68. https://doi.org/10.1021/acs.jafc.9b04501

70. Bello OA, Ayanda OI, Aworunse OS, Olukanmi BI, Soladoye MO, Esan EB, et al. *Solaneciobia frae*: An underutilized nutraceutically important African indigenous vegetable. Phcog Rev. 2018;12:128-32. https://doi.org/10.4103/phrev.phrev_43_17

71. Tassoni A, Tedeschi T, Zurlini C, Cigognini IM, Petrusan JI, Rodríguez Ó, et al. State-of-the-art production chains for peas, beans and chickpeas-valorization of agro-industrial residues. Molecules. 2020;25:1383. https://doi.org/10.3390/molecules25061383

72. Sies H. Oxidative stress: Oxidants and antioxidants. Exp Physiol. 1997;82:291-5. https://doi.org/10.1113/expphysiol.1997.sp004024

73. Halliwell B, Gutteridge JM. Lipid peroxidation in brain homogenates: role of iron and hydroxyl radicals. J Neurochem. 1997;69:1330. https://doi.org/10.1046/j.1471-4159.1997.69031330.x

74. Troszynska A, Ciska E. Phenolic compounds of seed coats of pea (*Pisum sativum* L.) varieties and their antioxidant activity. Czech J Food Sci. 2002;20:15-22. https://doi.org/10.17221/3504-CJFS

75. Duenas M, Estrella I, Hernandez T. Occurrence of phenolic compounds in the seed coat and cotyledon of peas (*Pisum sativum* L.). Eur Food Res Technol. 2004;219:116-23. https://doi.org/10.1007/s00217-004-0938-x

76. Pinchao-Pinchao YA, Ordoñez-Santos LE, Osorio-Mora O. Ultrasound-assisted extraction of phenolic compounds from pea pod. DYNA. 2019;86:211-15. https://doi.org/10.15446/dyna.v86n210.72880

77. Xu BJ, Yuan SH, Chang SKC. Comparative analyses of phenolic composition, antioxidant capacity and color of cool-season legumes. J Food Sci. 2007;72:S167-72. https://doi.org/10.1111/j.1750-3841.2006.00261.x

78. Heim KE, Tagliaferro AR, Bobilya DJ. Flavonoid antioxidants: chemistry, metabolism and structure-activity relationships. J Nutr Biochem. 2002;13:572-84. https://doi.org/10.1016/S0955-2863(02)00208-5

79. Burguieres E, Mccue P, Kwon YI, Shetty K. Health-related functionality of phenolic-enriched pea sprouts. J Food Biochem. 2008;32:3-14. https://doi.org/10.1111/j.1745-4514.2007.00164.x

80. Jalili-Safaryan M, Ganjloo A, Bimakr M, Zarringhalami S. Ultrasound-assisted extraction and antioxidant activity of polysaccharides from green pea pods. Foods. 2016;5:78. https://doi.org/10.3390/foods5040078

81. Ganzon-Naret ES. Effect of processing methods on nutritional composition and antinutritional factors in *Pisum sativum*. ABAH Bioflux. 2018;10:18-26.

82. Guo FH, Tsao R, Li CY, Wang XY, Zhang H, Jiang L, et al. Polyphenol content of green pea (*Pisum sativum* L.) hull under *in vitro* digestion. J Agric Food Chem. 2022;70:3477-88. https://doi.org/10.1021/acs.jafc.2c00102

83. Urbano G, Aranda P, Gómez-Villalva E, Frejnagel S, Porres JM, Frías J, et al. Nutritional evaluation of pea (*Pisum sativum* L.) protein diets. J Agric Food Chem. 2003;51:2415-20. https://doi.org/10.1021/jf0209239

84. Roy F, Boye JI, Simpson BK. Bioactive proteins and peptides in pulse crops. Food Res Int. 2010;43:432-42. https://doi.org/10.1016/j.foodres.2009.09.002

85. Costantini M, Summo C, Centrone M, Rybicka I, D'agostino M, Annicchiarico P, et al. Macro- and micro-nutrient composition of chickpea and pea accessions. Pol J Food Nutr Sci. 2021;71:177-85. https://doi.org/10.31883/pjfns/135813

86. Ashokkumar K, Diapari M, Jha AB, Tar'an B, Arganosa G, Warkentin TD. Carotenoid diversity in pea and chickpea accessions. J Food Compos Anal. 2015;43:49-60. https://doi.org/10.1016/j.jfca.2015.04.014

87. Zhang SJ, Hu TT, Chen YY, Wang S, Kang YF. Polysaccharide fractions isolated from pea (*Pisum sativum* L.). J Food Biochem. 2020;44:e13248. https://doi.org/10.1111/jfbc.13248

88. Dominika Ś, Arjan N, Karyn RP, Henryk K. Glycated pea proteins and human intestinal bacteria. Int J Food Microbiol. 2011;145:267-72. https://doi.org/10.1016/j.ijfoodmicro.2011.01.002

89. Bazzano LA. Effects of soluble dietary fiber on LDL cholesterol and coronary heart disease risk. Curr Atheroscler Rep. 2008;10:473-7. https://doi.org/10.1007/s11883-008-0074-3

90. Slavin J. Fiber and prebiotics: mechanisms and health benefits. Nutrients. 2013;5:1417-35. https://doi.org/10.3390/nu5041417

91. Becerra-Tomás N, Papandreou C, Salas-Salvadó J. Legume consumption and cardiometabolic health. Adv Nutr. 2019;10:S437-50. https://doi.org/10.1093/advances/nmz003

92. Anderson JW, Major AW. Pulses and lipaemia: short- and long-term effects. Br J Nutr. 2002;88:S263-71. https://doi.org/10.1079/BJN2002716

93. Narayan S, Lakshmipriya N, Vaidya R, Bai MR, Sudha V, Krishnaswamy K, et al. Dietary fiber intake and serum cholesterol in Asian-Indian adults with type 2 diabetes. IJEM. 2014;18:624. https://doi.org/10.4103/2230-8210.139215

94. Papandreou C, Becerra-Tomás N, Bulló M, Martínez-González MA, Corella D, Estruch R, et al. Legume consumption and mortality in the PREDIMED study. Clin Nutr. 2019;38:348-56. https://doi.org/10.1016/j.clnu.2017.12.019

95. Perez-Vizcaino F, Duarte J. Flavonols and cardiovascular disease. Mol Aspects Med. 2010;31:478-94. https://doi.org/10.1016/j.mam.2010.09.002

96. Voutilainen S, Nurmi T, Mursu J, Rissanen TH. Carotenoids and cardiovascular health. Am J Clin Nutr. 2006;83:1265-71. https://doi.org/10.1093/ajcn/83.6.1265

97. Veenstra JM, Duncan AM, Cryne CN, Deschambault BR, Boye JI, Benali M, et al. Effect of pulse consumption on gastrointestinal function. Food Res Int. 2010;43:553-9. https://doi.org/10.1016/j.foodres.2009.07.029

98. Liu D, Guan X, Huang K, Li S, Liu J, Yu W, et al. Protective effects of mung bean (*Vigna radiata* L.) and pea (*Pisum sativum* L.) against oxidative stress. Food Sci Nutr. 2019;7:4063-75. https://doi.org/10.1002/fsn3.1271

99. Ndiaye F, Vuong T, Duarte J, Aluko RE, Matar C. Antioxidant and immunomodulating properties of pea seed hydrolysate. Eur J Nutr. 2012;51:29-37. https://doi.org/10.1007/s00394-011-0186-3

100. Bibi S, Moraes LFD, Lebow N, Zhu MJ. Dietary green pea protects against DSS-induced colitis in mice. Nutrients. 2017;9:509. https://doi.org/10.3390/nu9050509

101. Utrilla MP, Peinado MJ, Ruiz R, Rodriguez-Nogales A, Algieri F, Rodriguez-Cabezas ME, et al. Pea (*Pisum sativum* L.) seed albumin extracts show anti-inflammatory effect. Mol Nutr Food Res. 2015;59:807-19. https://doi.org/10.1002/mnfr.201400630

102. Aluko RE, Girgih AT, He R, Malomo S, Li H, Offengenden M, et al. Yellow field pea (*Pisum sativum* L.) peptide characterization. Food Res Int. 2015;77:10-16. https://doi.org/10.1016/j.foodres.2015.03.029

103. Jakubczyk A, Baraniak B. ACE inhibitory peptides after hydrolysis of pea globulins. Biomed Res Int. 2014;2014:438459. https://doi.org/10.1155/2014/438459

104. Girgih AT, Nwachukwu ID, Onuh JO, Malomo SA, Aluko RE. Antihypertensive properties of pea protein hydrolysate. J Food Sci. 2016;81:H1281-7. https://doi.org/10.1111/1750-3841.13272

105. Wang X, Bhullar KS, Fan HB, Liao W, Qiao YJ, Su D, et al. Regulatory effects of pea-derived peptide LRW. J Agric Food Chem. 2020;68:3947-53. https://doi.org/10.1021/acs.jafc.0c00028

106. Inagaki K, Nishimura Y, Iwata E, Manabe S, Goto M, Ogura Y, et al. Hypolipidemic effect of autoclaved extract from pea (*Pisum sativum* L.) pods. J Nutr Sci Vitaminol. 2016;62:322-9. https://doi.org/10.3177/jnsv.62.322

107. Rigamonti E, Parolini C, Marchesi M, Diani E, Brambilla S, Sirtori CR, et al. Hypolipidemic effect of dietary pea proteins. Mol Nutr Food Res. 2010;54:S24-30. https://doi.org/10.1002/mnfr.200900251

108. Ruiz R, Olias R, Clemente A, Rubio LA. Pea (*Pisum sativum* L.) seed vicilins hydrolysate and adipocyte differentiation. Foods. 2020;9:793. https://doi.org/10.3390/foods9060793

109. Eslinger AJ, Eller LK, Reimer RA. Yellow pea fiber improves glycemia and gut microbiota. Nutr Res. 2014;34:714-22. https://doi.org/10.1016/j.nutres.2014.07.016

110. Mayengbam S, Lambert JE, Parnell JA, Tunnicliffe JM, Nicolucci AC, Han J, et al. Dietary fiber supplementation and metabolic axes in obesity. J Nutr Biochem. 2019;64:228-36. https://doi.org/10.1016/j.jnutbio.2018.11.003

111. El-Saadony MT, El-Hack MEA, Swelum AA, Al-Sultan SI, El-Ghareeb WR, Hussein EOS, et al. Bioactive peptides of pea and kidney bean improve quality of buffalo meat. Ital J Anim Sci. 2021;20:762-76. https://doi.org/10.1080/1828051X.2021.1926346

112. El-Araby MM, El-Shatoury EH, Soliman MM, Shaaban HF. Characterization and antimicrobial activity of lectins from legume seeds. AMB Express. 2020;10:90. https://doi.org/10.1186/s13568-020-01024-4

113. Hadrich F, El Arbi M, Boukhris M, Sayadi S, Cherif S. Valorization of the peel of pea: *Pisum sativum* by evaluation of its antioxidant and antimicrobial activities. J Oleo Sci. 2014;63:1177-83. https://doi.org/10.5650/jos.ess14107

114. Liu YP, Su YY, Yang Q, Zhou TB. Stem cells in the treatment of renal fibrosis: a review of preclinical and clinical studies of renal fibrosis pathogenesis. Stem Cell Res Ther. 2021;12:333. https://doi.org/10.1186/s13287-021-02391-w

115. Hidayat M, Prahastuti S, Yusuf M, Hasan K. Nutrition profile and potency of RGD motif in protein hydrolysate of green peas as an antifibrosis in chronic kidney disease. Iran J Basic Med Sci. 2021;24:734-43.

116. Hidayat M, Prahastuti S, Afifah E, Widowati W, Yusuf M, Hasan K. The role of green peas protein hydrolysate in TGF/Smad signaling to prevent renal fibrosis. J King Saud Univ Sci. 2022;34:101920. https://doi.org/10.1016/j.jksus.2022.101920

117. Vohra K, Dureja H, Garg V. An insight of pulses: from food to cancer treatment. J Pharmacogn Nat Prod. 2015;1(108). https://doi.org/10.4172/2472-0992.1000108

118. Rungruangmaitree R, Jiraungkoorskul W. Pea, *Pisum sativum* and its anticancer activity. Pharmacogn Rev. 2017;11(21):39. https://doi.org/10.4103/phrev.phrev_57_16

119. Mathers JC. Pulses and carcinogenesis: potential for the prevention of colon, breast and other cancers. Br J Nutr. 2002;88(S3):273-79. https://doi.org/10.1079/BJN2002717

120. Matscheski A, Richter DU, Hartmann AM, Effmert U, Jeschke U, Kupka MS, et al. Effects of phytoestrogen extracts isolated from

rye, green and yellow pea seeds on hormone production and proliferation of trophoblast tumor cells JEG3. Horm Res Paediatr. 2006;65(6):276-88. https://doi.org/10.1159/000092591

121. Martens LG, Nilsen MM, Provan F. Pea hull fibre: novel and sustainable fibre with important health and functional properties. EC Nutr. 2017;10:139-48.

122. Arora H, Shang N, Bhullar KS, Wu JP. Pea protein-derived tripeptide LRW shows osteoblastic activity on MC3T3-E1 cells via the activation of the Akt/Runx2 pathway. Food Funct. 2020;11:7197-207. https://doi.org/10.1039/D0FO00497A

123. Stanisavljevic NS, Ilic MD, Matic IZ, Jovanovic ZS, Cupic T, Dabic DC, et al. Identification of phenolic compounds from seed coats of differently colored European varieties of pea (*Pisum sativum* L.) and characterization of their antioxidant and *in vitro* anticancer activities. Nutr Cancer. 2016;68:988-1000. https://doi.org/10.1080/01635581.2016.1190019

124. Kabir SR, Nabi MM, Haque A, Zaman RU, Mahmud ZH, Abu Reza M. Pea lectin inhibits growth of Ehrlich ascites carcinoma cells by inducing apoptosis and G2/M cell cycle arrest *in vivo* in mice. Phytomedicine. 2013;20:1288-96. https://doi.org/10.1016/j.phymed.2013.06.010

125. Feng T, Huang YY, Tang ZH, Wei DD, Mo JM. Anti-fatigue effects of pea (*Pisum sativum* L.) peptides prepared by compound protease. J Food Sci Technol. 2021;58:2265-72. https://doi.org/10.1007/s13197-020-04737-3

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.