

CHAPTER-1

INTRODUCTION

1. Potential health benefits of garden pea seeds and peel

Pea (*Pisum sativum* L.), a nutritious agricultural commodity belongs to the Leguminosae family, has potential to withstand freezing temperature which is widely cultivated across the globe. [47, 97]. In terms of productivity, India stands as the second largest producer of green peas next to China and ranks ten among the vegetable crops.

The annual global production of green pea and dry pea seeds are approximately 14.5 million tons and 22 million tons, respectively (FAOSTAT, 2019, 60, 84). Pea seeds are well known for its pivotal nutrients that can be differentiated in mainly soluble and insoluble fibers, proteins (tryptophan and lysine), complex carbohydrates, vitamin B, folate, minerals viz., calcium, potassium, iron but low content of saturated fat, cholesterol, and sodium (Fig 1.1). Fresh green pea seeds contain 17-22g carbohydrates, 20-50g starch, 14-26g dietary fiber, 6.2-6.5g protein, 0.4g fat, 1.0g ash per 100g with 9-10mg calcium, 3-5mg sodium, 97-99mg potassium per 100g and vitamin contents are 0.7mg riboflavin, 5-6mg thiamine and folate 0.54mg per kg [59, 78, 31, 45, 19, 34]. It possesses various health benefits by lessening the prevalence of colon cancer, upbringing type-2 diabetes, coronary disease and LDL-cholesterol [47, 80]. Pea protein ranges from 244 to 275 g kg⁻¹ and starch content ranges from 440 to 462 g kg⁻¹ on dry basis [40]. In various countries, processed peas are in high demand which is used after dehulling and utilized as best source of dietary fiber and natural antioxidants. Chloroplast rich fractions are also being isolated from pea vine haulm by physical fractionation method using centrifugation [92]. Different processing methods viz., soaking, germination, fermentation, pasteurization, and incorporating advance techniques like pulse electric field or ultrasonication have shown remarkable impact on the efficiency by improving nutritional quality and techno-functional properties of pea and its protein [50, 58].



(a)



(b)



(c)



(d)

Fig 1.1 (a) Freshly obtained garden green peas, (b) Separation of green peas from its peel, (c) Green pea seeds, (d) Green pea peel or pea peels

1.1 Pea Peel

By-products defining something which has almost negligible use, may excreted out during the processing and create undesirable environmental pollution. Here the peel, or peel of the pea are considered as waste by-products which occupies 55% of the total volume of green peas at the fresh harvested time, the majority of which is disposed as waste and have not generally gained much attention intending to be used (Figure 1.1). Peapeel are agro-industrial by-products emanating from food industries and represents abundant source of natural food bioactive and phenolic antioxidants [33, 37]. Annually in India, peapod waste is discarded in a large amount of almost 1 million ton. Many peapod waste utilization has been reported for cellulolytic enzyme production, feed for the animals and ruminants [101]. Various literatures also reported that peapeel obtained from mature fresh green peas have remarkable amount of dietary fiber and protein and also calcium as compared to broad bean pod and okra by-products. Biscuits have been reported to be prepared with 20% peapod powder which was highly acceptable [28]. Literature also suggested that cake with 5% of pea pod flour is highly admissible and can avoid the addition of synthetic colour as it gives natural green pistachio colour [4]. The utilisation of the by-products is mainly of two reasons i.e., contribution to the diet positively and lesser quantity of anti-nutritional factors [90]. They also contain phenolic antioxidant which comes under bioactive non-nutrient compounds [95].

‘Functional foods’ are described as nutrients by addition which gives positive effects on biological metabolic activities by improving general state of health [78]. Generally the legume by-products possess higher dry matter digestibility, as a result it gives out more energy for metabolism [90]. In recent times, peapod fortified foods are considered to be functional foods as they contain a decent amount of fibers and essential minerals. Pea peel have protein denaturing property that shows anti-cholinesterase activity and anti-inflammatory effect and because of strong anti-diabetic properties of pea, it shows shielding effects against various disorders like reproductive damages, alloxan-induced hepatic and renal issues [57]. Thus, it enhances enzymatic antioxidant activity, anti-inflammatory effects and inhibit lipid peroxidation which shows a positive effect on health [57, 106]. Due to its seasonal and perishable nature, peas must be subjected to preservation as it is a rich source of nutrition and highly beneficial for health [84]. and thus it requires further processing. Pea and its by-product have much more positive effects which influence human health. Because of the universal application and

recommendation of pea as a nutritional food source, as well as being environmental friendly crop, the objective of this review has been focused on nutritional composition, the dietary recommendation for its consumption, effects of their consumption, and the role of various biomolecules on chronic diseases.

2. Nutritional Compositions

2.1 Carbohydrates

Pea carbohydrate has unique stability to high range viscosity and temperature in contrast to tuber starch or cereals [32]. Glucose, galactose, arabinose are present in pea's carbohydrate where stachyose and tetrasaccharide, are the most abundantly found polysaccharides. Polysaccharide extraction from peapeel are also reported which contain galactose, xylose, and arabinose as monosaccharides [5]. Glucose is derived from similar polymers of starch. Cellulose belongs to the largest part of the carbohydrate whereas other pectic polysaccharide derivatives are rhamnose, arabinose, galactose and uronic acids. Peas have 3.73% total oligosaccharides of total solids [93].

Basically, starch has three forms on the basis of digestibility of glucose release and its absorption into the gastrointestinal tract. They are rapidly digestible starch (RDS), slowly digestible starch (SDS) and the third one, resistant starch (RS) [24, 86]. After ingestion, there is a sudden hike of blood glucose quantity because of RDS fraction which is present nearly 9.2% to 10.7% and SDS fraction from 23.3% to 26.5% which gets digested completely but slowdown in small intestine. RS fraction changes its phase by fermenting itself in large intestine but still 10.1% to 14.7% does not get digested in the small intestine [16, 86]. The fractions of starch digested in the small intestine resulting to low glycaemic index which directly impacts the metabolic rate of digestions [32]. Starch is also composed of a linear glucan chain of amylose and highly branched molecular chain of amylopectin. The ratio of both imparts digestibility and postprandial glucose response. As pea contains $38.2 \pm 0.2\%$ apparent amylase [14], which results in reduced digestibility and low glucose release that contribute to low glycaemic index (Table 1.1). A natural mutation in pea seeds improves the starch assembly and glucose homeostasis [68]. α -Galactosides one of the oligosaccharides present in pea which may not get easily digested in the gastrointestinal tract. The high fermentability of these oligosaccharides leads to gas production which is responsible for digestive discomfort (Table 1.3). These non-digestible oligosaccharide food components potentially to be identified as prebiotic

agents and has positive impacts on consumer's health.

Table 1.1 Studies related to the metabolic health benefits and functions of pea and its by-products

Study type	Pea constituents	Result	Reference
Glycemic response, blood glucose and insulin resistance	Dietary fibers, carbohydrates	Enhance glucose tolerance, No change in glycaemic response, Lower PP insulin.	[16, 86, 57, 30]
Intestinal microflora and its fermentability	Pea proteins (glycated), dietary fiber	Help in homeostatis, improve gastrointestinal microbiota	[21]
Cardiovascular health	Dietary fibers, proteins and polyphenols	Lessen cardiovascular diseases, Reduce cholesterol level, improve serum lipid levels, reduce incidence of chronic disease	[3,86, 87]
α -Galactosidic effect / α -Galacto-oligosaccharides	α -Galactosidase	Normalising bowel functions, increasing lactobacilli and bifidobacteria	[77, 86]
Anti-acetylcholinesterase property (anti- AChE)	Anti-acetylcholinesterase, antioxidants	Anti-diabetic, antihyperlipidemic, reduce the risk of oxidative stress	[57, 30]
evention	Phenolic compound, isoflavin, dietary fibers	Anti-cancer activity, DNA repair, reduce inflammations	[86]
anagement	Dietary fibers, resistant starch, phytochemicals, oligosaccharides and many more	Increased stool weight	[86]

2.2 Protein

Peas are beneficial protein sources used as functional ingredient for many food industries. A variety of field pea contains 14.5-28.5 % protein where the range goes up to 24.4% to 27.4% [83, 59, 40, 76]. Pea protein is labelled as a non-allergic food substance with remarkably high nutritional value without any modification in the genetic profile [30]. Pea protein can broadly be classified into four major groups: globulin, albumin, prolamin, and glutelin where the main storage protein is globulin and albumin which accounts for 55-65% and 18-25%, respectively that help in seed germination (Table 1.2).

Globulin is divided into two types viz., legumin (hexameric protein, 320-400 kDa) and vicilin (trimeric protein, 150-180 kDa). Prolamin and glutelin are present in a small amount (Table 1.1) nearly 3-5% each. In crude protein of pea, there are 10-15% of non-protein nitrogen-containing materials and rest 70-80% of crude protein are hormones, enzymes, enzyme inhibitors, storage protein and some non-storage proteins. Solubility and modification of pea protein has been reported by using industry-scale microfluidization that will promote food industry to use pea protein without involving exogenous substances [38]. Quantities of essential amino acids and its bioavailability determine the nutritional profile of protein which is digested by the organism. Pea seeds are rich in threonine, cysteine, methionine, lysine, glycine, alanine, leucine and phenylalanine amino acids [64]. The protein content of pea seeds have a high level of lysine, leucine and phenylalanine but relatively less level of sulphur-containing amino acid viz., methionine and cysteine. Total α -galactosides, verbascose, arginine, glutamic, carotenoid pigments have positive correlation with protein content [76]. One of the proteins found in legume called lectins or phytohemagglutinin is able to agglutinate the red blood cells which are found in the pea [64]. Recent study showed that pea protein hydrolysates can inhibit the metabolic by-product, nitric oxide which could damage the cell excessively. Pasta like sheets were developed using protein and dietary fiber fractions from yellow pea [62]. Mixed sumiri gels also developed by pea protein isolates through partial substitution of myofibrillar proteins [7]. Fermentation using co-culture of LAB and yeast may improve the sensory defects in pea protein based products [23].

Table 1.2 Nutritional components of pea and pea peel

Study type	Pea constituents	Result	Reference
Glycemic response, blood glucose and insulin resistance	Dietary fibers, carbohydrates	Enhance glucose tolerance, No change in glycaemic response, Lower PP insulin.	[16, 86, 57, 30]
Intestinal microflora and its fermentability	Pea proteins (glycated), dietary fiber	Help in homeostatis, improve gastrointestinal microbiota	[21]
Cardiovascular health	Dietary fibers, proteins and polyphenols	Lessen cardiovascular diseases, Reduce cholesterol level, improve serum lipid levels, reduce incidence of chronic disease	[3,86, 87]
α -Galactosidic effect / α -Galactooligosaccharides	α -Galactosidase	Normalising bowel functions, increasing lactobacilli and bifidobacteria	[77, 86]
Anti-acetylcholinesterase property (anti-AChE)	Anti-acetylcholinesterase, antioxidants	Anti-diabetic, antihyperlipidemic, reduce the risk of oxidative stress	[57, 30]
Cancer prevention	Phenolic compound, isoflavin, dietary fibers	Anti-cancer activity, DNA repair, reduce inflammations	[86]
Weight management	Dietary fibers, resistant starch, phytochemicals, oligosaccharides and many more	Increased stool weight	[86]

2.3 Vitamins and minerals

Peas and its peel are rich in vitamins and minerals and have numerous health benefits [78, 29]. Potassium, a most prominent major mineral element which contains 1.04% of dry and dehulled weight of peas, followed by phosphorus, magnesium and calcium which were 0.39%, 0.10%, 0.08%, respectively and also rich in vitamin B [16, 59]. Various extractions were performed to isolate different types of vitamins and minerals where E group of vitamins entirely consists of β and γ tocopherols [8]. Field or garden pea seeds contained ranges of potassium (97-99mg/100g), calcium (9-11mg/100g), magnesium (5-7mg/100g), sodium (3-4mg/100g) and trace amount of copper, nickel,

selenium, folate and boron [59, 57]. Among them selenium and folate may be used as preventive measures against deficiency diseases thus it could be used as health promoting minerals [36].

In recent past, low phytate lines have been developed to reduce the concentration of phytate that are helpful in improving the mineral absorption [44]. Biofortification is an advancing method to improve the nutritional profile of pulse crop which lacks in micro-nutrients such as iron, zinc, folic acid, β -carotene, carotenoids, folates, iodine and many more by genetic engineering, agronomic intervention and plant breeding. Thus peas are rich in iron, zinc, manganese, and naturally low phytic groups, which can be used in biofortification and can be a hidden solution for nutrient deficient hunger [44, 1]. Pea seeds reported to be used as zinc biofortification combined with selenium which enhance the bioavailability in food products [78, 75, 70, 71]. Whereas phosphorous biofortification has been done to increase the soil microbiome in nutrient for higher pea production to combat micronutrient malnutrition [72].

2.4 Dietary fibers

Dietary fibers (DF) are compounds which restrict digestion (hydrolysis) by enzymes and consist of non-digestible carbohydrates. They are classified as soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) based on the water solubility (Table 1.1). Lignin, cellulose, and some hemicelluloses come under the category of IDF whereas β -glucans, galactomannans, pectin, inulin and other non-starch polysaccharides are part of SDF [51, 59].

Soluble fiber have excellent prebiotic and enhancer properties which have the potential to lower down the glucose absorption in small intestine and cholesterol reduction whereas the insoluble fiber are responsible for increasing faecal bulk, water absorption and intestinal regulation. Physiologically, the water absorption is more important in the body as it improves laxative effects and refines peristalsis. Mainly the insoluble fiber is derived from cereals whereas the soluble fiber is available in fruits and vegetables that is dissolved in water and fermented in the area of colon [77, 87].

Pectin is an abundant water-soluble partially methylated polysaccharide which is completely digested by colonic bacteria. Pectin with its gelling property may reduce the gastric emptying by influencing small intestinal transit moments which shows its

hypoglycemic properties [10, 46]. Investigation shows that pea contains 1.2- 1.7% pectin, 2.4% cellulose, 1.0% hemicellulose, 2.5% lignin [20]. The AOAC enzymatic-gravimetric hydrolysis methods are used for the extraction process of dietary fiber in peapeel. The latter have abundant glucose and xylose which is proved when the soluble sugars were processed under high-performance liquid chromatography (HPLC) that resulted glucose as a prominent component. The ferric reducing antioxidant power in peapod is 25.9 $\mu\text{molTrolox equivalents g}^{-1}$ and showed scavenging effect on 2, 2-diphenyl-1-picrylhydrazyl radical as 16.0 mgmL^{-1} were also measured [53].

The functional foods have a great economic impact as well as various health benefits. Dietary fibers have an incredible property to flourish into the fiber rich market. To satisfy this need, several sources have been identified and working for its extraction to be recovered from fruits, vegetables as well as wastes are on-going. There are many research methods used previously like dry processing, alkali wet milling, conventional wet milling, enzymatic-gravimetric, non-enzymatic gravimetric, microbial, chemical treatments, but there is no such standardized procedure for fiber extraction [51, Amongst other methods, the most frequently used methods are enzymatic-gravimetric method and ultrasound assisted alkali extraction method for TDF, SDF and IDF [89]. Acidic extraction method and cellulose assisted alkaline extraction method are some other procedures that are used to extract soluble dietary fiber and further optimized by response surface methodology (RSM) technique [41].

Table 1.3 Pea nutritional bioactive constituents and their effects on human health

Nutritional components	Function	References
Carbohydrate	Resistant starch acts as pre biotic. Increases faecal bulk, reduces colonic pH, reduce post-prandial glycemic response.	[86, 90]
Dietary fiber	Low glycemic response and insulin resistance. Improve cardiovascular health, decrease blood pressure, enhance serum lipid level, lower indicator of inflammation	[16, 87]
Protein	Glycosylated protein may escape small intestine, help in haemostatis and improve gastrointestinal microbiota.	[21]
Phenolic compounds	Antioxidant protect against disease such as cancer and various inflammatory	[52, 57, 30, 25]
Isoflavin	Anti-cancer activity, DNA repair, induction of apoptosis, cell proliferation migration and invasion	[6]
Lectin	Cytotoxic or tumor inhibition	
Saponin	Bind cholesterol and bile acid which may have hypocholesterolaemic effects	[52]
Oligosaccharide (α -galactosidase)	Normalising bowel function, increasing Lactobacilli and Bifidobacteria	[77]
Polyphenol	Antioxidant and reduce incidence of chronic diseases	[25, 77]

2.5 Phytochemicals and Antioxidants

Antioxidants are bioactive molecules having inhibitory function that reduced the damage caused by free radicals reactive species [30, 11, 86]. Many bioactive compounds combined together like phenolics, antioxidants and other phytochemicals which are non-nutritive elements present in pea by-products, whereas tannin found to be the essential natural antioxidants (Table 1.2). The metabolism of green pea hull phenolics, their absorption and *in vivo* antioxidant activities were also studied [33]. Concentration of phenolics present in seed coat of pea depends on the variety of seeds [25]. Numerous active phytochemicals determined in pea-like flavonoids along with daidzein, genistein, asparaginase, apigenin, lectin, kaempferol and several phenolic compounds include catechin, coumaric acids, caffeic acids, vanillic acids, ferulic, pisatin, protocatechuic, proanthocyanidin, steroid phytohormone and tannins [6]. Pea genotypes with different

maturity level and seed coat colour showed prominent phenolics, total flavonoids along with high antioxidant activities [18, 107]. Presence of techno-functional properties and phytochemical compositions in pea protein isolates could be used as value added ingredient in formulated foods [66]. Pea residues are considered to be a potential source of bioactive molecules that have been certified to exert a beneficial impact on human health [90]. Exploration of pea germplasm with high polyphenol content is helpful for pea breeding cultivars [43].

Oxidative injury can be inhibited by the antioxidative substances which have an active quenching effect against free radicals or damages (Table 1.3) caused by them [85, 35]. Antioxidant properties were determined from tannin crude extract from the seed coat of pea by phosphatidylcholine (PC) liposome system. Condensed tannins of coloured seed coat of pea were found to be 1560mg of catechin equivalent/100g [85]. Proanthocyanidines, condensed tannins present in seed coats (hulls) are also found in the legume seeds. There was a marked difference in the sum of free phenolic acids extracted from soluble esters and glycosides of coloured seed coat and the white seed coat that was 78.53g/g and 17.17g/g dry matter, respectively. The hydroxycinnamic acids, coumaric and ferulic were present in white seed coat and phenolic acids like vanillic, benzoic acids, protocatechuic, and gentisic were found in coloured seed coat [96].

The seed coat of peas has high concentration of glycosides, in particular luteolin, quercetin and apigenin and its cotyledon possesses hydroxycinnamic and hydroxybenzoic which have flavonol and flavone glycosides. Cotyledon also has conjugated compounds of malic acids which was p-hydroxybenzoyl-malic acid and trans p-coumaroyl-malic acid whereas seed coat has stilbene trans-resveratrol-3-glucoside compound only. Scientists investigated the bioactive compounds in different varieties of legume that grown in the cool season including pea using advance methods like UAE [69, 22, 105]. Phenols acts as a proficient agents that aid in chelating metal catalysts, eliminating free radicals, start-up antioxidant enzymes and impeding oxidases [39]. TPC (Total polyphenol content) concentration also differs in the colour of pea e.g, yellow pea had 0.85mg to 1.14mg whereas green pea had 0.65mg to 0.99mg of TPC. Flavonoids are known to be the secondary metabolites of plants, thus TFC (Total flavonoid content) in yellow pea and green pea were 0.09mg to 0.17mg and 0.05 mg to 0.15 mg, respectively (Table 1.4). Simple phenolic condensed to form tannins that show variation in molecular configuration and those phenolic split into hydrolysable and condensed pro-

anthocyanidins (polymers of flavan-3-ols). Condensed tannin content (CTC) was almost similar in yellow pea and green pea that was 0.22mg to 0.59mg and 0.23mg to 0.61mg, respectively (Table 1.4). Diphenylpicrylhydrazyl (DPPH) free radical scavenging is a trusted method for screening antioxidant which is important to prevent the detrimental effect of free radicals involved in different types of diseases, including cancer.

FRAP (Ferric reducing antioxidant power) analysis is used to find out the antioxidant property that prohibits the cell damage caused by the free radicals [105]. In recent advances through diet, due to increase in phytochemical, there is scope of enhancement of functional or designer food which would help in prevention of numerous diseases [9]. Green pea pod polysaccharide (GPPP) was extracted through an ultrasound extraction technique that showed an appreciable amount of scavenging activity (91.03%) by the free radicals obtained from DPPH assay [42]. It has a reducing power of 63% and also contains ferric reducing antioxidant power of 0.34 mmol/L which is obtained from a total amount of 0.9mg/mL. Different processing condition may reduce the level of antioxidant such as trypsin inhibitors, phytic acid and saponins thus improve the bioavailability of nutrients in pea [27].

Table 1.4 Phytochemicals and antioxidants content of pea and pea peel

Phytochemical and antioxidant	Pea	Pea peel	References
TPC (mg GAE/g extract)	1.53	32 ± 1	[57 , 25, 33]
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	
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	

2.6 *In vitro* Digestibility

The amount of enzyme digestibility differed significantly among species which subdivided in rapid digestible starch (RDS), slow digestible starch (SDS), and the third component resistant starch (RS) [15]. The *in vitro* digestibility of protein in raw pea is reported in some literature where, because of protease inhibitor, the digestibility reduced

whereas it was higher in soybean and several other pulses [49, 91, 80, 16]. The rate of hydrolysis between the native starches in pea was found to be 90% in 3 h which showed a significant affinity of the digestibility of starches in the short period [13]. The starch that present in the native form may not be able to provide a functional attribute. The experimental evidence based on enzyme hydrolysis of pea showed that amount of RDS, SDS and RS were found to be 27.0%, 62.9%, 10.0%, respectively, where, in case of gelatinized starch, the RDS, SDS and RS were 94.2%, 0.6%, 5.2%, respectively [14]. The value of RDS changed in gelatinized starch which was much higher than the previous value.

2.7 Anti-nutritional factor

Anti-nutritional compounds (ANCs) are those molecules that disrupt the digestion process. ANCs are generally non-fibrous natural substances causing negative effects on health in humans as well as in animals which affect growth along with the metabolic activity.

ANCs further systematized into two categories viz., protein associated ANCs and non-protein associated ANCs. Non-protein ANCs include alkaloid, phytic acid, phenolic compounds whereas the protein associated ANCs have lectins, chymotrypsin inhibitor, trypsin inhibitors, anti-fungal peptide and ribosome-inactivating proteins. The correct proportion of anti-nutrients to nutrients can break down the negative impacts on digestibility and perform a key role in cellular operation including antioxidant and anti-inflammatory activities [59]. Mild hydrothermal treatment has significant reduction in the level of α -galactosides, trypsin inhibitors and phytic acid and enhances the digestion of pea protein utilization [98].

Recent evidences have shown that there are some health benefits from protein anti-nutritional compounds present in the pea seeds like lectins and protease inhibitors which have the positive impact on immune deficiency by providing vitamins and minerals. The non-anti-nutritional compounds like angiotensin I-converting enzyme (ACE) inhibitor relaxes the veins and arteries to treat blood pressure. Lectins own the ability to bring down the effect of certain types of cancers by improving innate defence mechanisms and obesity. Trypsin and chymotrypsin which are protease inhibitors also showed the best result in preventing some cancers along with formidable anti-inflammatory properties. ACE inhibitor may also help in the reduction in hypertension [80].

3. Health benefits

3.1 Glycemic response, blood glucose and insulin resistance

The glycemic index (GI) is a comparative ranking arrangement that provides a relative analysis of carbohydrate levels in food models by measuring blood glucose levels. Carbohydrates having lower GI values (55 or less) are slow in digestion and absorption. The slow metabolism thus leads to lower hike in the absorption of blood glucose level; consequently decreasing insulin resistance. Pea is established on a lower rank on the glycemic index table having a GI value of 22. There is a scientific relation between blood sugar, insulin and glycemic index. The two key enzymes which are involved in breakdown of starch and intestinal glucose absorption are α -amylase and α -glucosidase, whose inhibition process have been recorded to slow down the transit period of carbohydrates that flows into the bloodstream [9]. The fiber and protein constituents of pea help in the process of slow digestion which, reversibly helps to smooth out the blood sugar level after eating. Excessive sugar intake is the reason to promote various diseases like obesity, diabetes and other heart relating diseases, and now the current research has evinced to unhealthy cholesterol and triglyceride level. The soluble fiber in food lowers the LDL cholesterol which is also known as bad cholesterol and keeps the blood glucose level steady (Table 1.1). Reduction in triglyceride level in blood plasma and in liver after ingestion of pea fiber supplementation is reported. Starches in the pea with low GI might be treated as an advantageous tool for well-being and distinctly for the elimination of diseases associated with the resistance of insulin [32]. It is also been reported that pea polysaccharides is potential in ameliorating diabetes-induced injury to pancreatic tissues [106].

3.2 Intestinal microflora and its fermentability

The microfloras that are present in the gut play an indispensable character in the process of food digestion, enhancing immunity, and other metabolic activities (Table 1.5). Dietary fiber is contemplated as one of the leading sources for energy utilization by microbes aggregating in the generation of different fermented outcomes; where short-chain fatty acids are treated as principal metabolite having neuroactive properties [52]. Apart from dietary fiber pea protein modulates both metabolic as well as the adhesive potential of intestinal bacteria to the cell lining and exert a health promoting effects on the local environments [30]. Gut luminal environment undoubtedly impacts the starch

structure by modulating its morphology which later on slows down the glucose availability that eventually lower the post prandial glucose (PPG) level [68].

Uncontrolled immune response of intestinal microbiome leads to prevalence of chronic intestinal inflammation which is termed as inflammatory bowel disease (IBD). The severe inflammatory area includes both the intestine and gives rise to serious chronic diseases: ulcerative colitis and Crohn’s disease [46]. The dietary fibers restore balance in the gut microbiota and influence the homeostasis directly in it.

Along with the pea seed, pea hull fiber has also been associated with modulation of gut microbiota, especially bifidobacteria [16]. Low-phytate biofortified pea varieties have positive effects on bioavailability of dietary iron, intestinal gut microbiome and improves brush border membrane (BBM) functionality [104]. Bifidobacteria shows beneficial health benefits in the gut by preventing enteric infections, and suppression of pathogenic bacteria which enhances the immune system of the host [73]. The non-digestible oligosaccharides, particularly fructo-oligosaccharide, activate the extension of bifidobacteria, which later on alter the composition of the colonic microbiota notably (Table 1.1). Although the prebiotic effect have been demonstrated widely in the field of oligofructose, fructo-oligosaccharides including inulin [32]. Pea fiber affected the gut microbiota along with a high protein diet. There are also some results shown by some group of scientists regarding the fermentability and digestibility of the pea hull fiber.

Table 1.5 Functional properties of pea peel

Functional properties	Constituents	References
Bulk density (g/mL)	0.8 ± 0.04	
Least gelation concentration (%)	12 ± 0.6	[4, 37]
Oil retention capacity (ORC) (g/g)	1.14 ± 0.06	
Water retention capacity (WRC) (g/g)	3.69 ± 0.18	
Swelling capacity (SC) (mL/g)	5 ± 0.25	
Foaming capacity (FC) (%)	23 ± 1.15	
Emulsifying activity index (EAI) (m ² /g)	14.45 ± 0.72	
Emulsion stability index (ESI) (min)	52.38 ± 2.62	

3.3 Cardiovascular health

Recently cardiovascular disease (CVD) is a prominent cause for increasing rates of death in the developing countries. Hypertension is directly linked with expansion of cardiovascular disease by enhancing blood pressure level [30]. Higher risk with 72% coronary heart disease (CHD) has been reported due to overweight and found prominent in obese women. Hypercholesterolemia is a major risk factor for CHD which is preventable through lifestyle measures [2]. Higher consumption of dietary fiber is associated with fewer cardiovascular diseases [88]. Experimental data demonstrated that higher intake of dietary fiber may lead to slowing down the process of low-density lipoprotein cholesterol (LDL-C) absorption as well as in fasting glucose concentration and decline possibilities of CHD (Table 1.1). Particularly, the water-soluble varieties of dietary fiber have highlighted in reducing the probability of cardiovascular disease [3]. The average dietary fiber intake was found to be around 29g per day. Person who consumed DF less than 29 g per day was found to have 38% of inflated risks for hypercholesterolemia and 43% increase in LDL cholesterol as compared to those consume more than the average DF intake [63]. Green peas are naturally packed with flavonols, carotenoids, vitamin C and antioxidants which lessen the chances of heart stroke by modifying cardiometabolic risks and various diseases related to heart because of their ability to protect the cells from damage [67, 103, 65].

3.4 α -Galactosidic / α -Galacto-oligosaccharides effects

α -Galactosides are important constituents obtained from sucrose having several units (1-3) of galactose conjugated by α -1,6 bonds. They have the properties of high solubility and rapid fermentation that were observed in colonic microflora (Table 1.1). They are considered as the ultimate source for energy required by plants but not utilised properly during the time of germination. Various types of gases (e.g. CO₂, H₂, CH₄) are released due to high fermentability that is responsible for digestive discomfort and flatulence caused by indigestible oligosaccharides. This non-digestible oligosaccharide which is soluble carbohydrates having low molecular weight is identified as prebiotic agents [87]. The oligosaccharides belong to the raffinose family creating interest in pulse research where raffinose, stachyose, and verbascose are treated as a broad base for experimentations. They are fermented in colonic flora that stimulates bifidobacteria which carries several beneficial health benefits having potential preservative effect

shows against colorectal cancer and infectious bowel diseases. Result showed improved carbohydrate and lipid metabolism as oligofructosaccharide cause suppression of hepatic triacylglycerol. The biosynthesis of these α -galacto-oligosaccharides are reported in some literature [32, 99].

3.5 Anti-acetylcholinesterase (anti-AChE) and antioxidant properties

The *in vitro* and *in vivo* studies have revealed that 32% of anti-acetylcholinesterase (anti-AChE) was found in peapod. Some antioxidants and protein denaturing properties were performed by *in vitro* whereas antidiabetic, cytoprotective and antihyperlipidemic properties were done by *in vivo*. The pea peel are rich in nutrients as it contains 24.34% carbohydrates, 13.37% crude protein, 51% fiber, 4.5% lipids and 4.5% ash (Table 1.1). The imbalance of free radicals is defined as oxidative stress that is closely associated with hyperlipidemia [48]. The profile of fatty acid (FA) of pea has mainly linoleic, linolenic and palmitic acids component which showed a promising anti-hyperlipidemic effect in reducing the risk of diabetes including the oxidative stress level and preventing organ damage viz., liver, kidney and testis [57, 30] (Table 1.1). These are essential fatty acids for human consumption that should be recommended in the diets.

3.6 Cancer prevention

The inclination of population towards the western diet which includes high fat, animal protein and refined carbohydrate effectively lowers their immune system and is prone to carcinogenic effects. Although diet is not considered to be carcinogenic agent, it may provoke the cancer causing elements [102]. The extracts of pea have proven to be pharmacologically active along with its anticancer activity [6, 81, 61]. Peas are usually a rich source of biologically active compound, which may have impactful effects that bring down the tumor risk when consumed at certain levels [55]. Generally, the yellow peas are excellent source for having isoflavones: genistein (dimerized) and daidzein (deoxydiglycosidic), that belongs to phytoestrogens which possess several important functions, including anti-carcinogenic effects. Genistein evinced the anti-proliferative out-turns on cell growth stimulated by mitogen of breast cancer cells in humans. This is a potential agent to be demonstrated in the field of reduction of breast cancer [56]. Besides there are several pieces of evidences which evinced that pulses which are rich in dietary fiber seem to contribute to lessening the effects of certain type of cancer especially colorectal and rectal cancer (Table 1.1). Other bioactive compounds found in pulses may have a

defensive role against cancer, those are resistant starch, non-starch polysaccharides, oligosaccharides, folate, selenium, zinc, saponins, lectins [56]. The presence of several bioactive micronutrients and phytochemicals in pea makes it a contributor towards a healthy diet and lessen the risk of cancer.

3.7 Weight management

Pulse consumption significantly reduced body weight under negative energy balance as well as neutral energy balance conditions [100, 61]. Fibers are known for their low caloric constituents which not only have nutritional attributes but also numerous functional benefits during digestion and assimilation inside the human body (Table 1.1). Pea fiber binds about 3 times water, however shows lower viscosity compared to wheat and potato fibers. Higher ingestion of fiber is been associated to lower the body weight [88]. Pea protein hydrolysates showed beneficial effects on obesity associated disorders. The pea ingredients are collectively responsible for body weight management having irrespective functions [82].

Furthermore, long term consumption of pea and its by-products are not adequately addressed and the nutritional values of peas and its peel has not been explored by genetic variation much to its full extent as some genetic traits are still unknown. In future, supplementation and incorporation of pea seeds and its pod could fulfill the emerging popularity of vegan, or flexitarian diet [78, 74]. Also it can enhance the infant food by supplementing with fiber rich prebiotic oligosaccharide properties as well as improve the efficacy and safety of crop biofortification and mineral bioavailability approach.

4. Modification of dietary fiber

There are various techniques used in order to modify the DF constituents such as chemical (alkali and acid method), physical (such as ultrahigh pressure, extrusion technology and ultrafine pulverization) and using biotechnology (mostly enzymatic method) that break the glycosidic bonds of IDF by lowering the degree of polymerization. The modification leads to the breakdown of pectic polysaccharide or the degradation of partial cellulose and hemicellulose into simple saccharide structure. Ash and pectine content also greatly reduced by the modification. The IDF microstructure linked together with bloc and platy shape where it possesses a dense structure having no pores. The modification removed the protein around the DF showing a spongy structure

having more porous structure exposed to hydroxyl groups. Biological and physical methods are highly recommended to modify DF where the enzymolysis modification can enhance the extraction yield and considered to an effective method for reducing the particle size because of their high efficiency, high specificity [106, 107]. In the colonic fermentation, the role of DF is significantly correlated with the digestive health. Research on prebiotic DF has evidenced that it modifies the specific gastrointestinal taxa by modulating the colonic bacteria (*Bifidobacterium*) [110]. So collectively prebiotic is the fermented ingredient conferring health benefits by altering the colonic micro-flora. As a result the intestinal transit improved by increase faecal bulk. Prebiotic stimulates no carcinogenic or genetic material but the decrease in pH and increase in SCFA (short chain fatty acids) production indicate the fiber fermentation which suggests a potential prebiotic effect. Modification of IDF showed smaller particle size, specific large surface area as well as the roughness on fiber that contribute to structural changes of dietary fiber to simple matrix enhances the fermentability that convey prebiotic effects on appropriate general health, as well as in technical aspects such as growth properties and industrial processing in functional food formulations.

5. CONCLUSION

The pea which is virtually grown worldwide for its edible seeds is nutritionally very rich and in addition it is laden with high dietary fiber, antioxidants, numerous important biomolecules and having low glycemic index and is extremely useful in curing diabetes, cardio problems, certain cancers and many degenerative diseases. The current review provides the nutritional information of peas and its underexploited by-products particularly its peel and focussing primarily on their impact on health and various functional properties. The desirable functionality of pea and its waste make them potentially suitable for food industry. Incorporation of dietary fiber in food model may change and improve the consistency, rheological behaviour, texture, and sensory properties of foods as well as the health directly. Yogurt is contemplated as symbiotic functional food because of its prebiotics and probiotics properties that provides therapeutic, nutritional implications to human health. The effect of different modifications in physicochemical, functional, and structural properties of pea peel dietary fiber has not been explored and also, limited studies have been carried out on the digestibility of pea peel insoluble dietary fiber and about its prebiotic potential.

Moreover, there is scanty of research on lactose free yogurt with modified pea peel insoluble dietary fiber. So the use of DF as functional food with low cost, rich in bioactive compounds and promising therapeutic effects without compromising its quality parameters enrich with prebiotic compounds can be obtained.

In the light of the above background and its importance, the following objectives have been undertaken in the proposed research work:

Objectives

1. To study the effect of various extraction methods on dietary fiber from pea peel and its process optimization
 - I. Study and optimization of conventional, ultrasound and ultrasound assisted alkaline extraction
 - II. Separation of insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) and study of physicochemical, functional, morphology and rheological properties of extracted IDF.
2. Modification of extracted insoluble dietary fiber and evaluation of its prebiotic potential and gastrointestinal effect
 - I. Modification of extracted optimized insoluble dietary fiber using enzymatic and extrusion based method
 - II. Study of *in vitro* gastrointestinal effect and prebiotic potential of extracted insoluble dietary fiber
3. Combination of extracted insoluble dietary fiber with yogurt for development of functional food
 - I. Effects of the level of dietary fiber on microbiota in yogurt
 - II. Development of yogurt with varying dietary fiber during storage and its rheological properties

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