

Review of the health benefits of peas (*Pisum sativum* L.)

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(Submitted 28 November 2011 – Accepted 13 December 2011)

Abstract

Pulses, including peas, have long been important components of the human diet due to their content of starch, protein and other nutrients. More recently, the health benefits other than nutrition associated with pulse consumption have attracted much interest. The focus of the present review paper is the demonstrated and potential health benefits associated with the consumption of peas, *Pisum sativum* L., specifically green and yellow cotyledon dry peas, also known as smooth peas or field peas. These health benefits derive mainly from the concentration and properties of starch, protein, fibre, vitamins, minerals and phytochemicals in peas. Fibre from the seed coat and the cell walls of the cotyledon contributes to gastrointestinal function and health, and reduces the digestibility of starch in peas. The intermediate amylose content of pea starch also contributes to its lower glycaemic index and reduced starch digestibility. Pea protein, when hydrolysed, may yield peptides with bioactivities, including angiotensin I-converting enzyme inhibitor activity and antioxidant activity. The vitamin and mineral contents of peas may play important roles in the prevention of deficiency-related diseases, specifically those related to deficiencies of Se or folate. Peas contain a variety of phytochemicals once thought of only as antinutritive factors. These include polyphenolics, in coloured seed coat types in particular, which may have antioxidant and anticarcinogenic activity, saponins which may exhibit hypocholesterolaemic and anticarcinogenic activity, and galactose oligosaccharides which may exert beneficial prebiotic effects in the large intestine.

Key words: Peas: *Pisum sativum* L: Health benefits

Pulses are defined by the FAO as legumes harvested solely for their seed which is consumed directly. The FAO list includes eleven primary pulses, including peas, and excludes the oilseed legumes and those consumed in immature form as vegetables⁽¹⁾. Peas, more specifically the yellow or green cotyledon varieties known as dry, smooth or field peas, are the naturally dried seeds of *Pisum sativum* L. and are grown around the world for human and animal consumption. World production of peas in 2009 was more than ten million tonnes, the major producers being Canada, the Russian Federation, China, the USA and India⁽²⁾. Peas have long been recognised as an inexpensive, readily available source of protein, complex carbohydrates, vitamins and minerals. The high nutrient density of peas makes them a valuable food commodity, capable of meeting the dietary needs of the estimated 800–900 million undernourished individuals worldwide⁽³⁾. The US Department of Agriculture *My Plate Guidelines* recommend consuming at least three cups of dry beans and peas per week⁽⁴⁾. The majority of the US population consumes

less than the recommended serving, with only 7.9% of adults consuming dry beans or peas on any given day⁽⁵⁾.

In recent years, many studies have identified potential health benefits of pulses, including peas, beyond meeting basic nutrient requirements. The purpose of the present paper is to provide a comprehensive review of the demonstrated and potential health benefits associated with pea consumption. The nutrient composition (summarised in Table 1)^(6–13) and phytochemical constituents of peas are described in order to provide context for the proposed mechanisms by which pea consumption benefits health. Limitations of current research and recommended future directions are discussed to encourage advancement in the field.

Compositional information

Protein

Peas are a valuable source of protein for both man and animals. The protein content of peas may be influenced by

Abbreviation: ppm, parts per million.

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Table 1. Compositional data for peas (*Pisum sativum* L.)^(6–13)

Constituent	Concentration (%)*
Protein (% N × 6.25)	21.2–32.9
Starch	36.9–49.0
Resistant starch	2.1–6.3
Amylose	20.7–33.7
Total dietary fibre	14–26
Insoluble fibre	10–15
Soluble fibre	2–9
Soluble sugars	5.3–8.7
Total lipid	1.2–2.4
Ash	2.3–3.4

* Values are expressed on a moisture-free basis except for amylose, which is expressed on a starch basis.

both environmental conditions and genetic factors^(6,14). Tzitzikas *et al.*⁽¹⁵⁾ found that the concentration of protein in fifty-nine pea lines ranged from 13.7 to 30.7% of seed DM, with an overall average of 22.3%. Hood-Niefer *et al.*⁽⁶⁾ reported an effect of environment on the concentration of protein in peas, but observed a narrow range in protein concentration (24.2–27.5% on a moisture-free basis) in ten genotypes grown in four locations in Saskatchewan, Canada, over two growing seasons.

The chemical and physico-chemical characteristics, processing and use of proteins from pulses, including peas, were reviewed recently by Boye *et al.*⁽¹⁶⁾. The majority of pea proteins are storage proteins, or globulins, and the amino acid profile of these proteins determines their nutritional value^(14,16). Tömösközi *et al.*⁽¹⁷⁾ compared the amino acid compositions of flour and protein concentrates and isolates from peas with corresponding products from lupin and soyabeans. The amino acid profiles of all products were similar overall, with the greatest contributions from glutamine, followed by aspartic acid, arginine and lysine, and the lowest contributions from methionine, tryptophan and cysteine. Products from peas tended to be higher in arginine, valine and methionine, and lower in glutamic acid and cysteine, than those from lupin and soyabeans. Relative to human requirements⁽¹⁸⁾, the protein in peas and other pulses is rich in lysine and marginal or deficient with respect to methionine. The *in vitro* digestibility of raw pea protein is reduced by the presence of protease inhibitors, although the digestibility of pea protein has been reported to be higher than that of soyabean and several other pulses^(16,19). The ability of peas to improve CVD and promote weight loss may be attributable to their high protein content⁽²⁰⁾. The bioactive proteins and peptides of several pulses, including peas, were reviewed recently by Roy *et al.*⁽¹⁹⁾. In that review, the negative physiological and nutritional effects of lectins and protease inhibitors in pulses are described, as are the potential nutraceutical effects of lectins, which include anticancer and immunomodulatory properties. Hydrolysis of pea and other pulse proteins generates peptides with a variety of bioactivities *in vitro*, including angiotensin I-converting enzyme inhibitor activity, which has an antihypertensive effect, and antioxidant activity⁽¹⁹⁾.

Complex carbohydrates

Starch and fibre are major components of peas, 46 and 20% of seed DM, respectively, on average⁽¹⁵⁾. The chemical attributes and functional characteristics of starch and fibre in pulses, including peas, were reviewed by Hoover *et al.*⁽²¹⁾ and Tosh & Yada⁽⁷⁾, respectively.

Starch is composed of amylose, a linear glucan with few branches, and amylopectin, a larger and more highly branched molecule. The ratio of amylose to amylopectin influences the digestibility of starch and thus its impact on the postprandial glucose response⁽²²⁾. Pea starch, like that of most other starchy pulses, contains an intermediate level of amylose, which is reflected in its unique functionality and its higher levels of enzyme-resistant starch and slowly digestible starch (as compared with cereal, root and tuber starches, most of which are lower in amylose)⁽²¹⁾. The relatively low degree of digestibility of starch in pulses has also been attributed to the non-availability to amylases of starch granules enclosed in intact cell wall structures, the presence of anti-nutrients such as amylase inhibitors, phytates and phenolics, and their significant content of dietary fibre⁽²³⁾. Perera *et al.*⁽²⁴⁾ concluded that variety, processing method and analytical methodology all affected starch digestibility, specifically levels of resistant starch, in peas and other pulses. Flours from three pea genotypes contained 9.2–10.7, 23.3–26.5 and 10.1–14.7% of rapidly digestible starch, slowly digestible starch and resistant starch, respectively⁽²⁵⁾. Starch isolated from the same three genotypes consisted of 18.2–23.8, 53.7–59.0 and 8.1–12.6% of rapidly digestible starch, slowly digestible starch and resistant starch, respectively⁽²⁶⁾. The proportion of the starch in peas that is slowly digestible is noteworthy. Annealing and heat-moisture treatment of pea starch had variable effects on the *in vitro* digestibility of pea starch^(23,27). The effect of treatment on starch digestibility was variety dependent, and with all treatments, gelatinisation of starch converted essentially all of the slowly digestible starch, and in some cases most of the resistant starch, to rapidly digestible starch.

The amylose content of pea starch has been reported to vary widely among varieties and mutant lines⁽²⁸⁾. Starch from wrinkled peas, which are technically not pulses since they are consumed in immature form as a vegetable, contains 60% or more of amylose⁽²¹⁾. Wrinkled pea starch has been reported to contain 76.8% amylose and 4.5–17.7% of resistant starch, as compared with 27.8% amylose and 2.1–6.3% resistant starch in smooth peas, with the concentration of both amylose and resistant starch dependent on variety and the growth environment⁽¹³⁾. Hood-Niefer *et al.*⁽⁶⁾ saw no effect of variety or environment on the amylose content of pea starch. However, this study did not include wrinkled pea varieties.

Dietary fibre in peas arises from both the seed coat (outer fibre), commonly referred to as the hull, and the cotyledon (inner fibre). The seed coat contains largely water-insoluble polysaccharides, primarily cellulose, whereas the cotyledon fibre consists of polysaccharides having various degrees of solubility, including hemicelluloses and pectins, along with cellulose^(7,28,29).

The properties of both their starch and fibre constituents make peas a low-glycaemic index food, and hence beneficial in the prevention and management of type 2 diabetes⁽³⁰⁾. In addition, fibre may reduce blood cholesterol by decreasing the reabsorption of bile acids⁽³¹⁾. Peas, like other legumes, contain significant concentrations of raffinose-family and other galactose-containing oligosaccharides⁽⁷⁾ which may exert prebiotic effects in the large intestine⁽³²⁾.

Vitamins and minerals

Reichert & MacKenzie⁽²⁹⁾ determined the concentrations of the major minerals in four pea samples. Potassium (1.04% of dry, dehulled weight) was found to be the most prominent element, followed by P (0.39%), Mg (0.10%) and Ca (0.08%). The quantities of seven trace minerals also were measured. The pea samples contained an average of 97 parts per million (ppm) Fe, 42 ppm Se, 41 ppm Zn, 12 ppm Mo, 11 ppm Mn, 9 ppm Cu and 4 ppm B. Gawalko *et al.*⁽³³⁾ determined that yellow peas from Canada contained higher levels of Fe, Mg and Mn, but lower levels of K, compared with green peas. In the same study, Se was found to exceed the maximum residue level established by the People's Republic of China in 56% of the samples analysed. However, Se is considered an essential element, and this maximum residue level value is currently being re-evaluated. The authors suggested that peas produced in Canada may be beneficial for areas of the world where Se deficiency is prominent.

Despite the high mineral content of peas, bioavailability may be poor due to high phytate concentrations. Sandberg⁽³⁴⁾ reported that phytate acts as an inhibitor of Zn, Fe and Ca absorption. A study by Trinidad *et al.*⁽³⁰⁾ found that phytate content affected Fe but did not influence Zn and Ca availability in pulses. In fact, these authors concluded that when Fe availability was low, Ca and Zn availability was high. The study also reported that peas have greater *in vitro* Ca bioavailability compared with other pulses. More research should be carried out to understand the effects of food processing techniques on phytate degradation. If phytate is degraded, peas could be considered a significant source of Ca, Zn and Fe⁽³⁴⁾.

Dang *et al.*⁽³⁵⁾ reported that peas contained 101 µg folate per 100 g. Han & Tyler⁽³⁶⁾ determined that the concentration of folate in two yellow pea genotypes grown in six locations in 1 year in Saskatchewan, Canada, ranged from 23.7 to 55.6 µg/100 g DM, as determined by a microbiological assay; concentrations of folate in two green pea genotypes grown in three locations in each of two growing seasons ranged from 24.9 to 64.8 µg/100 g DM. Low dietary folate levels have been associated with anaemia and neural tube defects in humans^(35,36).

Phytochemicals

The concentrations of minor constituents in pulses, including peas, and their potential impacts on human health were reviewed recently by Campos-Vega *et al.*⁽³⁷⁾. Peas, like other pulses, contain a variety of phytochemicals, including phenolic compounds, phytates, saponins and oxalates. The major

phenolic constituents in pulses are tannins, phenolic acids and flavonoids⁽³⁷⁾. Phenolic compounds have been recognised for their ability to act as antioxidants and are the best characterised phytochemicals in peas. Peas contain a variety of phenolics, with the highest concentrations of most occurring in the seed coat, particularly in dark-seeded varieties^(37–40). Accordingly, Xu *et al.*⁽⁴⁰⁾ determined that the antioxidant activity of pea varieties was correlated significantly with seed coat colour. Examination of the seed coat and cotyledon in two dark-coloured pea varieties revealed that the seed coat contained glycosides of quercetin, luteolin and apigenin, along with a variety of simple phenolics and proanthocyanadins. The cotyledon contained mainly hydroxybenzoic and hydroxycinnamic compounds and some of the glycosides found in the seed coat⁽³⁹⁾.

Peas contain other minor constituents which exhibit bioactivity and which may have positive benefits on human health, including saponins and phytates, which may exhibit hypocholesterolaemic and anticarcinogenic activities⁽³⁷⁾.

Evidence for health outcomes

Epidemiological, *in vitro* and interventional studies all have demonstrated the role of peas and pea constituents in maintaining metabolic, cardiovascular and gastrointestinal health in humans. Table 2 summarises the clinical evidence.

Glycaemic response and insulin resistance

Due to their high fibre content, peas may mediate the glycaemic response as compared with low-fibre foods with equal carbohydrate proportions. A randomised controlled study by Marinangeli *et al.*⁽⁴¹⁾ investigated the use of whole yellow pea flour to create foods with a lower glycaemic index than comparable foods made from wholewheat flour. The results demonstrated that foods made with whole yellow pea flour reduced postprandial glucose responses in individuals and, thus, may have a role in the management of type 2 diabetes.

Marinangeli & Jones⁽⁴²⁾ compared the use of whole pea flour (WPF) and fractionated pea flour (FPF; pea hulls) on insulin resistance. WPF and FPF reduced fasting insulin levels by 13.5 and 9.8%, respectively, compared with baseline. Homeostatic model assessment of insulin resistance (HOMA-IR), a method used to quantify insulin resistance and β-cell function, revealed that insulin resistance was reduced by 25% in both the WPF and the FPF groups compared with the control group receiving white wheat flour. HOMA-IR showed no difference in β-cell function among groups.

A study by Seewi *et al.*⁽⁴³⁾ compared the use of yellow pea flour and pea starch with maize starch on glycaemic response and found a benefit with both pea flour and pea starch. Lunde *et al.*⁽⁴⁴⁾ found that bread containing 17% pea hull fibre significantly reduced glycaemic response; however, the fibre breads also contained higher protein.

Table 2. Clinical studies related to the metabolic, cardiovascular and gastrointestinal health outcomes of peas

Reference	Study type	Study size/participants	Length of study	Treatment products	Control products	Background diet	Percentage change
Glycaemic response and insulin resistance							
Marinangeli & Jones (2011) ⁽⁴²⁾	Randomised, controlled clinical study	Twenty-three hypercholesterolaemic, overweight patients	28 d followed by 28 d washout periods	50 g carbohydrate from WPF or 50 g FPF	50 g carbohydrate from white wheat flour	NCEP-Step 1 diet, energy intake adjusted based on individual RMR so participants did not gain or lose weight	WPF: 13.5% reduction in fasting insulin and 25% reduction in insulin resistance (HOMA-IR) FPF: 9.8% reduction in fasting insulin and 25% reduction in insulin resistance (HOMA-IR)
Marinangeli <i>et al.</i> (2009) ⁽⁴¹⁾	Randomised, controlled cross-over clinical study	Twenty-two healthy patients	1 d	50 g carbohydrate from whole yellow pea flour in banana bread (100%), biscotti (100%) and pasta (30%)	50 g carbohydrate from wholewheat flour in banana bread (100%), biscotti (100%) and pasta (100%)	No change to normal background diet	Banana bread: 61.9% reduction in IAUC Biscotti: 55.1% reduction in IAUC Pasta: 43.1% increase in IAUC
Seewi <i>et al.</i> (1999) ⁽⁴³⁾	Randomised, controlled clinical study	Ten healthy patients	1 d	30 g carbohydrate from pea starch dissolved in 500 ml cold tap water	30 g carbohydrate from maize starch preparations dissolved in 500 ml cold tap water	No change to normal background diet	Pea starch: 47% reduction in post-meal glucose, 54% reduction in serum insulin, and 37% reduction in C-peptide responses
Cardiovascular health							
Sandström <i>et al.</i> (1994) ⁽⁴⁶⁾	Randomised, controlled cross-over clinical study	Eight healthy male patients	2-d treatment period with 2-week washout where patients consumed their habitual diets	7.4 g pea fibre product added to breakfast and 9.3 g pea fibre product added to the following lunch baked into bread	Low-fibre diet matched for energy content and macronutrient distribution	Diet matched for macronutrient distribution: 37% energy from fat, 14% from protein and 49% from carbohydrate	Pea fibre: trend to lower postprandial TAG ($P < 0.01$); no change in fasting lipid profile
Trinidad <i>et al.</i> (2010) ⁽³⁰⁾	Randomised, controlled clinical study	Twenty patients with moderately elevated cholesterol	Six, 2-week treatment periods, each separated by a 2-week washout	50 g carbohydrate from green peas, cowpeas, mung beans, pole sitao, chickpeas, groundnuts, pigeon peas or kidney beans	Individuals served as their own controls	No change to normal background diet (foods were recorded during the experimental period)	Pea product: no significant reduction in total or LDL-cholesterol levels
Gastrointestinal health							
Dahl <i>et al.</i> (2003) ⁽⁵⁰⁾	Controlled clinical study	114 elderly patients	4-week baseline followed by 6-week treatment period	4 g pea hull fibre added to foods	Foods without added fibre	Daily menu administered by long-term care institution for the elderly	Pea fibre: 7.5% increase in bowel movement frequency
Flogan & Dahl (2010) ⁽⁵¹⁾	Randomised, controlled cross-over clinical study	Thirteen paediatric patients with a history of constipation and/or abdominal pain in the past 12 months	3-week treatment, 3-week placebo period	5 g of inulin, two servings of study snacks with 1.4–3.4 g added pea hull fibre	5 g of maltodextrin and two servings of study snacks without added fibre	No change to normal background diet (3 d food intake records were taken for each 3-week period)	Pea fibre: 24% increase in bowel movement frequency

Table 2. Continued

Reference	Study type	Study size/participants	Length of study	Treatment products	Control products	Background diet	Percentage change
Veenstra <i>et al.</i> (2010) ⁽⁵²⁾	Randomised, controlled cross-over clinical study	Twenty-one healthy male patients	28-d treatment period	100 g dry weight green peas, Kabuli chickpeas or green Laird green lentil	100 g dry weight potatoes	No change to normal background diet	Green peas: no differences in bowel movement frequency or perceived flatulence, bloating, cramping and intestinal discomfort compared with potatoes or other pulses Pea starch: 21 % decrease in H ₂ exhalation and 65 % decrease in flatulence
Seewi <i>et al.</i> (1999) ⁽⁴³⁾	Randomised, controlled clinical study	Eight healthy patients	36-h treatment (five meals)	30 g carbohydrate from pea starch dissolved in 500 ml cold tap water	30 g carbohydrate from crude yellow pea flour dissolved in 500 ml cold tap water	No change to normal background diet	

WPF, whole pea flour; FPF, fractionated pea flour; NCEP, American Heart Association's National Cholesterol Education Program; HOMA-IR, homeostatic model assessment of insulin resistance; IAUC, incremental area under the curve.

Cardiovascular health

Fibre-rich diets have been shown to lower blood pressure, improve serum lipid levels and reduce indicators of inflammation⁽⁴⁵⁾. Sandström *et al.*⁽⁴⁶⁾ investigated the effect of fibre preparations made from pea cell wall fibre on cardiovascular health. Subjects placed on the pea fibre diet showed a trend for lower postprandial TAG responses compared with subjects on a low-fibre diet matched in macronutrient content. However, no changes were seen in fasting lipid concentrations. In a randomised, cross-over intervention study, Trinidad *et al.*⁽³⁰⁾ found no differences in serum total, LDL- or HDL-cholesterol after 2 weeks of consumption of cooked, cooled peas. The failure to affect serum cholesterol may have been due to the short length of follow-up (2 weeks). Other studies of mixed legume diets have demonstrated significant improvements in markers of cardiovascular health^(20,47,48).

Weight management

The impacts of a hypoenergetic diet rich in various legumes have been investigated^(20,47). However, little research relating pea intake to weight control has been undertaken. Lang *et al.*⁽⁴⁹⁾ showed no effect of pea protein on satiety, 24 h energy or macronutrient intakes, or on postprandial plasma glucose and insulin concentrations when compared with egg albumin, casein, gelatin, soya protein and wheat gluten. Lunde *et al.*⁽⁴⁴⁾ found that pea fibre-enriched bread increased duration of satiety, when compared with intake of regular bread. Research is needed to understand how peas specifically may influence weight management, with body weight, BMI or waist circumference as primary endpoints.

Gastrointestinal function and homeostasis

The effects of peas and pea fractions on gastrointestinal function and symptoms have been investigated. Dahl *et al.*⁽⁵⁰⁾ demonstrated that the addition of 4 g pea hull fibre per d resulted in a significant increase in bowel movement frequency in residents of a long-term care facility, particularly in those with the lowest frequency. Flogan & Dahl⁽⁵¹⁾ showed that the addition of pea hull fibre to snack foods, in combination with an inulin fibre supplement, provided to children with constipation significantly increased bowel movement frequency; no adverse symptoms were reported. Veenstra *et al.*⁽⁵²⁾ investigated the effect of consuming 100 g dry weight of peas per d for 4 weeks and found no differences in bowel movement frequency or perceived flatulence, bloating, cramping and intestinal discomfort compared with potatoes, chickpeas and lentils, with the exception of increased cramping in the early phase of the treatment with peas. Seewi *et al.*⁽⁴³⁾ compared the use of yellow pea flour and pea starch and found that pea starch caused less flatulence in study participants and was more tolerable than pea flour.

Although peas contain potential prebiotic oligosaccharides as well as resistant starch and fermentable fibre, limited research has been carried out on the effects of consumption of peas and pea fractions on gastrointestinal microbiota and

related health outcomes. Pea proteins often undergo spontaneous glycosylation during storage and processing due to the high concentration of lysine. A study by Swiatecka *et al.*⁽⁵³⁾ demonstrated that glycosylated pea proteins may escape enzymic breakdown early in the small intestine and may have an impact on the homeostasis of the large intestine by modulating the activity of the microbiota. Dominika *et al.*⁽⁵⁴⁾ used human gastrointestinal tract simulators to predict the effects of glycosylated pea proteins on intestinal bacteria. Results of the study demonstrated a significant increase in autochthonic bacteria (*Bacteroides*, *Lactobacillus* and *Bifidobacterium*) and a subsequent increase in their metabolic activity and production of SCFA. Researchers concluded that pea proteins could be used to improve intestinal microbiota homeostasis. Research is needed to explore the potential impacts of consumption of peas and pea fractions on gastrointestinal microbiota and wellness.

Antioxidant activity

Phenolic compounds are considered natural antioxidants that may help protect against diseases such as cancer and various inflammatory-related diseases. Dueñas *et al.*⁽³⁹⁾ confirmed the presence of phenolic compounds in the seed coat and cotyledon of peas. A study by Troszynska & Ciska⁽³⁸⁾ compared the phenolic composition and antioxidant activity of white and coloured peas. Phenolic acids were found in both free and esterified form in both white and coloured peas, but higher concentrations were seen in the coloured varieties. Condensed tannins, which have been shown to have very high antioxidant activity⁽⁵⁵⁾, were detected only in the coloured seed coats. The phenolic compounds were extracted with acetone and methanol, and the liposome system was used to measure antioxidant activity via the extent of peroxidation of phosphatidyl choline. The antioxidant activity in the acetone extract from the coloured seed coats was significantly higher than in the white coat extract. These properties were slightly altered by cooking the seeds for 30, 60 or 90 min. More research should be done to investigate the heat stability of polyphenols in peas.

Current research on the antioxidant activity of peas is limited to *in vitro* studies. Intervention studies are needed to investigate the efficiency of pea antioxidant activity in providing health benefits to humans.

Limitations of current knowledge and future directions

Current research on the health benefits of peas does not adequately address long-term consumption. Future studies should address the differences between acute and chronic consumption. There is also a lack of long-term studies with large, diverse (ethnicity, sex, age, etc.) subject populations.

Currently there is limited understanding of how food processing methods affect the physicochemical properties of peas, as well as a need for research looking at the effects of various pea fractions (i.e. fibre, protein, starch) on relevant health outcomes. In addition, further research is needed to identify whether different genotypes of peas are more

effective in achieving the specific health benefits discussed in the present paper.

Summary

The present review briefly describes the nutritional characteristics of peas, along with demonstrated and potential health benefits associated with their consumption. Although some health benefits, such as improved gastrointestinal function and reduced glycaemic index, have been documented, others require further research.

Acknowledgements

The authors declare no conflicts of interest and no funding was received for the preparation of this paper. All authors contributed substantially to the preparation of the manuscript.

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