ECRONICON OPEN ACCESS

EC NUTRITION

Mini Review

# Pea Hull Fibre: Novel and Sustainable Fibre with Important Health and Functional Properties

**Laura Gil Martens[1]*, Mari Mæland Nilsen[2] and Fiona Provan[2]**

*[1]AM Nutrition AS, Stavanger, Norway*

*[2]IRIS (International Research Institute of Stavanger), Norway*

***Corresponding Author**: Laura Gil Martens, R & D Department, AM Nutrition AS, Stavanger, Norway.

**Received:** July 19, 2017; **Published:** August 23, 2017

## Abstract

Pea hull fibre (PHF) represents an important source of fibre and has been shown to exert various beneficial physiological effects in human health. Rich in dietary fibre and in bioactive components, such as polyphenols and iso-flavonoids, PHF is a valuable ingredient in the mitigation of a number of cardiovascular and chronic metabolic diseases, such as diabetes and metabolic syndrome, among others. From a nutritional point of view, PHF is an ideal ingredient to improve dietary fibre content in human dietary regimes due to its low energy content, low fermentation potential, good bulking properties and relatively neutral taste. Furthermore, PHF exerts positive functional properties in the formulation of foods due to a high water and oil binding capacity and increased viscosity, among other important food technological properties. The purpose of the present paper is to review the existing literature and current state of the art regarding health benefits and functionality associated with the consumption of PHF.

***Keywords:*** *Pea Hull Fibre (PHF); Dietary Fibre; Yellow Peas; Pea Concentrates*

## Abbreviations

PHF: Pea Hull Fibre; CVD: Cardiovascular Diseases; SCFA: Short Chain Fatty Acids

## Introduction

Dietary fibre is an important component in human dietary regimes, especially when taking into consideration the increasing prevalence of obesity and related metabolic disorders affecting the global population nowadays. Pulses, the edible seeds of leguminous crops, are a rich source of dietary fibres that promote various beneficial physiological effects in human health [1].

Yellow peas (*Pisum sativum*) have historically been part of the human diet due to their wide availability, low cost and high nutritional value. Peas are important sources of high quality protein, starch, dietary fibre, minerals and vitamins. In addition, peas contain a wide range of phytochemicals with known bioactivity and potential health effects.

Dietary fibre is a key component in the human diet due to its beneficial effects on a number of metabolic functions such as reducing plasma lipid levels, improving glucose metabolism and enhancing satiety that helps to reduce food intake [2,3]. Pea hull fibre represents an important source of dietary fibre [4].

Epidemiological studies have consistently shown an association between consumption of pulses and a reduced risk of obesity, diabetes mellitus and components of metabolic syndrome [5]. In fact, high-fibre diets based on whole grain cereals, legumes, fruits, and vegetables have been prescribed in the management of various colonic and circulatory disorders [6].

There are two sources of dietary fibre in yellow peas: "outer fibre" and "inner fibre". The first fraction consists of the seed coat and is known as pea hull fibre (PHF), while the second fraction corresponds to the cotyledon fibre. The outer fibre contains non-soluble polysaccharides, primarily cellulose, whereas the cotyledon fibre consists of polysaccharides including hemicelluloses and pectin, as well as cellulose [1]. Recent literature has described the overall nutritional and potential health effects of pulses, particularly yellow peas, very well [7,8], while only few papers have focused on the potential role of PHF in human nutrition and health. Some of these studies were conducted using rodents as the experimental model, while the literature regarding metabolic effects of PHF in humans specifically is limited to just a few studies [3]. Some of the reported effects associated with ingestion of PHF are modulation of blood glucose levels, the cholesterol and phospholipids' metabolism [9,10], as well as to impact on gastro-intestinal function and health [7,11].

There is a need to obtain a more complete overview of the state of the art concerning the composition of the fibre fraction of peas in order to create awareness of their important role in nutrition and promote the use of PHF in human food [12].

The purpose of the present paper is to review the existing literature related to functionality and health benefits associated with the consumption of PHF. Furthermore, the current document aims to give insight to food manufacturers, health care professionals and consumers on the potential role of PHF in the formulation of functional foods that improve long-term health.

## Pea hull fibre structure and composition

Pea hulls consist mainly of a mix of soluble and insoluble dietary fibres (SDF and IDF) in which insoluble cellulose is present in the majority. Ideally, if pea hulls were purified and up-concentrated in a fraction, the total amount of dietary fibre content would be around 75 - 80% of the dry matter (L. Martens, internal comm.). According to McCartney and Knox [13], from a structural point of view, PHF consists of four layers: the outer macrosclereid layer with thickened cell walls, a layer of osteosclereids and two parenchyma layers. This structure forms a tough outer covering for the seed and has different mechanical properties than the inner fibre present in pea cotyledons.

The insoluble fibre fraction consists of cellulose (60 - 70%), hemicelluloses (3 - 9%) and lignin (< 1%), while soluble fibres are mainly represented by pectin and pectic substances such as homogalacturonans, rhamnogalacturonan I, rhamnogalacturonan II [13] and xylogalacturonans [14] (Figure 1).

The amount of soluble fibre in PHF can range between 16 - 21% on dry matter basis.

| **Nutrient composition**<br>**Approx. value, %** | |
|---|---|
| Dry matter | 89 |
| Dietary fibre | 80 |
| Protein | 3.6 |
| Fat | 1 |
| Oligosaccharides | 4.6 |
| Simple sugars | 5.4 |

DM, dry matter basis

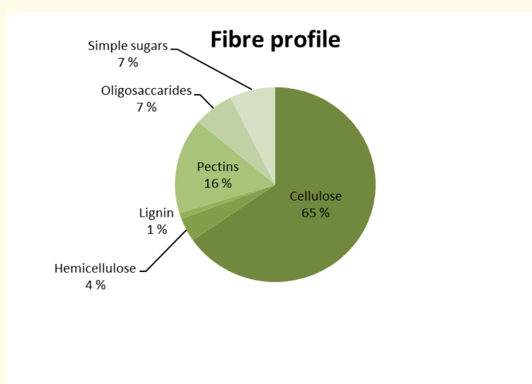


***Figure 1:*** *Typical composition of PHF commercially available for the food market. Source: AM Nutrition, Stavanger, Norway.*

Cellulose is a polysaccharide consisting of a linear chain of several hundred to many thousands of β(1→4) linked D-glucose units. In a randomized crossover study designed to compare the effects of supplemental pectin (12 g/day), cellulose (15 g/day) and lignin (12 g/day) on stool characteristics in healthy volunteers, cellulose was shown to increase faecal bulk. Cellulose was the only type of fibre that significantly decreased mean stool transit time by 27% and increased mean wet stool weight by 57% [15].

Pectin is an important cell wall polysaccharide that allows primary cell wall extension and plant growth. Pectin is not a large bulking agent with respect to stool weight. However, pectin was shown to have a hypocholesterolemic effect [16,17], and regulate postprandial triglyceridaemia [18]. Viscous fibres, such as pectin, were found to induce a significant reduction in glycaemic responses in 33 of 50 studies (66%) [19].

**PHF and it antioxidative activity**

Legume seed coats are important sources of polyphenolics and natural antioxidants, which could eventually replace the synthetic antioxidants in foods [20]. A number of studies on phenolic and other compounds with antioxidative effects in pulse hulls are available in the literature, with flavonoids being the most important compounds found in this fraction [21-23]. According to Dueñas., *et al*. [21], flavones, flavonols, and pro-anthocyanidins are the compounds that make a major contribution to the antioxidant activity in pea hulls, whereas the flavonoid catechin is the major antioxidant contributor in the cotyledon fraction.

As indicated in table 1, yellow pea hulls contain almost twice the concentration of total phenolics and over six times the anthocyanin content thanthe whole pulse seed.

| Mill streams Concentration[a] | | | | | TEAC[b](ORAC) | |
|---|---|---|---|---|---|---|
| Yellow peas | Total phenolics | Tartaric esters | Flavonoids | Anthocyanin | Mg/g | Umol/g |
| Whole | 3.45 | 0.30 | 0.16 | 0.020 | 2.59 | 10.36 |
| Hull | 6.89 | 0.81 | 0.45 | 0.136 | 5.73 | 22.89 |
| Residue | 5.69 | 0.52 | 0.43 | 0.134 | 10.15 | 40.56 |

***Table 1:*** *Phenolic content and antioxidant activity of pulses extracted with acetone.*

*(Adapted from [24])*

*(a) Concentration of phenolic compounds is expressed as mg (+) catechin, caffeic acid, quercetin, or cynidin-3-glucocyde equivalent per gram sample (dry matter) for total phenolics, tartaric esters, flavonoids and anthocyanins, respectively.*

*(b) Trolox equivalent antioxidant capacity.*

**PHF and its health benefits**

A number of chronic diseases such as cardiovascular diseases (CVD), obesity, and diabetes are continuously growing in the world population [25,26]. The role of blood glucose levels in the development of some of these diseases has been demonstrated [27], in particular, post prandial blood glucose seems to have an important role in the development of diabetes 2 and CVD [28,29], therefore its reduction might help to mitigate chronic diseases in general. Pulse hulls are naturally rich in dietary fibre, ranging from 75% (chickpeas) to 87% (lentils) and 89% (peas) of the dry matter [30]. Pulses are also an important source of bioactive compounds including lectins, phytates, oligosaccharides and phenolic compounds [12]. Some of these compounds have a dual role in human metabolism, since they can both benefit certain metabolic functions but also limit others, as indicated in table 2 [31,32].

| Bioactive compound | Negative effects | Positive effects | Mechanisms of action |
|---|---|---|---|
| Enzyme inhibitors Lectins | Diminish protein digestibility Reduce nutrient absorption | Enzyme inhibitors and lectines have reduced activity after cooking | Complementary and overlapping. Modulation of detoxifying enzymes, stimulation of immune systems, regulation of lipid and hormone metabolism, antioxidant, antimutagenic and antiangiogenic and anticarcinogenic effects |
| Phenolic compounds | Reduce protein digestibility and mineral bioavailability | Antioxidant activity and other important physiological functions | |
| Galactoligosaccharides | May cause flatulence | Pre-biotic activity | |
| Phytic acid | May diminish mineral bioavailability | Antioxidant activity and protects DNA damage | |
| Saponins | Anti-nutritional factor | Bind cholesterol and/or bind to bile acids and may exhibit hypocholesterolemic effects | |

***Table 2:*** *Dual role of some bioactive compounds present in pulses (adapted from [31, 32]).*

**PHF and blood glucose, insulin and glycemic index**

There is scientific evidence on the beneficial effect of pulses on short-term satiety and weight loss [33]. The use of PHF in breads reduces energy intake, which primarily is due to pea fibre having a low energy content given the limited extent of fermentation. In the study conducted by Mellem [34], the effect of adding increasing quantities of PHF (4.5 to 13.5g per 100g dietary fibre) in bread was evaluated in relation to different blood parameters, including insulin and lipid markers. No significant differences in blood insulin, glucose, triglycerides, cholesterol, HDL-cholesterol and LDL-cholesterol were found compared to the control group. These results differ with Lambert., *et al*. [35], in which postprandial blood glucose response was markedly reduced by the ingestion of pea hull fibre though inclusion of pea hull fibre was at slightly higher levels (15g pea fibre). In that study, the reduced glucose response to PHF ingestion was accompanied by a significant reduction of insulin level only after 30 minutes post-ingestion. This is also consistent with results from Lunde., *et al*. [29], who concluded on that pea fibre-enriched breads, can reduce post-prandial plasma glucose (PPG) and prolong satiety. Lambert., *et al*. [36] concludes that by incorporating 15 g/day yellow pea fibre for a period of 12 weeks, important metabolic benefits and support for obesity management can be achieved.

**PHF and triglyceride and cholesterol level**

Diets rich in fibre content have been proven to reduce blood pressure, improve serum lipid levels and reduce indicators of inflammation. However, results from Mellem [34] are consistent with results from Sandström., *et al*. [10], who observed no differences in fasting cholesterol levels after feeding young healthy adults a low-fibre diet or a low-fibre diet supplemented with 33 g/day pea fibre product (corresponding to 20g dietary fibre). However, the same author found reduced triglyceride levels in plasma and in liver after pea fibre supplementation.

**PHF as bulking agent**

PHF is currently being used as a food ingredient in several food segments. Fitzpatrick [37] reported the benefits of PHF on intestinal health, particularly on the health of the elderly. PHF is naturally rich in cellulose and is known to reduce the dry matter digestibility of foods [38], representing an effective bulking agent. In a study by Dahl., *et al*. [11], the intestinal transit time of elderly long-term care residents was significantly reduced by the addition of 4g PHF/day to their diet. These results are consistent with the study of Knudsen and Hansen [39]. There are several factors that influence the bulking properties of faeces and the retention time; among them, are the amount and digestibility of the dietary fibre, the water holding capacity and the particle size of the fibres since small particles have a larger surface area contact with the interphase than large particles.

**Fermentability and intestinal microflora**

The gut microflora plays an important role in food digestion, immunity, and other metabolic functions, and is naturally modulated by environmental factors, where diet plays a very important role. Dietary fibre is one of the main energy sources utilized by intestinal microbes resulting in the generation of different fermentation products; short chain fatty acids (SCFA) among them. The production of the SCFA propionate may also stimulate satiety [40]. PHF has also been closely associated with increased stool frequency and can modulate gut microbiota, potentially due to the passage of high microbial mass [11], especially with an increase in bifidobacteria. *Bifidobacteria* confer beneficial health properties in the gut such as prevention of enteric infection, suppression of pathogenic bacteria stimulation of the immune system [41]. Hardy., *et al*. [42] investigated to what degree PHF affected the gut microbiota in combination with a high protein diet. Results indicated that the addition of PHF did not affect overall faecal microbiota diversity but seemed to affect the frequency in the expression of specific bacterial gene sequences. Moreover, PHF addition correlated with a decrease in lactic acid bacteria and a slight increase in *bifidobacteria*. The fermentability and digestibility of PHF was analysed based on the work done by Tokvam Aas [43]. Results indicated that PHF has a lower fermentability and digestibility than whole-wheat fibre, which indicates a lower energy value. In the work conducted by Eslinger., *et al*. [44], PHF was shown to modulate metabolic parameters and gut microbiota in obese rats.

**PHF and phytoestrogens**

Phytoestrogens have chemical structures that allow them to bind to estrogen receptors in humans. Matscheski., *et al*. [45] studied the effects of crude phytoestrogen extracts from green and yellow pea (*Pisum sativum*) and rye (*Secale cereale*) on cell proliferation and the production of progesterone in trophoblast tumour cells. Results indicated that green and yellow pea seeds contain measurable concentrations of iso-flavones and potential phytoestrogens that can reduce "*in vitro*" proliferation and progesterone production of trophoblast tumour cells.

**PHF and cancer prevention**

Pulses contain a rich variety of bioactive compounds, which may help to reduce tumour risk when consumed at certain levels [46]. Yellow peas are known for containing iso-flavones: genistein (dimerized) and daidzein (deoxydi-glycosidic), which belong to the phytoestrogens that display several functions in organisms, including an anticarcinogenic effect. Genistein has anti-proliferative effects on mitogen-stimulated cell growth of human breast cancer cells in culture and could be a potential agent to be evaluated in the prevention of breast cancer [45]. In addition, pulses rich in dietary fibre seem to contribute to lowering the incidence of certain types of cancer, especially colon and rectal cancers [47,48]. Other bioactive compounds present in pulses which may have a protective role against cancer are resistant starch, non-starch polysaccharides, oligosaccharides, folate, selenium, zinc, phytoesterols, saponins, lectins, phytates and protease inhibitors such as Bowman-Birk inhibitors [46,49]. The Bowman–Birk inhibitors (BBI) from legumes are present in soybean, peas, lentils and chickpeas. BBI are plant protease inhibitors that have potentially health promoting properties within the mammalian gastrointestinal tract. BBIs are able to survive the pH and enzymatic conditions found in the human digestive system, and can reach the large intestine to exert bioactivity. Clemente., *et al*. [49], has reported BBIs as compounds with anti-carcinogenic and anti-inflammatory properties. These findings are of high relevance in the potential prevention and therapy of colorectal cancer, which has a very high prevalence in the population worldwide.

**PHF and its functional properties**

PHF displays special functional properties because its capacity to absorb water and oil, thereby exerting swelling properties that can change product rheology and behaviour. The particle size of PHF is important since it influences the functional properties of the fibre. Furthermore, PHF can have a stabilization effect on the foaming and gelling capacity of blends.

**Swelling and water binding capacity**

The swelling capacity of a fibre can be defined as the ratio of the volume occupied when the sample is immersed in excess water to the actual weight. A high swelling capacity of a fibre is usually followed by a shorter transit time in the gut [50]. Swelling capacity of is influenced by the ratio insoluble/soluble fibre and particle size. The smaller the particle size, the lower the swelling capacity [51]. PHF is reported to have a swelling capacity of 1.88 ml $g^{-1}$, which significantly lower than in other pulses such as chickpeas (3.61 ml $g^{-1}$) and lentils (2.38 ml $g^{-1}$) [30,52]. According to Daveby and Aman [53], water binding capacity is generally higher in whole pea flour rather than in PHF. In house results indicate that 1g pea hull fibre (particle size 0.8 mm) can bind 3.1 ml water [54].

**Oil binding capacity**

The oil binding capacity of a fibre can be calculated by stirring a known quantity of fibre into 10 ml vegetable oil (corn or sunflower) for a certain time (e.g. 1 min) and then centrifuging at 2200g for 30 minutes [55]. In house results indicate that 1g pea hull fibre (particle size 0.8 mm) can bind 1.3 ml oil, being PHF an important natural binder that can reduce cooking losses in foods with medium/high fat levels such as sausages, hamburgers, hams and other meat products [54].

**Binding of minerals and organic molecules**

It has been reported that some type of dietary fibres have the ability to bind bile acids and triglycerides and therefore exert a hypocholesterolemic effect [34]. The mode of action for this is not completely understood. Other possible binding related effects of fibre have been associated to impaired mineral absorption due to charged polysaccharide (such as in pectins and phytates), but so far this effect has not been scientifically documented with PHF.

**PHF and food applications**

PHF has a broad use in different sectors of the food and feed industries, as well as in technological applications. As an important source of dietary fibre, PHF can be used to improve fibre content in bakery products (breads, cakes, waffles, pizza, and tortillas), batters and breading [56], production of pasta, in reformulation of meats and meat products such as sausages, hamburgers, cooked hams. The use of PHF in reformulation of beef patties improves water-holding capacity, which increases cooking yield and minimises the production cost without affecting the sensorial properties of the product [57].

## Conclusions

PHF is a novel and sustainable source of dietary fibre with important health and functional properties. Highly functional and with important positive health implications, the spectrum of applications of PHF seem to be increasing. High in dietary fibre and in biologically active components, such as polyphenols and iso-flavonoids, the positive effects of PHF supplementation on human dietary regimes has been proven to contribute in the mitigation of a number of cardiovascular and chronic metabolic diseases, such as diabetes and metabolic syndrome, among others. From a nutritional point of view, PHF is an ideal ingredient to improve dietary fibre content in human dietary regimes due to its low energy content, low fermentation potential, good bulking properties and relatively neutral taste.

Furthermore, pulse crops are very sustainable since they contribute to improving soil quality by fixing nitrogen, increase yield of grain crops and low consumption of water by kilogram protein. The present review has been written as a follow up activity of United Nation´s International Year of Pulses (IYOP 2016) which aimed, among other goals, to encourage awareness of the high nutritional value of pulses and help consumers to adopt healthier dietary regimes.

## Bibliography

1. Tosh SM and Yada S. "Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications". *Food Research International* 43.2 (2010): 450-460.

2. Clemens R. *et al*. "Filling America's fiber intake gap: summary of a roundtable to probe realistic solutions with a focus on grain-based foods". *Journal of Nutrition* 142.7 (2012): 1390S-1401S.

3. Lambert JA., *et al*. "Evaluation of yellow pea fibre supplementation on weight loss and the gut microbiota: a randomized controlled trial". *BMC Gastroenterology* 14 (2014): 69.

4. Krumina-Zemture G., *et al*. "Aminoacid and dietary fiber content of pea and buckwheat flours". In: Proceeding of the 22st Annual International Scientific Conference, Research for Rural Development 2016. Latvia Research for Rural development 1 (2016): 84-90.

5. Papanikolaou Y and Fulgoni VL. "Bean consumption is associated with greater nutrient intake, reduced systolic blood pressure, lower body weight, and a smaller waist circumference in adults: results from the National Health and Nutrition Examination Survey 1999-2002". *Journal of the American College of Nutrition* 27.5 (2008): 569-576.

6. Staub HW., *et al*. "Modern dietary fibre product development and nutrient bioavailability". In: Dietary Fibre, G. G Birch and KJ Parker, eds. Applied Science Publishers: New York (1983).

7. Dahl WJ., *et al*. "Review of the health benefits of peas (Pisum sativum L.)". *British Journal of Nutrition* 108.1 (2012): 3-10.

8. Curran J. "The nutritional value and health benefits of pulses in relation to obesity, diabetes, heart disease and cancer". *British Journal of Nutrition* 108.1 (2012): S1-S2.

9. Dubois C., *et al*. "Effects of pea and soybean fibre on postprandial lipaemia and lipoproteins in healthy adults". *European Journal of Clinical Nutrition* 47.7 (1993): 508-520.

10. Sandström B. *et al*. "A Pea Fiber Lowers Fasting and Postprandial Blood Triglyceride Concentrations in Humans". *Journal of Nutrition* 124.12 (1994): 2386-2396.

11. Dahl WJ., *et al*. "Increased stool frequency occurs when finely processed pea hull fiber is added to usual foods consumed by elderly residents in long-term care". *Journal of the American Dietetic Association* 103.9 (2003): 1199-1202.

12. Campos-Vega R., *et al*. "Minor components of pulses and their potential impact on human". *Food Research International* 43.2 (2010): 461-482.

13. McCartney L and Knox JP. "Regulation of pectic polysaccharide domains in relation to cell development and cell properties in the pea testa". *Journal of Experimental Botany* 53.369 (2002): 707-713.

14. Le Goff A., *et al*. "Extraction, purification and chemical characterisation of xylogalacturonans from pea hulls". *Carbohydrate Polymers* 45.4 (2001): 325-334.

15. Hillman LC., *et al*. "Effects of the fibre components pectin, cellulose, and lignin on bile salt metabolism and biliary lipid composition in man". *Gut* 27.1 (1986): 29-36.

16. Durrington PN., *et al*. "Effect of pectin on serum lipids and lipoproteins, whole gut transit time and stool weight". *Lancet* 2.7982 (1976): 394-396.

17. Kay RM and Truswell AS. "Effect of citrus pectin on blood lipids and fecal steroid excretion in man". *American Journal of Clinical Nutrition* 30.2 (1977): 171-175.

18. Guillon F and Champ MM. "Carbohydrate fractions of legumes: uses in human nutrition and potential for health". *British Journal of Nutrition* 88.3 (2002): S293-S306.

19. Jenkins DJ., *et al*. "Effect on blood lipids of very high intakes of fiber in diets low in saturated fat and cholesterol". *New England Journal of Medicine* 329.1 (1993): 21-26.

20. Moise JA., *et al*. "Seed coats: structure, development, composition, biotechnology". *In Vitro Cellular Developmental Biology-Plant* 41.5 (2005): 620-644.

21. Dueñas M., *et al*. "Assessment of in vitro antioxidant capacity of the seed coat and the cotyledon of legumes in relation to three phenolic contents". *Food Chemistry* 98 (2006): 95-103.

22. Amarowitcz R., *et al*. "Polyphenolics extracts from legume seeds: correlations between total antioxidant activity, total phenolics content, tannins content and astringency". *Journal of Food Lipids* 11.4 (2004): 278-286.

23. Troszynska A and Ciska E. "Phenolic Compounds of Seed Coats of White and Coloured Varieties of Pea (Pisumsativum L.) and Their Total Antioxidant Activity". *Czech Journal of Food Sciences* 20.1 (2002): 15-22.

24. Oomah DB., *et al*. "Phenolics and antioxidant activity of lentil and pea hulls". *Food Research International* 44.1 (2011): 436-441.

25. Joshi R., *et al*. "Global Inequalities in access to cardiovascular health care. Our greatest challenge". *Journal of the American College of Cardiology* 52.23 (2008): 1817-1825.

26. Kosti RI and Panagiotakos DB. "The epidemic of obesity in children and adolescents in the world". *Central European Journal of Public Health* 14.4 (2006): 151-159.

27. Ceriello A., *et al*. "Guideline for management of post-meal glucose". *Nutrition, Metabolism and Cardiovascular Diseases* 18.4 (2008): S17-S33.

28. Ceriello A., *et al*. "Postprandial hyperglycaemia and cardiovascular complications of diabetes: an update". *Nutrition, Metabolism and Cardiovascular Diseases* 16.7 (2006): 453-456.

29. Lunde MS., *et al*. "Variations in postprandial blood glucose responses and satiety after intake of three types of bread". *Journal of Nutrition and Metabolism* (2011): 437587.

30. Dalgetty DD and Baik BK. "Isolation and characterization of cotyledon fibers from peas, lentils, and chickpeas". *Cereal Chemistry* 80.3 (2003): 310-315.

31. Champ M. "Non-nutrient bioactive substances of pulses". *British Journal of Nutrition* 88.3 (2002): S307-S319.

32. Singh J and Basu PS. "Non-Nutritive Bioactive Compounds in Pulses and Their Impact on Human Health: An Overview". *Food and Nutrition Sciences* 3 (2012): 1664-1672.

33. McCrory MA *et al*. "Pulse Consumption, Satiety, and Weight Management". *Advances in Nutrition* 1 (2010): 17-30.

34. Mellem KJ. "Dietary fiber and the effect on digestive function, energy intake and major consequences for human nutrition". Master of Science Thesis. University in Oslo. Department of animal and aquacultural science (2013).

35. Hamberg O., *et al*. "Blood glucose response to pea fiber: comparisons with sugar beet fiber and wheat bran". *American Journal of Clinical Nutrition* 50.2 (1989): 324-328.

36. Lambert JE., *et al*. "Consuming yellow pea fiber reduces voluntary energy intake and body fat in overweight/obese adults in a 12-week randomized controlled trial". *Clinical Nutrition* 36.1 (2017): 126-133.

37. Fitzpatrick K. "Novel fibers in Canada: Regulatory developments". *Cereal Foods World* 52.1 (2007): 22-23.

38. Cadden A., *et al*. "Physiological responses of rats to high fiber bread diets containing several sources of hulls or bran". *Journal of Food Science* 48.4 (1983): 1151-1156.

39. Knudsen KEB and Hansen I. "Gastrointestinal implications in pigs of wheat and oat fractions. Digestibility and bulking properties of polysaccharides and other major constituents". *British Journal of Nutrition* 65.2 (1991): 217-232.

40. Liljeberg HG., *et al*. "Sourdough fermentation or addition of organic acids or corresponding salts to bread improves nutritional properties of starch in healthy humans". *Journal of Nutrition* 125.6 (1995): 1503-1511.

41. Anand S., *et al*. "Pathogen-induced secretory diarrhoea and its prevention". *European Journal of Clinical Microbiology and Infectious Diseases* 35.11 (2016): 1721-1739.

42. Hardy H., *et al*. "Probiotics, prebiotics and immunomodulation of gut mucosal defences: homeostasis and immunopathology". *Nutrients* 5.6 (2013): 1869-1912.

43. Tokvam Aas R. "Effect of fiber added in bread on energy value and glucose response". Master thesis. Universitet for BiomiljøogBiovitenskap, Oslo, Norway (2011).

44. Eslinger AJ., *et al*. "Yellow pea fiber improves glycemia and reduces Clostridium leptum in diet-induced obese rats". *Nutrition Research* 34.8 (2014): 714-722.

45. Matscheski A., *et al*. "Effects of phytoestrogen extracts isolated from rye, green and yellow pea seeds on hormone production and proliferation of trophoblast tumor cells". *Hormone Research* 65.6 (2006): 276-288.

46. Mathers JC. "Pulses and carcinogenesis: potential for the prevention of colon, breast and other cancers". *British Journal of Nutrition* 88.3 (2002): 273-279.

47. Howe GR., *et al*. "Dietary intake of fiber and decreased risk of cancers of the colon and rectum: evidence from the combined analysis of 13 case-control studies". *Journal of the National Cancer Institute* 84.24 (1992): 1887-1896.

48. Harris PJ and Ferguson LR. "Dietary fibers may protect or enhance carcinogenesis". *Mutation Research* 443.1-2 (1999): 95-110.

49. Clemente A., *et al*. (2012) "The anti-proliferative effect of TI1B, a major Bowman-Birk isoinhibitor from pea (Pisumsativum L.), on HT29 colon cancer cells is mediated through protease inhibition". *British Journal of Nutrition* 108.1 (2012): S135-S144.

50. Tiwari U and Cummins E. "Meta-analysis of the effect of β-glucan intake on blood cholesterol and glucose levels". *Nutrition* 27.10 (2011): 1008-1016.

51. Huang SC., *et al*. "In vitro interactions on glucose by different fiber materials prepared from mung bean hulls, rice bran and lemon pomace". *Journal of Food and Drug Analysis* 17.4 (2009): 307-314.

52. Dalgetty DD and Baik BK. "Fortification of bread with hulls and cotyledon fibers isolated from peas, lentils, and chickpeas". *Cereal Chemistry* 83.3 (2006): 269-274.

53. Daveby YD and Aman P. "Chemical composition of certain de-hulled legume seeds and their hulls with special reference to carbohydrates". *Swedish Journal of Agricultural Research* 23 (1993): 133-139.

54. AM Nutrition AS. Global supplier of pea concentrates. Sandvikveien 21. Stavanger, Norway (2016).

55. Chau CF and Cheung PCK. "Effects of the physicochemical properties of three legume fibers on cholesterol absorption in hamster". *Nutrition Research* 19.2 (1999): 257-265.

56. Singh OP., *et al*. "Refrigerated storage stability of chicken nuggets containing pea flour". *Journal of Food Science and Technology* 45 (2008): 460-462.

57. Besbes S., *et al*. "Partial replacement of meat by pea fiber: effect on the chemical composition, cooking characteristics and sensory properties of beef burgers". *Journal of Food Quality* 31.4 (2008): 480-489.

**Volume 10 Issue 4 August 2017**