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Health and nutritional properties of pears (*Pyrus*): a literature review

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For Hort Innovation and Apple and Pear Australia Ltd (APAL)

Final report

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Abbreviations

ADH	Alcohol dehydrogenase
ALDH	Aldehyde dehydrogenase
AUC	Area under the curve
CABI	The Centre for Biosciences and Agriculture International
CCC	Current Contents Connect
CHD	Coronary heart disease
CI	Confidence interval
CVD	Cardiovascular disease
EAEPC	Ethyl acetate
EEPC	Ethanolic extracts
FODMAP	Fermentable oligosaccharides, disaccharides, monosaccharides and polyol
FSANZ	Food Standards Australia New Zealand
FSTA	Food Science Technology Australian
GI	Glycaemic index
HDL-C	High density lipoprotein cholesterol
HCL	Hydrochloride
HR	Hazard ratio
IBD	Inflammatory bowel disease
IBS	Irritable bowel syndrome
IGT	Impaired glucose tolerance
LDL-C	Low density lipoprotein cholesterol
MPO	Myeloperoxidase
NHMRC	National Health and Medical Research Council
OR	Odds ratio
P-CNF	Pear cellulose nanofibre
PEN	Practice-based Evidence in Nutrition
PV	Pear vinegar
RCT	Randomised controlled trial
RR	Relative risk
SCFA	Short chain fatty acid
T2DM	Type 2 diabetes mellitus
TC	Total cholesterol
TG	Triglyceride
UC	Ulcerative colitis
WoS CC	Web of Science Core Collections

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Executive summary

Background:

Pears are globally enjoyed and are one of the oldest human cultivated plants. The European pear (*Pyrus communis*) is the major pear of commerce in Australia with eight varieties available. While the Asian pear (*Pyrus pyrifolia*) or "Nashi" is mostly grown in Asia it has been produced commercially in Australia for over 25 years. European and Asian pears differ slightly in appearance, taste, texture as well as nutritional composition and hence may differ slightly for some health attributes. Pears have been used as a traditional folk remedy in China for more than 2000 years because of their supposed anti-inflammatory, antihyperglycemic, diuretic activities, cough relief and as a prophylactic agent for alcohol hangover. The various bioactive compounds in pears may contribute to these health outcomes. The apple & pear Industry have identified a need to understand the current status of relevant nutritional science and evidence for pears to improve awareness of their health benefits.

Aim:

To conduct a comprehensive systematic literature review investigating the health benefits and nutrition properties of pear and pear components to provide Hort Innovation and APAL with an up-to-date understanding of the current scientific evidence in order to promote the health benefits of pears.

Methods:

Relevant original research reports published in English up to 10 July 2015 were identified by a comprehensive systematic search of seven scientific journal databases. Search restrictions were limited in order to capture all studies related to health benefits of pears and pear components conducted in humans (including intervention and association studies), animal studies and studies reporting nutritional composition information on pears. A total of 72 studies (4 human interventions, 15 association studies, 22 animal, 30 compositional and 1 review) were included in the literature review after screening 7365 records. Human studies were subjected to quality appraisal; all studies were of acceptable to high quality. The strength of the scientific evidence were evaluated using the National Health and Medical Research Council (NHMRC) criteria. Although animal studies are useful to inform the body of scientific evidence, recommendations can only be based on evidence from human studies. The NHMRC rating is based on the type of studies (intervention studies generally provide stronger evidence of causality than association studies), the quality of studies, the consistency of the results, the potential impact and generalisability of the evidence to the target population.

Results:

- Pears surpass all other fruits for its high content of digestive regulating nutrients including fibre, fructose and sorbitol. The fibre content of a medium size pear (4.1g) meets the FSANZ criteria for a nutrient content claim that pear is a "good source" of fibre. Furthermore, pears, particularly the peel, are rich in several phytonutrients, especially phenolic acids which has been associated with multiple health benefits related to diabetes, cardiovascular disease and obesity.
- Because of their unique composition of fibre, sorbitol and fructose pears have the potential to play an important role in regulating normal bowel function. However, to date no human study has been performed to substantiate this benefit. Based on the fibre content of pears (≥2 g/serving) a general level health claim can be made for its contribution to laxation. It is important to note that these same features of pear may result in discomfort in a small proportion of the population who inadequately absorb fructose.
- One small intervention study indicated that the addition of pears to a weight reducing diet may contribute to weight loss through its low energy density resulting in reduced energy intake. However, further intervention studies are needed to confirm this effect.

- Consumption of pear juice prior to alcohol consumption have been shown to reduce blood alcohol levels, particularly in individuals with a genetic variant associated with a reduced ability to metabolise alcohol, while in normal individuals hangover symptoms and severity were reduced. The key component proposed to stimulate alcohol metabolism is arbutin, found in the skin of Korean pear. These effects have only been tested in one animal and one human intervention study in a Korean population and only using a Korean pear variety. Hence a general recommendation regarding pear consumption and alcohol hangover cannot be made at present. Human intervention studies in an Australian population are needed to confirm these effects and other potential pear varieties should also be investigated.
- Pears have earned their reputation as a low allergenic food and are often one of baby's first foods or used in elimination diets (used to identify food allergies and intolerances) due to is low allergenic potential.
- Prospective observational studies (association type studies which cannot proof causality, but compared to other association studies are highest in the hierarchy of proving causality) have consistently shown that the consumption of apples and pears (combined) are associated with reduced risk of stroke. Some evidence is also available to show that apples and pears are associated with a reduced risk of coronary heart disease.
- Prospective observational studies have also consistently shown that apples and pears (combined) are associated with a reduced risk of type 2 diabetes. Pears have a low glycaemic index (GI) which may assist in the prevention and managing of type 2 diabetes. Further support for pear's anti-diabetic potential is provided from three animal studies that showed favourable effects on blood glucose from pear extracts, potentially related to insulin-like activity of various bioactive compounds in pear, in particular blocking of carbohydrate digestion by certain phenolic acids.
- Consumption of pear pulp, peel and wild pear leaf extract improved metabolic health markers such as glucose levels and cholesterol/lipid profiles in animal models. Pears contain several bioactive components such as polyphenols and fibre that may contribute to these effects. However, intervention studies in humans are needed before recommendations can be made.
- Consumption of pear or pear components increases *in vivo* antioxidant activity in animal models. The effect is greater with pear peel extract than pear pulp, which is consistent with greater levels of polyphenols in the peel, compared to the pulp. Thus, to obtain all the benefits of pear it should be consumed with the peel. Animal studies suggest the antioxidant mechanisms of pears may be at play in wound healing and liver protection.
- Evidence from association type studies (prospective and case-control studies) showed that increased consumption of apples and pears (combined) were associated with reduced risk of cancer including lung, bladder, oral, pancreatic and breast cancer. However the number of studies per type of cancer have been limited.
- Evidence from cross-sectional studies (association studies low in the hierarchy of proving causality) suggests some benefit of consuming pears (and apples) for asthma and other respiratory diseases and a limited number of animal studies support these findings. However, further research is required before any recommendations can be made regarding pears role in allergic and respiratory conditions.

Recommendations:

Potential health messages regarding pears based on current evidence:

- Pears are unequalled compared to other fruit for its content of fibre, sorbitol and fructose. Pear may therefore offer a natural package of digestive regulating nutrients and may well be our "daily prescription for digestive health". Consuming pears may be a more preferred method for alleviating constipation than taking medications, particularly in children who may be averse to taking medications and older adults who are often already taking several medications.

  It is surprising that, to date, no human studies have been conducted to substantiate the potential digestive benefits of pears. However, in the absence of human studies, a general level health claim promoting the laxative effects of pears can be made based on its fibre content (≥2g fibre/serving).

It is important to note that in a small proportion of the population (i.e. FODMAP malabsorbers) the high content of fructose and the combination of fructose and sorbitol may result in gastrointestinal discomfort.

- Pears also meet the FSANZ criteria for a nutrient content claim that pear is a "good source" of fibre (≥4g/serve). Adding one medium pear per day to the daily diet could make a significant contribution to achieving daily fibre recommendations. In fact, one pear per day could bridge the shortfall between Australian women's fibre intakes (21g/d) and recommended intakes (25g/d).
- Pears have a low GI and may therefore be included in a diabetic diet to assist with managing glucose levels.
- Pears are low in energy density and may therefore play a role in weight reducing diets by adding weight to the diet without increasing calories.
- Pears, particularly the skin of pears, are rich in several phytochemicals, especially phenolic acids, which have been associated with multiple health benefits. Thus, to gain the most benefit from consuming pears it needs to be consumed with the peel.
- Apples and pears combined are associated with reduced risk of stroke, coronary heart disease, type 2 diabetes and cancer. Unfortunately, studies investigating these relationships have always combined apples and pears hence the independent effects of pears cannot be elucidated. Any messages regarding these associations should thus be for apple and pear combined. In addition, since these results are based on association type studies any messages should refer to these health benefits as associations and not causal effects.

Health attributes of pears requiring further research:

The following potential health attributes of pears or pear-based products are worth further investigation within human intervention studies before specific recommendations can be made:

- The phenolic acid arbutin, found in high concentrations in the peel of Korean pear has the potential to stimulate alcohol metabolism and decrease blood alcohol levels and hangover symptoms. Identification of an Australian pear high in arbutin (potentially Nashi), development of products containing high arbutin pear peel (e.g. beverages, ciders) and subsequent human intervention studies is recommended.
- The high content of soluble fibre and polyphenols in pears, previously shown to have hypoglycaemic and hypolipidaemic effects, may contribute to metabolic health by improving lipid profiles, glycaemic control and reducing chronic inflammation. The fruit itself may not contain these compounds in sufficient amounts to have a clinical benefit, but pear peel and pulp extracts may be effective, as shown in some animal studies. Novel products containing these extracts could be developed and substantiated in human intervention studies.
- There is limited evidence from cross-sectional studies and animal studies suggesting some benefit of consuming pears for managing and treating asthma and other respiratory and allergic diseases such as rhinitis. Human interventions studies are recommended to substantiate and investigate this mechanism further.
- While research has quantified some nutritional components of pear waste, namely oil and fibre, further analysis of other aspects such as phytonutrients and sugars e.g. sorbitol, could provide indications of other potential uses for pear by-products.
- Waste products of pear including the peels and seeds have potential to be further processed to seed oil, or a fibre product which could be used to fortify low fibre foods e.g. baked goods, medical nutritional therapy products or commercial fibre supplements. The feasibility of this would depend on current levels of waste produced and processing costs, however it is recommended that this is explored.

Conclusion:

Pears have some unique features that could have important health benefits, but studies in humans have been limited which restricts specific health recommendations. The most unique feature of pears compared

to other commonly consumed fruit is its high content of digestive regulating nutrients, namely fibre, sorbitol and fructose. Hence, the daily consumption of pear may be an effective natural strategy for ensuring normal bowel function across all life stages. Pears may well be our “daily prescription for digestive health”. Pears are rich in several phytonutrients, mainly found in the skin of the pear, which may contribute to multiple health benefits. Thus, to gain the most benefit from consuming pears it should be consumed with the peel. Only half of the Australian population consume the recommended two serves of fruit per day of which pears are the 6th most consumed fruit in Australia. It may be beneficial for all Australians to increase their intake of pears in order to capitalize on its high fibre content; consumption of one pear a day will make an important contribution to achieving daily fibre recommendations and in some individuals one pear a day may bridge the gap between low and recommended fibre intakes.

Introduction

1.1 Project background and scope

The apple & pear industry have identified a need to understand the current status of relevant nutritional science and evidence for pears to improve awareness of health benefits. CSIRO conducted a review of the health benefits of apples in 2008 and findings were published as The Apple Report which was highly effective in generating media coverage with a reach of 10.5 million viewers within the first month of publication. CSIRO was approached to conduct a similar scientific review for pears. Apple and Pear Australia Limited (APAL) is the peak industry body representing commercial apple and pear growers in Australia. APAL is charged with providing leadership, support and additional resources to drive key industry initiatives. APAL also works closely with the industry to provide growers with essential tools and market opportunities to assist industry growth and increase the competitiveness of Australian apple and pear growers. APAL intend to use this information to explore potential product opportunities; harnessing science and nutritional evidence in so doing, creating a value added positioning for the pear sector – capitalising on the potential, realising the opportunities and promoting the advantages of pears. This review document will be used to direct future levy investment in communication and marketing programs to increase awareness of the health benefits of Australian Pears and an increased demand for pears and pear based products.

1.2 Pear (*Pyrus*) – Background

Pears are consumed throughout the world and are one of the oldest plants cultivated by humans. They are most commonly enjoyed as fresh fruit but they also respond well to being cooked, canned, juiced, dried, and fermented into pear cider. The pear is the common name for about 20 species of trees of the genus *Pyrus* in the rose family (*Rosaceae*). Pears are medium-sized trees of up to 10 m with white flowers and are relatively easy to grow. The fruit is a pome (with a compartmented core) and is juicier than an apple.

The **European pear** (*Pyrus communis*) is the major pear of commerce in Australia. It has a pyriform pome and takes the classic "pear shape". European pears are native of temperate Europe and have been cultivated there since ancient times. The most important growing areas have always been in France, Germany and Belgium from which countries the ancestors of many modern varieties were developed. Pears arrived in Australia with the earliest settlers and were important fruits in the diet of the first settlers. Pear trees were purchased at Cape Town, South Africa, in 1787 by the First Fleet on its voyage to Australia. These trees were planted within a few weeks of arrival and took root and established themselves soon afterwards [3].

There are eight varieties of Australian pears, all cultivars of *Pyrus communis*. They are available from early autumn till late summer. The varieties include Beurre Bosc – one of the best all-rounders for cooking; Corella Forelle – great eaten fresh or in a salad; Josephine de Malines – renowned for its rich flavour; Packham's Triumph – ideal as a snack, baked, poached or in salads; Red Anjou – flesh is white and fine which is perfect for salads; Red Sensation – distinctive red and gold tone, perfect for desserts; Williams' Bon Chretien – versatile medium sized pear; and the Winter Nelis – its sweet flavour make it ideal for cooking or bottling. Pears must be ripened to come to optimum quality and are best stored at room temperature until ripe. Pears are available in Australia most of the year and only in December and January are they hard to come by [4].

The **Asian pear** (*Pyrus pyrifolia*) is also called the “Japanese” or “Oriental” pear, or “Nashi” which is the Japanese word for pear. Grown mostly in Asia, this fruit has been increasing in popularity over the last 20 years. Pears have been used as traditional medicine in China for more than 2000 years because of their anti-inflammatory, antihyperglycaemic, diuretic and antitussive effects [5]. The Asian pear appears more like an apple than the European pear and have hard, crisp flesh like an apple that do not require ripening like the European pear. Asian pears were domesticated in China about the same time European pears were in Europe which is 3000 years ago. [6] The Nashi pear has been produced commercially in Australia for over 25 years. It was originally brought to Australia by Chinese gold miners in the 1850s. The main variety in Australia, Nijisseiki, is available from March to November. There are at least 20 commercial Nashi growers in Australia however 90% of production is from the Goulburn Valley in Victoria [7] .

The top pear producer in the world in 2013 was China by far with nearly 17.5 million metric tonnes, then USA with nearly 800k tonnes, Argentina and Italy at 750k tonnes each, and Turkey with 460,000. Australia produced nearly 110,000 tonnes [8].

1.3 Description and definitions of pear and pear components

Scientific research on pears has typically focussed on a range of different components of the fruit including whole pear, pear pomace, pear pulp, pear peel or pear extracts. Each component is defined below and will be referred to by these terms for the purpose of this review.

Whole pear: includes the peel and pulp of the pear. For the purpose of this review a medium pear is considered to be 150g (total weight) and 130g edible portion. This is based on the Australian Dietary Guidelines [9] which states that one serve of fruit e.g. a medium pear is 150g and NUTTAB 2010 data which reports that the edible portion of the pear (flesh and skin) is 88% of the total weight [10].

Pear peel: only the outer skin of the pear, pulp excluded
Pear pulp: the flesh only of the pear with no skin
Pear pomace: the waste products of pear production, skins, seeds and core
Pear extract: Pear which has gone through a range of physical and chemical extraction processes, usually including but not limited to: drying of the raw pear material (peel, pulp or a combination) followed by solvent extraction e.g. methanol and then a filtration process (usually via filter paper) to produce a liquid which is then further concentrated by evaporation or vacuum drying to produce the final extract.

2 Methodology for evaluation of the scientific evidence

2.1 Aim and objectives

The aim was to conduct a systematic literature review investigating the health benefits and nutritional properties of pear and pear components to provide APAL with an up-to-date understanding of relevant nutritional science of the health benefits and nutritional properties of pear. The review document, which will provide a thorough analysis and interpretation of the relevant findings, will be used to direct future levy investment in communication and marketing programs to increase awareness of the health benefits of Australian Pears. The target audiences for adoption would include health professionals, health policy departments and consumers. Where research gaps are identified it may also generate recommendations to industry for future R&D investment in human nutrition pear studies.

2.2 Literature search strategy

A comprehensive systematic literature search of relevant databases was performed during the period 3 to 10 July 2015 by a librarian experienced with systematic literature reviews. The keywords pear, pears and *pyrus* were used with limited restrictions in order to capture all studies related to the health benefits of pears and pear components conducted in humans, including intervention and observational studies, and animal models as well as studies related to the nutritional composition of pears. Reference lists of included studies and reviews were also scanned to identify studies missed during the database search. Separate literature searches were undertaken for studies conducted in humans; animals; and nutrition compositional studies.

Although results from animal studies cannot be extrapolated to recommendations for humans they were included in the literature review as supplementary evidence of potential mechanisms by which pears may affect health outcomes and also to identify potential health benefits of pears not studied in humans before that could be followed up with human studies. *In vitro* ("test tube") studies were not included because results from these studies cannot be extrapolated to humans and information from these studies are less informative and equivocal. Anti-oxidant capacity of foods measured *in vitro* does not predict *in vivo* antioxidant capacity. This could be explained by the fact that most polyphenols in food are incompletely absorbed in humans and they undergo extensive modification during metabolism reaching the circulation and tissues in lower levels and in different forms than is present in the food source [11].

To ensure full coverage of the literature a range of databases were searched including;

- Pubmed
- Web of Science Core Collections (WoS CC);
- The Centre for Biosciences and Agriculture International (CABI);
- Current Contents Connect (CCC);
- Cochrane Central (Database of Systematic Reviews and Cochrane Collaboration Central Register of Controlled Trials);
- Food Science Technology Australian (FSTA);
- Scopus

These databases were chosen to encompass existing literature from a range of sources including scientific, medical and food technology.

Nutrition compositional data was also derived from reputable databases including: NUTTAB 2010 [10], USDA database of flavanoid content of selected foods [12] , the University of Sydney Glycaemic Index database [13] and the International Tables of Glycaemic Index and Glycaemic Load Values: 2008 [14].

The number of records identified from each of these databases are summarised in a PRISMA diagram (Figure 1); a total of 9183 records were identified.

2.3 Study selection, data synthesis and quality assessment

The librarian removed all duplicates as well as obvious non-relevant records by screening the titles. Relevant studies were then identified by authors (GJM & GW) by first screening titles and abstracts followed by full text against in- and exclusion criteria (see below). Any doubts whether a study should be included or not were resolved by discussion between authors. The search results at each stage of the filtering process are documented in Figure 1.

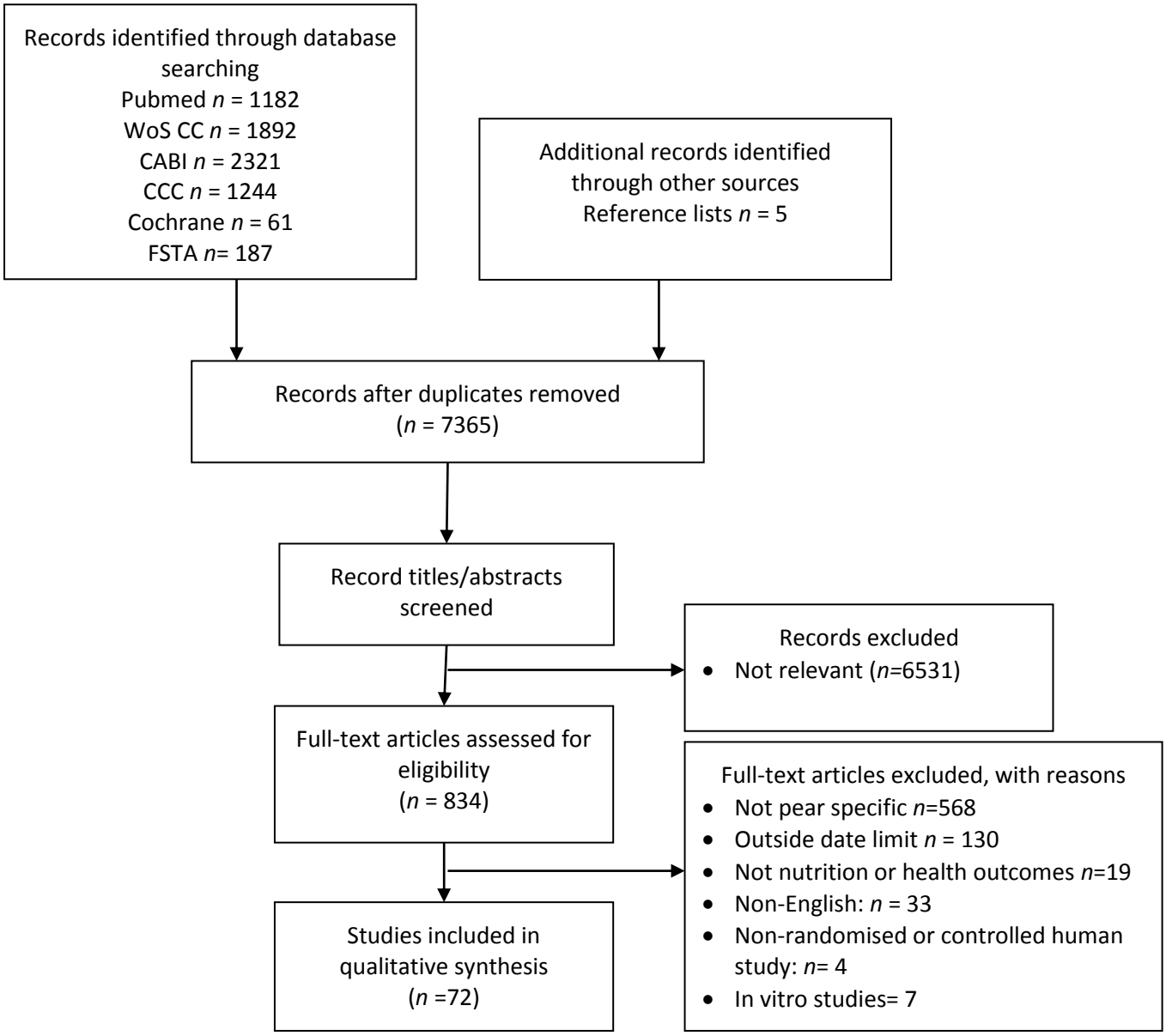


Figure 1. PRISMA diagram for selection of studies
(WoS CC, Web of Science Core Collection, CABI, The Centre for Biosciences and Agriculture International, CCC, current contents connect, FSTA, Food Science Technology Australia)

Inclusion- and exclusion criteria:

Human interventions studies:

- Only studies that used randomised controlled study designs were included – important quality criterion for human interventions studies.
- Only studies that investigated a health related effect of pears or pear components were included
- Multi-component interventions where the independent effect of pears could not be distinguished from other components were not included (e.g. pear juice combined with other fruit juices).
- Only English-language studies were included.

Observational studies:

- All observational studies investigating the relationship between pear consumption and a health related aspect were included (e.g. prospective, cross-sectional, case-control studies)
- Studies reporting associations with pears when pears were combined with apples were included, but studies were pears were part of total fruit intake were not included.
- Only English-language studies were included.

Animal studies:

- All animal intervention studies investigating the effects of pear or pear components on a health aspect were included.
- Only English-language studies were included.

Nutritional composition:

- All studies reporting compositional data of pears or pear components and published after 1990 were included.
- Only English-language studies were included.

Critical characteristics from human, animal and composition studies needed for in-depth assessment of the evidence were extracted into tables. Information from 72 studies was extracted (4 human intervention studies; 15 human observational studies; 22 animal studies; 30 composition studies and 1 review) (see appendix tables 10, 12, 14 and 15). Human studies (intervention and prospective observational studies) were furthermore subjected to quality appraisal using the Health Canada Quality Appraisal Tools for Intervention Studies and Prospective Cohort Studies [15] (see appendix 11 and 13 for quality appraisals). All these studies were of acceptable to high quality.

Pears in the literature
72 studies on pears
4 human intervention
15 observational
22 animal
30 composition
1 review

The nutritional composition of different pear varieties available in Australia were summarised using Australian nutrition composition data from NUTTAB 2010, Food Standards Australia and New Zealand's most recent reference database which compiles Australian analysed food composition data [10]. The average nutrition composition of Australian pear varieties where compared to other commonly consumed fruit in Australia based on the results of the most recent Australian nutrition survey, the Australian Health survey 2011-12 [16]. Additional relevant compositional information on pears was extracted from composition studies summarised in the appendix table 15 and summarised in the report, e.g. sugar, fibre and polyphenol composition.

2.4 Evaluation of the level of evidence

The National Health and Medical Research Council (NHMRC) criteria were used to assess the strength of the body of scientific evidence to support conclusions regarding the health benefits of pears [17]. Recommendations can only be based on evidence from human studies. The strength of the evidence is rated by five key components: the evidence base in terms of the level of evidence (Type of study design – Appendix 8.2), number of studies and quality of studies (risk of bias); consistency of the study results; potential clinical impact; the generalisability of the body of evidence to the target population; and the applicability to the Australian healthcare context [17]. Based on these criteria the evidence is graded as A (Excellent); B (Good); C (Satisfactory); and D (Poor) (Appendix 8.3). Grade A evidence can be trusted to guide practice; Grade B evidence can be trusted to guide practice in most situations; Grade C evidence provides some support for recommendation(s) but care should be taken in its application; Grade D evidence is weak and recommendation must be applied with caution [17].

3 Nutritional composition of pears

Pears are a nutritious fruit, which due to their botanical relationship to apples bear much resemblance in their nutritional properties. The nutritional composition of varieties common to Australia have been summarised in Table 1, this includes one Asian variety, the Nashi pear, which is readily available in Australia. Analysis of Australian brown (Beurre Bosc), Nashi, William Bartlett and Packhams Triumph pear varieties show only small between cultivar differences, with a higher total sugar and glucose content in the Nashi pear and a higher fibre content in the William Bartlett pear compared to the other varieties.

Dietary fibre

Overall pears boast a high fibre content compared to other commonly consumed fruits (Table 4) at 3.16g per 100g or 4.1g for a medium pear (130g), making them a "good source" of dietary fibre in accordance with Foods Standard Australia New Zealand (FSANZ) criteria for nutrient content claims requiring a serving to contain at least 4g fibre [18]. Their insoluble fibre content is also the highest of any of the commonly consumed fruits at 2.3g/100g (Table 4).

Pears are one of the highest fibre containing fruits at 4.1 g fibre per medium size pear.

Sugars

Pears are unique in their composition of sugars. Unlike most fruits that contain sucrose or glucose as the predominate sugar; pears contain a higher fructose content (Table 3). As evident from the review of compositional data (Appendix Table 15) sugar contents can vary significantly depending on the species and cultivar of pear. Most notably Asian pear varieties (*Pyrus serotina* Redh) contain more glucose compared to European pears (*Pyrus communis*). Hudina and Štampar (2000) compared the sugar content of 18 European pear varieties and 4 Asian pear varieties grown in Slovenia. The results, summarised in Table 5, show that the European pear has a lower glucose content compared to the Asian pear and while total sugar content was not significantly different between European and Asian pears (5.23-9.90 vs 5.85-8.07g/100g), the European pears contain a higher fructose to glucose ratio (4.33:1 vs. 1.51:1), which produces a sweeter flavour in the pear.

Pears are a natural source of sorbitol used for the treatment and prevention of constipation.

The other unique sugar in pears is sorbitol, an alcohol sugar, present in pears in greater quantities than other common fruit (Table 3). Sorbitol content is greater in European pear cultivars compared to the Asian cultivars (1.25-2.58 vs 0.50-1.90g/100g) (Table 5).

Glycaemic index

The glycaemic index (GI) of whole pears range from 33 to 42 (average 38) based on four studies in participants with type 2 diabetes mellitus (T2DM) or impaired glucose tolerance (IGT) [13-14]. The GI of pears is comparable with apples and lower than other commonly consumed fruits (Table 2). This ranks pears as a low GI fruit. GI is a relative ranking of carbohydrate in foods according to how they affect blood glucose levels. Carbohydrates with a low GI value (55 or less) are more slowly digested, absorbed and metabolised and cause a lower and slower rise in blood glucose and consequently insulin levels. Eating foods with a low GI can be beneficial for those trying to control their weight and manage their diabetes [19-21]. GI

Pears are a low GI food (Low <55)

Whole pear	**38**
Canned pear in natural juice	**43**
Canned pear in reduced-sugar syrup	**25**
Dried pear	**43**

testing has also been undertaken in canned and dried pears, with pear halves, canned in reduced-sugar syrup, having a GI of 25 while pear halves, canned in natural juice and dried pears both had a GI of 43 [14].

Phytonutrients

Pears also contain a number of phytonutrients or phytochemicals. Phytonutrients are substances in plant foods that have health benefits but unlike traditional vitamins and minerals, phytonutrients are not essential for life. There may be as many as 100,000 different compounds, which contribute to particular properties of fruits and vegetables such as flavour and colour. It is widely believed that the health benefits of diets high in fruits and vegetables are partly due to the presence of phytonutrients. For instance, several act as antioxidants, preventing oxidative damage to cells, proteins, and DNA [22]. Many bioactive phytonutrients are yet to be identified, and those that are known may have additional properties in the body that are not yet understood. But it is thought that nutrients, phytonutrients, and other, as yet unknown, bioactive components act together to influence physiological responses [22]. Figure 2 shows the types and hierarchy of some known phytochemicals.

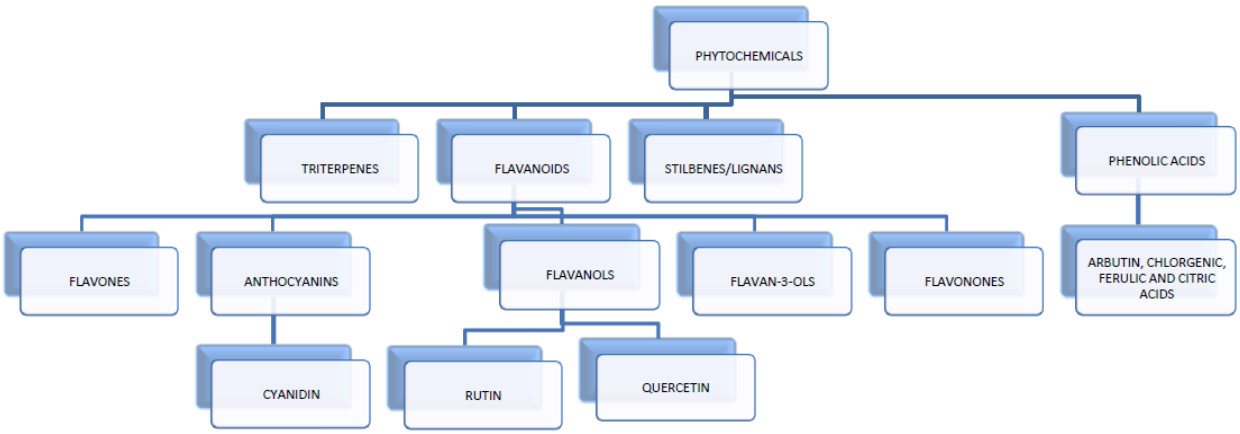


Figure 2 Types of phytochemicals. Adapted from [1]

The largest and most studied polyphenols are flavonoids categorised into anthocyanidins, flavan-3-ols, flavonones, flavones and flavonols. Pears contain a number of flavonoids particularly cyanidin from the anthocyanidin category found particularly in red skinned pears, and epicatechin from the flavan-3-ol category. However, compared to apples and other fruit pears do not particularly stand out with regard to their flavonoid content (summarised in Table 6).

Pears are a good source of phenolic acids, in particular chlorogenic acid, arbutin, ferulic and citric acid (Table 7). Chlorogenic acid is of interest due to its role in regulating glucose and lipid metabolism. A recent review [23] on chlorogenic acid identified 27 studies including 3 human clinical trials and 18 animal studies which showed improvements in a range of metabolic biomarkers related to diabetes, cardiovascular health and obesity including serum lipids, insulin resistance, glucose tolerance and obesity-related hormones. The human studies used varying doses and forms of chlorogenic acid including, 1g, 2.5 mmol and one study used Emulin™, a patented blend of chlorogenic acid, myricetin, and quercetin. The amount of chlorogenic acid found in pear is lower than these doses. To provide context, coffee, a rich source of chlorogenic acid provides around 96mg/200ml coffee or up to 800mg/day for frequent coffee consumers. Some pear varieties such as the Portuguese Rocha Pear stand out for their chlorogenic acid content, having 8-16 times the chlorogenic acid of other pear varieties at 624mg/kg or ~80mg/130g edible pear [24].

Citric acid increases iron absorption, with 1g of citric acid shown to increase iron absorption by up to 300% [25]. Some pear cultivars (Williams Bon Chrétin, Red Williams, Rosired and Clapp Favorite) have shown to contain over 2g/kg fresh fruit [26]. While this is high compared to apples that contain between 84-168mg/kg (Pyo 2014), it is modest in comparison with citrus fruit such as oranges which contain up to 10g/kg [25].

Ferulic acid is also reported to have a range of anti-inflammatory, anti-atherogenic, anti-diabetics, anti-ageing, neuroprotective and hepatoprotective effects attributed to its potent antioxidant activity, however most of this evidence comes from *in vitro* or a limited number of animal studies and at present it is not clear whether and how much dietary intake is adequate to generate biological effects [27-28]. While a review estimated that an individual following the recommended number of serves of fruits, vegetable and grain intake could reach 150-250mg/day [28], the Portuguese Rocha pear again stands out, providing 233mg/kg or 30mg/130g edible pear compared to 33-96mg/kg for other common pear varieties [24].

Little evidence was available on the health effects of arbutin from the edible pear fruit. Arbutin contained in the leaf of the Wild Himalayan pear, *Pyrus biossieriana* Buhse, was thought to contribute to antioxidant, antihyperglycaemic and antihyperlipidemic activities in hyperglycaemia induced rats (see section 4.5). Arbutin may also play a role in alcohol metabolism, as will be discussed in section 4.9.

In our review of the compositional studies that reported on the levels of polyphenols and other phytonutrients we found wide variation (Table 15); up to ten-fold in certain phenolic acids between cultivars or in the same cultivar between studies. Developmental stage and environmental factors such as nutrient availability, temperature, and light all influence the synthesis of polyphenols [29]. In addition, variations in analysis method between studies and over time may also impact results.

Composition changes with ripening

The changes in antioxidant content during ripening were described by Silvia et al (2010) who monitored the free radical scavenging activity by measuring two antioxidants, ascorbic acid and glutathione, over 8 months of storage of Rocha pears under normal and controlled atmosphere conditions. They found while there were differences in ascorbic acid depending on harvest time, these differences did not persist during long-term storage and the antioxidant capacity was maintained over the storage period under both conditions [30].

As for sugar content, this appears to change significantly depending on ripeness, as shown in Table 3 the content of fructose, glucose and sorbitol differs significantly in a firm compared to ripe Packham pear with firm pears containing greater excess fructose compared to ripe [31]. The content of fructose in excess to glucose (excess fructose) is important as the majority of fructose absorption occurs coupled to glucose, hence in its absence fructose absorption is reduced significantly which may contribute to gastrointestinal discomfort [31].

By-products

As well as the nutritional properties of the edible pear fruit, a small number of studies have also investigated the nutritional properties of the waste products of pear, namely pear pomace and pear seeds. Large quantities of fruit pomace are produced each year as a waste product of fruit juice production. Interest is increasing regarding how we can utilise waste products from food production to meet the nutritional needs of our population and create “more from less”.

Martin-Cabrejas et al (1995) compared the dietary fibre content of pear and kiwi pomace, classified as the skins, seeds and core. They found that pear pomace was superior to kiwi in dietary fibre content containing 36.6% dry matter (DM) as insoluble fibre and 7.6% DM soluble fibre (total % DM dietary fibre 43.9%) compared to 18.7% DM insoluble fibre and 7.1% DM soluble fibre for kiwi pomace [32]. The authors suggest that this pomace could be used to increase the fibre content of other foods, given the discrepancy between recommended and current fibre intakes.

The other waste products from pear with potential nutritional benefits are pear seeds. Three studies analysed the oil content and fatty acid composition of pear seeds to identify whether they may be a potential novel resource. One study reported insufficient seed to fruit ratio and immature seeds in the pears and therefore did not consider it worthwhile to attempt oil extraction (Fromm 2012), however the remaining two studies found that pear seeds contained substantial oil content. Matthaus & Ozcan (2015) looked at the European pear, *Pyrus Communis* and found 31.7g oil /100g seeds, predominately made up of oleic and linoleic oils, which was greater than Yukui et al (2009) who looked at the Asian pear cultivar *Dangshan Suli* and found it contained 179g oil/kg seeds. Yukini et al (2009) noted this was comparable with soybean oil, which ranges between 180-220g/kg seeds [33], however Matthaus & Ozcan (2015) qualified that oil extraction is not economically viable in seeds with oil contents below 20g/kg unless the meal contains valuable protein such as in the case of soya bean.

In summary, pears stand out for their combination of digestion regulating nutrients including fibre, fructose and sorbitol. While pears do not contain significant flavonoids compared to other common fruits, some cultivars contain high levels of certain phenolic acids, which may have a range of health benefits in humans as will be discussed further in this report. Finally, the waste products of pear including seeds and pomace have potential uses as foods or food ingredients.

Table 1: Nutritional composition of Australian pear varieties (raw, unpeeled, per 100 g edible portion) [10]

	PEAR BROWN (BEURRE BOSC) UNPEELED RAW	PEAR NASHI UNPEELED RAW	PEAR PACKHAMS TRIUMPH UNPEELED RAW	PEAR WILLIAM BARTLETT UNPEELED RAW	PEAR AVERAGE OF FOUR
Energy (kJ)	264	209	227	230	232.5
Protein (g)	0.3	0.4	0.3	0.3	0.3
Total fat (g)	0	0.1	0	0	0.0
Carbohydrate available (g)	14.3	11.1	12.5	11.7	12.4
Sugars (g)	10.4	10.6	9.1	8.9	9.8
Glucose (g)	1.7	4.4	2.1	1.4	2.4
Fructose (g)	6.3	6.0	6.8	6.7	6.5
Sucrose (g)	2.4	0.2	0.3	0.8	0.9
Starch (g)	0	0.5	0	0	0.1
Water (g)	81	86.7	83.8	84.2	83.9
Dietary-fibre (g)	3.4	2.1	2.4	4.3	3.1
Vitamin C (mg)	4	2	4.00	6.00	4
Potassium (mg)	100	130	102	115	112
Magnesium (mg)	7	8	6	7	7
Calcium (mg)	6	5	6	6	6

Table 2: Nutrition composition of pear compared to other commonly consumed fruit (raw, unpeeled, per 100 g edible portion) [10]

	PEAR AVERAGE, UNPEELED, RAW	APPLE, RED SKIN, UNPEELED, RAW	BANANA,CAVENDISH PEELED, RAW	ORANGE,NAVEL, PEELED, RAW	STRAWBERRY, RAW	PEACH,UNPEELED, RAW
Energy (kJ)	233	236	385	175	108	195
Protein (g)	0.3	0.3	1.4	1	0.7	1
Total fat (g)	0.03	0.2	0.3	0.1	0.2	0.1
Carbohydrate available (g)	12.4	12.4	19.6	8	3.9	9
Sugars (g)	9.8	11.6	12.8	8	3.8	8.5
Vitamin c (mg)	4	4	4	53	45	9
Potassium (mg)	112	96	346	147	158	241
GI [14] (mean)	33-42 (38) [1]	28-44 (36) [1]	47	33-40	NA	28-56[1]

[1] Values from IGT and T2DM subjects NA, not applicable

Table 3: Sugar compositions of pears and other commonly consumed fruits per 100g edible fruit [34]

	PEAR, PACKHAM FIRM, SKIN PEELED	PEAR, PACKHAM, RIPE, PEELED	APPLE,RED SKIN,UNPEELED	APPLE, RED, PEELED	BANANA,COMMON, MEDIUM RIPENESS, PEELED	ORANGE,NAVEL, PEELED	STRAWBERRY	PEACH,YELLOW, UNPEELED
Fructose (g)	9.32	3.4	2.2	1.89	2.45	2.09	NR	0.54
Glucose (g)	4.35	1.11	6.4	1.16	5.38	3.28	NR	1.23
Excess fructose (g)	4.97	2.29	3	0.73	-	-	NR	-
Sorbitol (g)	5.99	2.3	0.4	0.75	ND	ND	NR	0.68

[1] Muir 2009; [2] Li 2002 [3] Park 2015, ND not detected, NR not reported

Table 4: Fibre content of peeled and unpeeled pears and other common fruits (g/100g edible portion) [35-36]

	PEAR, RIPE, SKIN UNPEELED, RAW[2]	PEAR, SKIN PEELED, RAW[3]	APPLE, RED SKIN, UNPEELED, RAW[2]	APPLE, RED SKIN, PEELED, RAW[3]	BANANA, RIPE, PEELED, RAW[2]	ORANGE, NAVEL, PEELED, RAW[2]	STRAWBERRY, RAW[3]	PEACH, UNPEELED, RAW[2]	PEACH, PEELED, RAW[3]
Total dietary fibre (g)	3.16	2.13	2.21	1.22	1.79	2.35	2.07	2.85	2.07
Insoluble fibre (g)	2.25	1.29	1.54	0.86	1.21	0.99	1.29	1.54	1.27
Soluble fibre (g)	0.9	0.84	0.67	0.36	0.58	1.37	0.84	1.31	0.8

[1] Muir 2009; [2] Li 2002 [3] Park 2015, NA not applicable (due to insufficient CHO content)

Table 5: Comparison of sugar content in European compared to Asian pear cultivars (g/100g) [26]

	GLUCOSE	FRUCTOSE	SUCROSE	SORBITOL	TOTAL SUGAR	GLUCOSE: FRUCTOSE	FRUCTOSE (% TOTAL SUGAR)
European varieties (n=18)	0.48-1.53	2.37-6.61	0.22-2.11	1.25-2.58	5.23-9.90	0.12:0.52	42.9-68.4
Asian varieties (n=4)	1.37-2.18	2.79-4.57	0.26-1.54	0.50-1.90	5.85-8.07	0.39:0.59	40.4-58.9

Table 6: Flavonoid content of pears and other common fruits (mg/100g edible portion) [12]

	PEAR AVERAGE	APPLE,RED SKIN,UNPEELED,RAW	BANANA,CAVENDISH, PEELED,RAW	ORANGE,NAVEL, PEELED,RAW	STRAWBERRY,RAW	PEACH,UNPEELED,RAW
Anthocyanidins						
Petunidin	0	0	0	0	0.1	0
Delphinidin	0	0	7.4	0	0.3	0
Malvidin	0	0	0	0	0	0
Pelargonidin	0	0	0	0	24.8	0
Peonidin	0	0	0	0	0	0
Cyanidin	2.1	1.6	0	0	1.7	1.9
Flavan-3-ols						
(+)-Catechin	0.3	1.3	6.1	0	3.1	4.9
(-)-Epigallocatechin	0.6	0.3	0	0	0.8	1
(-)-Epicatechin	3.8	7.5	0	0	0.4	2.3
(-)-Epicatechin 3-gallate	0	0	0	0	0.2	0
(-)-Epigallocatechin 3-gallate	0.2	0.2	0	0	0.1	0.3
(+)-Gallocatechin	0	0	0	0	0	0
Flavanones						
Hesperetin	0.0	0	0	21.9	0	0
Naringenin	0.0	0	0	7.1	0.2	0
Flavones						
Apigenin	0.0	0	0	0	0	0
Luteolin	0.0	0.1	0	0.7	0	0
Flavonols						
Isorhamnetin	0.3	NR	NR	NR	NR	NR
Kaempferol	0	0.1	0.1	0	0.5	0.2
Myricetin	0	0	0	0	0	0
Quercetin	0.8	4	0	0.2	1.1	0.7

NR, not reported

Table 7: Selected phenolic acids (mg/kg) found in pear

	REFERENCE	CHLOROGENIC ACID	ARBUTIN	FERULIC ACID	CITRIC ACID
Whole fresh pear unpeeled					
2 Asian pear varieties (Danhshan and Nanguo)	Chen 2007 [37]	309-349			
4 European pear varieties (Williams Bon Chrétien, Red Williams, Rosired, Clapp Favorite, Early Morettini)	Hudina 2000 [26]				1,400-2,700
4 Asian pear varieties	Hudina 2000 [26]				400-1,000
Asian pear (*Pyrus pyrifolia* Nakai)	Pyo 2014 [38]				932
European pear (Rocha)	Salta 2010 [24]	624	22.5	233	
Pear peel					
European pear (*Pyrus communis* L var Blanquilla)	Gorinstein 2002 [39]			15	
European pear (*Pyrus communis* var Sarıkum)	Ozturk 2014 [40]	1348			
European variety (*Pyrus communis* var Decana)	Escarpa & Gonzalez 2000 [41]	96-607	453-634		
6 European pear varieties	Galvis Sanchez 2003 [42]				583-1158
Asian pear (Yaguang *P. Ussuriensis* Maxim)	Wang 2015 [43]	420	5311	145	
Pear pulp					
European pear (*Pyrus communis* var Sarıkum)	Ozturk 2014 [40]	892			
Asian pear (*Pyrus pyrifolia* Nakai)	Pyo 2014 [38]				975
European variety (*Pyrus communis* var Decana)	Escarpa & Gonzalez 2000 [41]	46	16.4		
Asian pear (Yaguang *P. Ussuriensis* Maxim)	Wang 2015 [43]	27	253	95	

N.b. As wide variation in phenolic acids was observed between varieties and studies this table presenting data only on those varieties that stand out for their significant phenolic acid content

4 Health benefits of pears

4.1 Pears and cardiovascular disease

Cardiovascular disease (CVD), including ischaemic heart disease and stroke, remains the leading causes of death in Australia [44]. Consumption of fruit and vegetables is an important dietary strategy for reducing CVD risk [45]. Evidence from three prospective studies [46-48] and a meta-analysis that included two of these studies [49] provide consistent evidence that increased consumption of apples and pears are associated with reduced risk of stroke. The risk of stroke decreased by 12% when lowest intakes were compared to highest intakes (Relative risk (RR) [95% confidence interval (CI) 0.88 [0.81-0.97]) [49]. Consumption of apples and pears were also associated with reduced risk of coronary heart disease (CHD) and CVD (intakes >1x/week vs. <1x/week, RR [95%CI]: 0.85 [0.75, 0.98] and 0.87 [0.78, 0.96], respectively) [47]. Unfortunately the independent effects of pears cannot be determined since all studies combined apples and pears.

The reduced risk of CVD may be explained by the independent and (or) synergistic actions of various constituents in pears such as fibre and polyphenols that may affect several CVD risk factors such as blood pressure, body weight, lipid profiles, inflammation and oxidative stress [46-48] (See sections 4.3 and 4.4).

The relationship between apple and pear consumption and CVD, particularly stroke, is supported by consistent level III-2 evidence; the evidence has substantial clinical impact; and is generalizable and applicable to the Australian population. Although observational studies cannot prove causality; prospective studies provide the highest level of evidence of observational studies due to its temporal nature (exposures precedes the outcome). Furthermore, Hu *et al.* [49], in their meta-analysis, showed a linear dose-response relationship, an important criteria for causation, between fruit consumption and risk of stroke; for every 200 g/day increment in fruit consumption risk of stroke decreased by 32%.

Satisfactory evidence (Grade C) is available for the association between combined apple and pear consumption and reduced risk for stroke. Emerging evidence suggest that apples and pears are also associated with reduced risk for CHD. However, the independent role of pears is unknown.

4.2 Pears and diabetes

Type 2 diabetes mellitus is the fastest growing chronic condition in Australia, with an estimated 1.7 million Australians having diagnosed or silent (undiagnosed diabetes) [50]. T2DM is characterised by insulin resistance and hyperglycaemia. Dietary factors, including fruits and vegetable intake, are potentially modifiable risk factors, however the mechanisms by which this intake may reduce T2DM risk remains unclear. Two prospective studies [51-52] , which pooled the results from three large US prospective cohort studies and three animal studies [43, 53-54] exploring this relationship between pears and T2DM were identified for review.

Muraki (2013) explored the relationship between fruit consumption and T2DM risk, while Wedick (2012) looked at dietary flavanoid intake. Both found inverse associations between apple and pear consumption (collectively) and T2DM, with an intake of >1 serve of apple or pear a day associated with a 17% reduction

in T2DM risk compared with the lowest quintile of intake (less than once a week consumption) (Hazard ratio (HR) for pooled results, 95% CI 0.83, 0.76-0.90 p<0.001). Furthermore, substituting three servings of fruit juice a week with the same amount of whole fruit (apples and pears) resulted in a 14% (11-18%) lower T2DM risk. Interestingly, the authors report that these findings were not associated with the glycaemic index or load of the fruit. This finding was supported by Wedick et al (2012), who reported an inverse association between intake of anthocyanins and anthocyanin-rich foods and T2DM risk, with the strongest inverse association seen with apple and pear consumption. Those in the highest quintile of intake (≥5 serves/week) compared with less than once a month having a 7% risk reduction, (pooled HR, 95% CI; 0.93, 0.86 –1.00). The authors analysed the results for the three studies individually and also pooled the results, finding a significant association in all studies. The authors could not attribute this effect directly to the anthocyanins and acknowledge that there may be other components which co-exist in these foods, requiring randomised controlled trials to elucidate the mechanisms.

Animal studies have explored some of the mechanisms by which apples and pear intake may be exerting the positive health benefits seen in T2DM. In an acute feeding study of hyperglycaemic rats, European pear (*Pyrus communis*) extract reduced the change in blood glucose levels by 28.11% (P<0.01) compared to the control (saline solution) at 30 minutes and a similar favourable response was seen for the change in the area under the curve (ΔAUC) in pear extract compared to control (5080±367.8 vs 7405.5±355.4 mg/min/dL at 120 minutes). The authors ascribed the effect to the antioxidant and insulin-like actions of the phenolics (not specified) in the pear extract [53].

Velmurugan et al also looked at two pear extracts, ethyl acetate (EAEPC) and ethanolic (EEPC) extracts from *Pyrus Communis* and compared their effects in hyperglycaemic rats to Glibenclamide, a sulphonylurea class of medication, which acts to stimulate insulin release from the pancreas. Over 11 days they found that the standard Glibenclamide, EAEPC and EEPC groups all showed significant decreases in blood glucose levels compared to the diabetic control (p<0.01). In addition, the pear extract groups produced a number of favourable effects on lipid profile, significantly reducing total cholesterol (TC), triglycerides (TG) and low-density lipoprotein cholesterol (LDL-C) and increasing high-density lipoprotein cholesterol (HDL-C) levels compared to the diabetic control. The authors speculated that this may be related to the presence of a range of bioactive compounds including lavanoids, steroids, alkaloids, carbohydrates, tannins and other phenolic compounds working synergistically, however their study did not investigate mechanisms by which this may occur [54].

These favourable results on lipid profile and glycaemic response were supported by another animal study by Wang (2015) who fed pear peel or pulp extract from the Yaguang pear (*Pyrus ussuriensis* Maxim) to T2DM mice over three weeks [43]. The Yaguang pear was selected as it had the highest concentration of phenolic acids of those tested. Pear peel, but not pulp, significantly reduced serum TC (P<0.01), TG (p<0.05) and LDL-C (P<0.01) and increased HDL-C/TC ratio (<0.01) compared to the diabetic control. Positive impacts on blood glucose levels were also seen, with a reduced fasting blood glucose level in the pear peel group after 2 weeks of treatment (P<0.01), a reduction in blood glucose level over three hours and a reduced AUC compared to the diabetic control. As these results were only seen in the pear peel group and not the pear pulp group these mechanisms may be mediated through compounds specifically isolated or at higher concentrations in the peel. Four compounds identified in pear peel, chlorogenic acid, vanillic acid, ferulic acid and rutin have been shown to have intestinal α-glucosidase inhibition activity *in vivo* that may delay digestion and absorption of carbohydrates. In addition, triterpenes, another class of phytochemical, also found in pear peel have been shown to have α-glucosidase and α-amylase inhibition activity *in vitro* [55].

In summary, two observational studies which pooled results from three large studies provide consistent level-III-2 evidence of the role of apples and pears combined in on reducing T2DM risk [51-52]. The evidence has substantial clinical impact; and is generalizable and applicable to the Australian population,

thus provides satisfactory evidence (Grade C) for the association between consumption of apples and pears combined and a lower risk of developing T2DM. Animal models point to some mechanisms by which pears may affect glycaemic response in T2DM. It is thought that these effects may be mediated by the phenolic compounds, mainly found in the peel of the pear, which have antioxidant and insulin-like actions and may reduce digestion and absorption of carbohydrate in the intestine. Pear extract also improved lipid profiles (decreased TC, LDL-C and increased HDL-C) in diabetic animal models. However human randomised controlled trials are needed to verify the responses in humans.

Observational studies support the role of apples and pears on reducing T2DM risk and animal models point to some mechanisms, however human RCT are needed to further investigate these responses.

4.3 Pears and metabolic health markers

Metabolic abnormalities such as dyslipidaemia (increased TC, LDL-C, TG and lower HDL-C), hypertension, chronic inflammation and abnormal glucose metabolism are important factors in the pathophysiology of several chronic conditions such as CVD, T2DM, cancer and dementia [56].

A dearth of evidence exist for the effects of pear or pear components on metabolic health markers (Table 10, 12, 14).

One small human study in overweight hypercholesterolaemic postmenopausal women showed that the consumption of 300g/day of apples/pears compared to 60g/day oat cookies resulted in a small reduction in plasma glucose, while TG levels increased and insulin and cholesterol were unaffected [57]. The authors speculated that the increase in TG levels may have been due to the high fructose content of pears. However, much larger dosages than what is available in pears is needed to increase TG levels; results from a meta-analysis suggested >100g fructose/day increased fasting TG and >50g/day increased postprandial TG [58]. A dosage of 300g pear/day provides 19.5g fructose and is therefore unlikely to increase TG levels.

Cassidy et al reported from cross-sectional analysis that apple and pear consumption was significantly associated with a lower inflammatory score (sum of a range of inflammatory markers). Those consuming ≥7 servings/week vs. <1 serving/week had a 65% lower inflammatory score [59]. No intervention studies in either human or animal models were found that investigated the effects of pear consumption on markers of inflammation.

No evidence for the effect of pears on blood pressure was found.

As discussed in section 4.2 pear extract improved lipid profiles in diabetic induced animal models [43, 54]. Consumption of pear peel or pulp counteracted cholesterol raising effects due to cholesterol feeding in rats [60]. Shahaboddin et al showed that consumption of wild pear (*Pyrus Biossieriana Buhse*) leaf extract by hyperglycaemia induced rats over 4 days resulted in reduced TG, glucose and TC and increased insulin levels compared to the control. The authors hypothesised that the effects may have been due to the high levels of phenolic acids, particularly arbutin, in wild pear leaf extract [61].

Pear (including peel and pulp) contain several bioactive components that may contribute to a healthy metabolic profile such as flavonoids (anthocyanidins) [12], phenolic acids (chlorogenic acid, ferulic acid) (Meng, 2013, Srinivasan, 2007, Zhao, 2008) and soluble fibre [62]. Brown et al 1999 showed in a meta-analyses that every 1g increase in intake of soluble fibre, specifically pectin, resulted in a reduction in total

cholesterol of 0.07mmol/L. Pear contains on average 1.17 g soluble fibre per 130g serving. Although the expected cholesterol reducing effects from the soluble fibre content may be small, the synergistic actions of several cholesterol lowering components in pear may result in meaningful clinical outcomes.

Very limited evidence suggests that pear and pear components may favourably affect metabolic health markers such as blood glucose and lipid profiles. The limited number of studies investigating the effects of pear or pear components on metabolic health markers is surprising, considering that there are several components in pear that could affect these markers. More human RCT are needed before recommendations can be made for the role of pears on metabolic health.

There are several components in pear, particular in the peel, which may contribute to metabolic health through improving blood glucose and lipid profiles, but these potential effects need to be substantiated in human studies.

4.4 Antioxidant effects of pears

Many chronic diseases have a common underlying mechanism of oxidative damage caused by imbalances between the formation of reactive oxygen species and the body's defence mechanisms. Diets high in anti-oxidants augment the body's antioxidant defences and protect against oxidative damage [63]. Pears contain several phenolic compounds that have antioxidant properties (see section 3).

Several studies described *in vitro* assays to measure the antioxidant capacity of pears. However, due the inherent limitations of this approach (as described in section 2.2), the focus of this section will be on the *in vivo* antioxidant activity of pears. No human studies were found.

Studies in animal models demonstrated increased *in vivo* antioxidant activity with consumption of European pear peel and pulp extract [60, 64], Asian pear peel and pulp extract [65], triterpenes extracted from Asian pear peels [66] and wild pear leaf extract [61]. The antioxidant activity from pear peel was generally higher than that of pear pulp [60, 65].

In summary, animal studies suggest that consumption of pear, particularly pear peel, or phenolic components from pear may increase antioxidant activity. However, in the absence of any human studies no recommendations can be made for pear's antioxidant activity effects.

Results from animal studies show that pear, particularly pear peel, have increased antioxidant activity in the body.

4.5 Pears and cancer

Increased consumption of fruits and vegetables are related to decreased risk of a range of cancers and this is reflected in the World Cancer Research Funds cancer prevention recommendation to "eat mostly plant foods" and to consume fruits everyday as a part of this [22].Furthermore the report summarises the evidence by stating that fruits probably protect against cancers of the mouth, pharynx, larynx, oesophagus, lung and stomach and foods containing fibre probably protect against colon cancer. The mechanisms behind prevention of cancer from fruit intake is likely multi-factorial with a range of vitamins, mineral, antioxidants and other bioactive compounds as well as fibre all possessing possible mechanisms to modify cancer development.

Three prospective studies were identified which assessed risk of various cancers and apple and pear intake [67-69] and three case-control studies [70-72]. Buchner et al [68] and Linseisen et al [69] both analysed data from the European Prospective Investigation into Cancer and Nutrition (EPIC), a large cohort study, which provides data from over 470,000 men and women across Europe. Buchner et al found apple and pear intake at 25g increments, was associated with a 7% protective association on bladder cancer risk amongst those who never smoked (Hazard ratio (HR) [95% CI]: 0.93 [0.89-0.98]) [68]. Similarly for lung cancer, each 100g increment of apple and pear intake was associated with a 14% reduction in lung cancer risk for all participants (HR [95% CI]: 0.86 [0.75-0.99]) [69]. The only prospective study which did not find a significant association with cancer was a Dutch study that reported a non-significant inverse association between apple and pear intake and stomach cancer (RR [95% CI] 0.76 [0.47-1.23], P=0.18) [67].

Two case- control studies also investigated the association between pears and cancer risk of the digestive system. Case-control studies are at greater risk of bias compared to prospective cohort studies as the development of disease/condition precedes the collection of dietary data. Zheng et al [72] found those with the highest pear consumption (≥2 serves a week) had a significant lower risk of oral cancer compared to those consuming one serve a week (Odds ratio (OR) [95% CI] 0.27 [0.15-0.49]). This was the strongest association seen for any of the fruits or vegetables investigated in this study [72]. As this was a study of a Chinese population it is likely that Asian pear varieties were being consumed. Rossi et al showed that for each portion of apple or pear consumed the odds for pancreatic cancer decreased by 27 % (OR [95% CI] 0.73 [0.60-0.90]) [71]. The authors were particularly interested in foods which contained proanthocyanins, a class of polyphenol present in apples and pears, which they believed may play a role in modifying cancer risk, and while their findings supported this, the observational nature of the study means no causative mechanisms could be identified.

A Swiss case-control study found that those in the highest tertile of pear intake had 50% lower risk of breast cancer compared to the lowest tertile of intake (P<0.05). The quality of this study was lower compared to others as there was minimal adjustment for confounders that are likely to affect the diet disease relationship [70].

In summary, five out of six prospective and case-control studies showed that increased consumption of pears or apples and pears combined, were associated with reduced risk of cancer, specifically lung, bladder, oral, pancreatic and breast cancer; hence the evidence is mostly consistent for cancer, but not for type of cancer. Unfortunately pears were rarely looked at individually in these studies and the independent association of pears can therefore not be ascertained. Considering the level of evidence (level III-2), consistency, number of studies, impact and generalisability it can be concluded that the evidence for the association between pear and apple consumption and cancer is satisfactory (Grade C).

Satisfactory evidence (Grade C) exists for an association between combined apple and pear consumption and reduced risk for cancer.

4.6 Pears and gastrointestinal health

There is interest in the role of pears in managing diseases of the gastrointestinal system including inflammatory bowel diseases (IBD) (ulcerative colitis and crohns' disease) and gastric ulcer disease. While only a small number of studies exist in each area, they represent potential areas of further research for pears and pear extracts as functional foods.

4.6.1 Inflammatory bowel diseases

Although diet is regarded as an important factor influencing inflammatory bowel diseases (IBD), there are

no accepted dietary recommendations presently available; hence this an important area for further research.

Animal studies have looked at different bioactive compounds in pear and their potential roles in modulating IBD. Azuma et al (2013) found Japanese pear cellulose nanofibres (P-CNF), which contain two forms of fibre (lignin and hemicelluloses) had a number of favourable effects, suppressing shortening of the colon length and significantly improving the histological tissue injury in the mice. It also had a number of anti-inflammatory effects, suppressing the activation of nuclear factor-kappa B (key regulator of pro-inflammatory signalling molecules) and fibrosis of the colon, as well as activation of inflammatory cells such as leukocytes. Dietary fibre has been shown to be beneficial in maintaining colonic health through the production of the short chain fatty acid (SCFA), butyrate, which provides an important energy sources for the colon epithelium [73]. P-CNF may therefore provide a new source of beneficial dietary fibre for IBD patients.

The same group of Japanese researchers have also investigated the effects of pear vinegar (PV) on ulcerative colitis (UC) based on the knowledge that both fruits and vinegar have shown beneficial effects on colon cancer. PV was administered orally at varying concentrations (4.5 and 9% w/v) over 7 days to UC-induced mice. The vinegar was brewed to be rich in galacturonic acid, the main constituent of pectin, which has previously been shown to inhibit UC in a rat model [74]. PV significantly improved clinical symptoms, colon inflammation, and histological tissue injury in the DSS-induced acute UC mouse model compared to the control group (water). Moreover, PV suppressed inflammation due to acute UC by suppressing the myeloperoxidase (MPO) mediated activation of inflammatory cells such as leukocytes and decreasing the serum concentration of IL-6, whereas commercial apple vinegar did not produce the same results. These findings indicate a potential role for PV as a functional food in UC (Wakuda et al 2013).

In conclusion, a number of bioactive compounds in pears may modulate IBD risk or disease, including the Japanese pear cellulose nanofibres and galacturonic acid-rich pear vinegar. Currently, no evidence is available for these effects in humans, limiting recommendations in this area, however this represents an emerging area which warrants further research.

4.6.2 Gastric ulcers

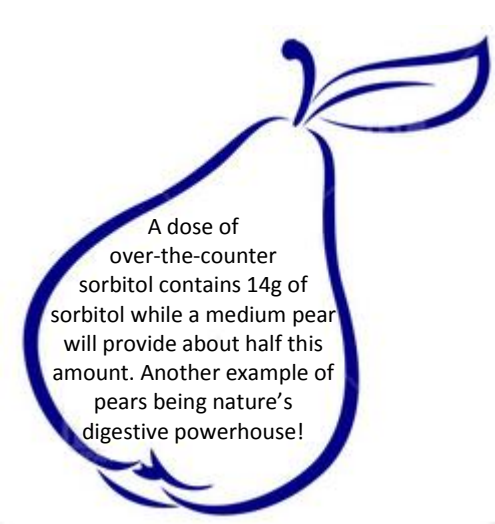
The effect of pear polyphenols, procyanidins and chlorogenic acid on hydrochloride (HCl)/ethanol induced gastric ulcers in mice were assessed by Hamauzu et al. Procyanidins are polyphenols present in significant amounts in some pear cultivars. As they are related to flesh browning they can be undesirable for commercial crops, however they are reported to have antioxidant activity. In this study the polyphenols of interest were extracted from a European pear variety, Winter Nelis pears and 20mg was given the mice intragastrically prior to the acidified ethanol (to induce the gastric ulcer). The procyanidins, and the mixture of procyanidins and chlorogenic acid both had a protective effect on ulcer formation, whereas chlorogenic acid alone increased ulcer severity. The procyanidins bound to the mucosa creating a protective layer against ethanol, reducing leukocyte migration, and then deploying a local antioxidant protection against free radicals [75].

4.6.3 Digestive effects

Pears contain a unique combination fructose and sorbitol as well as boasting a high fibre content. This nutritional composition may have an important role in the prevention and treatment of constipation. As sorbitol and fructose are poorly absorbed in the small intestine they move through the digestive tract into the large bowel attracting water along the way. This laxative effect helps to make the stool softer and easier to pass as well as increasing stool frequency. This, along with the well understood benefits of insoluble fibre for adding bulk to the stool, make pears a powerhouse for digestive health. This physiological mechanism may be particularly useful in children and infants where consumption of fruit or

fruit juice may be more palatable than medications for constipation. [76] Surprisingly, to date no human studies have been conducted to substantiate these effects.

It is worth noting that Practice-based Evidence in Nutrition (PEN) is a global resource for nutrition practice. They recommend pears as a top fibre containing fruit to prevent constipation in their "Fibre" factsheet [77].



The high level of fructose and sorbitol in pears, while beneficial to most people, can be problematic in others. None of the human studies reported on any adverse effects of pears or on potential intolerance effects of pears. There is however, a large body of evidence in the area of FODMAP (Fermentable Oligosaccharides, Disaccharides, Monosaccharides, and Polyol) malabsorption. This malabsorption results in gastrointestinal complaints that often present as Irritable Bowel Syndrome (IBS). Major FODMAPS include fructose found in fruit, honey and high fructose corn syrup, fructans such as inulin found in wheat and onions and polyols such as sorbitol found in fruit and certain artificially sweetened foods [78]. Pears have a high excess free fructose content (3-8g/100g, highest of any fruit) but also the combination of fructose and sorbitol makes it particularly problematic for FODMAP malabsorbers [79-80].

The unique combination of fibre, fructose and sorbitol in pears may have positive effect on digestive health. In the absence of human studies to substantiate this benefit of pears, a health claim can be made based on the fibre content of pears. FSANZ have approved a general level health claim for fibre and laxation. Foods that contain ≥2g fibre/serving can make the following claim: "Contributes to regular laxation" [2].

4.7 Pears and allergic and respiratory conditions

Allergic diseases such as rhinitis, asthma and eczema are common place throughout the world. Asthma is an atopic disorder characterised by chronic swelling and inflammation of airway affecting at least 20% of the population of developed countries [81]. Rhinitis is prolonged sneezing or runny or blocked nose without a cold while eczema can be defined as dry skin in combination with an itchy rash. The antioxidants in fruit and vegetables are thought to reduce airway inflammation by protecting the tissue from oxidative stress. We can learn a lot from traditional Chinese medicine, and the use of pears in managing respiratory diseases can be traced back 2000 years. The Asian pear is known for its effects on clearing the lung and dissipating phlegm [82].

Rosenlund et al conducted a cross-sectional study looking at a sample of 2447 eight year old children from the BAMSE cohort who had completed a 98-item FFQ and parental questionnaire about symptoms and diagnoses of allergic diseases. They found that there was an inverse association between apple and pear intake and allergic symptoms. The highest versus lowest tertile of intake of apples and pears were inversely associated with rhinitis, asthma and atopic sensitization (OR [95% CI], rhinitis: 0.46 [0.35-0.62] p=<0.001, asthma: 0.63 [0.42-0.94] p=0.038, atopic sensitization: 0.69 [0.54-0.87] p=0.007). It is important to note that when children who reported allergic symptoms related to fruit or vegetables were excluded from analysis (as they might have changed their diet as a result of the allergic symptoms) the associations disappeared [83].

Another cross-sectional study, conducted by Woods et al in young adults, showed that increased consumption of apples and pears was associated with fewer current asthma symptoms, less diagnosed asthma and less bronchial hyper-reactivity. The odds ratio (and 95%CIs) were: current asthma symptoms: 0.83 (0.71, 0.98) $p<0.05$, diagnosed asthma: 0.88 (0.78, 1.00) $P<0.05$, bronchial hyper-reactivity: 0.88 (0.77, 1.00) $P<0.05$. The consistency in the outcome measures gave the authors confidence in concluding that there are real underlying patterns of association between apple and pear intake and asthma rather than just from chance alone [84].

Rodruigez et al performed double-blind placebo controlled food challenges in 34 patients referred to the allergy division of a hospital complaining of an adverse reaction to one or more foods from the Rosaccea family. 231 skin prick tests were taken of which 126 were positive and only 18 were positive for pear. Of the 126 open food challenges, only one was positive to pear making it one of the least reactive fruits in the Rosaccea family [85].

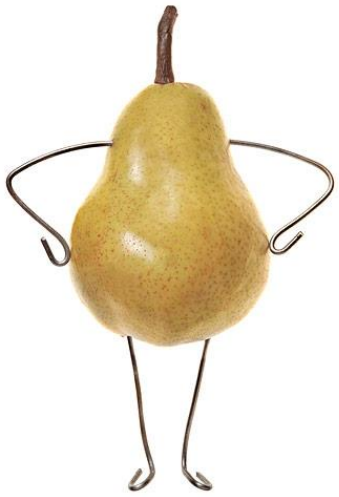
Lee et al conducted an animal study whereby a respiratory disorder resembling human allergic asthma was induced in mice. For 2 weeks prior to this sensitization the test mice were administered high dose (100 μg) Asian pear pectin solution while the controls received oral saline. The pectin-solution group significantly inhibited sensitivity of airway smooth muscle to electrical field stimulation and acetylcholine ($p<0.05$). Histologically, the pectin-solution group recovered the ovalbumin-induced abnormal signs to nearly normal state. IgE production was significantly decreased in the pectin-solution group ($p<0.05$). The authors concluded that the administration of Asian pear pectin solution in pre-sensitized mice suppressed the allergic asthmatic reaction and that this animal study provides justification for further respiration related studies to control the production of cytokines (TH1 and TH2 type).[81].

The combination of Asian pear (*P bretschneideri* Rehd) and the bulb of the Fritillaria ussuriensis (an Asian plant in the lily family) are used in traditional Chinese medicine for managing respiratory disease. Huang et al assessed the anti-inflammatory and synergistic activities of these plants in rats. The combination of the pear extract and bulb extract demonstrated significant inhibition of tissue oedema and the increase of vascular permeability ($p<0.01$) to a greater extent than either the pear or the bulb alone ($p<0.05$). This study confirmed the anti-inflammatory effects of the Asian pear and the bulb of the Fritillaria ussuriensis, as well as the synergistic effect between them. The authors concluded that there is potential for using these plants to treat acute inflammation and relieve throat and lung disease [82].

The mechanism by which pears have a beneficial role in the treatment of allergic inflammatory diseases may be related to their unique combination of polyphenols and flavonoids. Research on flavonoids, including the rutin and quercetin present in pears, indicates some potential activity for the treatment of allergic diseases such as asthma through the down-regulation of mast cell activation [86].

In summary, due to their reputation as a low allergen food, pears have long had a place on elimination diets (used to identify food allergies and intolerances). The findings from the above papers combined with the absence of any studies indicating any allergic response to pears, allow us to confidently conclude that pears have earnt their reputation as a low allergen food. Evidence from cross-sectional studies suggests some potential benefit of consuming pears (and apples) for asthma and other respiratory diseases and a limited number of animal studies support these findings. However, further research, particularly human RCTs, is required before any recommendations can be made regarding the consumption of pear and allergic and respiratory conditions.

4.8 Pear and weight control



One RCT in 49 overweight hypercholesterolaemic women, 30-50 years old, showed that consumption of 300 g/day pears or apples as part of a hypocaloric diet resulted in significantly greater weight loss over a period of 10 weeks compared to 60 g/day oat cookies [87]. The addition of pears to the diet as a snack food resulted in 1.05 kg greater weight loss, 0.34 kg/m^2 greater reduction in body mass index (BMI) and 0.49 cm greater reduction in mid-arm circumference compared to oat cookies despite similar energy and fibre content of the snacks. The authors ascribed the greater weight loss to significant decreased energy density of pears compared to oat cookies (-1.29 kcal/g) resulting in significant reductions in energy intake (-20.35 kcal/d compared to oat cookies). Similar results were seen with addition of apples with no differences between pears and apples [87].

In conclusion, the addition of pears to a weight reducing diet has potential to contribute to weight loss through its low energy density. In other words, pears could add weight to the diet without increasing calories resulting in reduced energy density and reduced energy intake and consequently weight loss. However, this finding is based on only 1 small study and needs to be confirmed in further RCT before recommendations can be made for the role of pears on weight control.

4.9 Pears and alcohol hangover symptoms

An interesting area of research, the effect of the Korean pear on hangover has been investigated in one animal and one human study. Alcohol drinking can result in a range of symptoms including headache, fatigue, diarrhoea, dizziness and poor concentration. This can result in lost productivity and absenteeism from workplaces [88]. This is a particularly pertinent issue in Asian populations because of a high prevalence of a genetic variation in the key enzymes responsible for alcohol metabolism, alcohol dehydrogenase (ADH) and aldehyde dehyrogenase (ALDH), which can increase hangover severity. The Korean pear (*Pyrus pyrifolia cv. Shingo*) has historically been used as a traditional medicine for alcohol hangover and these studies aimed to determine the mechanisms by which this fruit may reduce hangover symptoms.

Lee et al (2012) administered pear extract (10mL/kg BW) to ALDH2 normal (ALDH +/+) and ALDH2 deficient (ALDH2-/-) mice and after 30 minutes gave ethanol [89]. They found that in both the ALDH2 normal and deficient mice the blood alcohol levels were decreased compared to the control group (water) but this effect was more pronounced in the ALDH2 deficient mice (16.26±1.90mM vs 11.2±2.43mM; $p<0.05$). In addition, 2-fold higher alcohol and 7-fold higher acetaldehyde levels in blood, the toxic by-product of ethanol metabolism, were observed in Aldh2 deficient mice compared to Aldh2+/+ mice ($p <0.01$) which is reflective of excessive accumulation of acetaldehyde in the ALDH2 deficient mice caused by the delay in alcohol metabolism. *In vitro*, they observed that the pear treatment group had 2-3 and 1.3 fold activity in ADH and ALDH activity, respectively. Taken together this indicates that the pear extract stimulates the activity of the two alcohol metabolising enzymes (ADH and ALDH) and/or inhibited alcohol absorption and/or accelerated alcohol elimination due to this increased metabolism, with different patterns of elimination between the two genetic variants of ALDH2.

This was followed up with a human acute cross-over RCT [90] where 14 healthy males consumed 220mL of Korean pear juice or placebo juice (with added pear flavouring and fructose to provide a similar sugar composition) prior to alcohol consumption (540mL spirits with 20.1%w/v alcohol concentration). Similarly to the animal study blood alcohol level was significantly reduced after pear juice consumption compared to

placebo, particularly in the ALDH2 deficient participants. Alcohol hangover was assessed subjectively using a hangover severity scale and both the mean and total hangover scores were reduced after pear juice consumption compared to placebo, specifically in the normal (non-ALDH2 deficient) participants (reduction: 16% P<0.01 and 20% P<0.05 respectively). The authors ruled out fructose as the mechanism for alleviation of the hangover severity as the fructose content of the placebo was similar and concluded it is likely via the stimulation of alcohol metabolism. The details of these mechanisms by which the alcohol metabolism is stimulated are under registered patent in Korea. While a full copy of the patent is not available in English, the abstract indicates that the phenolic acid arbutin from the pear skin is the active ingredient responsible for reducing hangover

(http://engpat.kipris.or.kr/engpat/searchLogina.do?next=MainSearch).

Summary: Two studies, one animal and one human, show the potential for Korean Pear to reduce blood alcohol levels and hangover severity, particularly in persons who carry the ALDH2 genetic variant associated with reduced alcohol metabolism. Considering the limited evidence, only one small RCT in a Korean population, the evidence for the effects of pear on hangover symptoms is currently graded as poor. But, the current evidence provides good justification for follow-up studies in other population groups using pear components containing high levels of arbutin, which in Australia may be the Nashi pear based on the compositional data (Table 7).

4.10 Other – Wound healing and liver-protective mechanisms

Chinnasamy et al has recently conducted a study on the wound healing activity of various extracts of the European pear in rats. The authors indicated that no other studies had been conducted in this area despite the traditional use of pear leaves and bark in wound healing and the use of the phenolic acid arbutin as a human skin whitening agent. This study showed a significant improvement in all the models of wound healing in the rats for both ethyl acetate and ethanol pear extracts (200mg/kg administered orally) compared with the control. In the pear extract groups wound contraction was increased, and epithelisation and scar area decreased ($p<0.01$). It is thought that the polyphenolic flavonoids and tannins present in pears promote wound healing through a number of cellular mechanisms including scavenging of free radicals and reactive oxygen species, and increasing the formation of capillary vessels and fibroblasts. This study indicates that pear may have a role as a natural drug for wound healing [91].

The radical scavenging mechanism of polyphenols may be at play in relation to the liver-protective capacity of pears. In a recent paper for the 2013 International Conference on Biological, Medical and Chemical Engineering Ma et al argued that animal studies had shown that apple polyphenols had a significant protective effect against hepatotoxicity but that no trials had been conducted in pears, despite their similar polyphenol and triterpene content. Ma and colleagues investigated the hepatoprotective effects of the extracts of apple-shaped pear peels. Mice were administered with varying amounts and types of apple-shaped pear peel extract, saline (control) or standard drug (silymarin) for 7 days then induced with acute liver damage (using CCl_4). The pear peel extract significantly prevented the increase in serum levels of liver enzymes (alanine aminotransferase, ALT and aspartate aminotransferase, AST). The findings prompted the authors to suggest a role for apple-shaped pears in functional ingredients to prevent oxidative stress-induced liver damage [92].

In summary, the antioxidant mechanism of the polyphenols in pears may have benefits in relation to wound healing and liver protection though this effect has only been studied in a limited number of animal studies, therefore no conclusions can be drawn.

5 Pears as part of a healthy diet

The Australian Dietary Guidelines recommend the consumption of 2 serves of fruit a day for adults and ½ to 2 serves a day for children, toddlers and adolescents. A serve of fruit is approximately 150g or 350kJ, or 1 medium banana, apple, orange, 2 small fruits (e.g. apricot, kiwi, plum) or 1 cup of diced or canned fruit (no added sugar). It is suggested that only occasionally should fruit juice or dried fruit replace whole fruits, due to its high sugar and low fibre content, which can be detrimental for dental health and weight management. ½ cup (125mL) of fruit juice (no added sugar) or 30g of dried fruit is a serve.

Most commonly consumed fruits

1. **Apples**
2. **Bananas**
3. **Mandarins**
4. **Oranges**
5. **Berry fruits**
6. **Pears**

Source: ABS, Australian Health Survey 2011-12

The most recent Australian dietary survey, the National Health Survey 2011-12 collected information on dietary intakes of a representative sample of Australians using 24-hour dietary recalls. In addition, they asked respondents to report their usual fruit consumption (excluding fruit juice). Overall, just over half (54%) of Australians reported consuming the recommended serves of fruit (2 serves a day for adult) with females (58%) more likely than males (50%) to meet the recommendation.

Apples were the most commonly consumed with 23% of Australians consuming apple on the day before interview followed by bananas, mandarins, oranges, berry fruit and pears [16] (Figure 3). Canned pear (pears, commercially sterile), was only consumed by 0.2% of people.

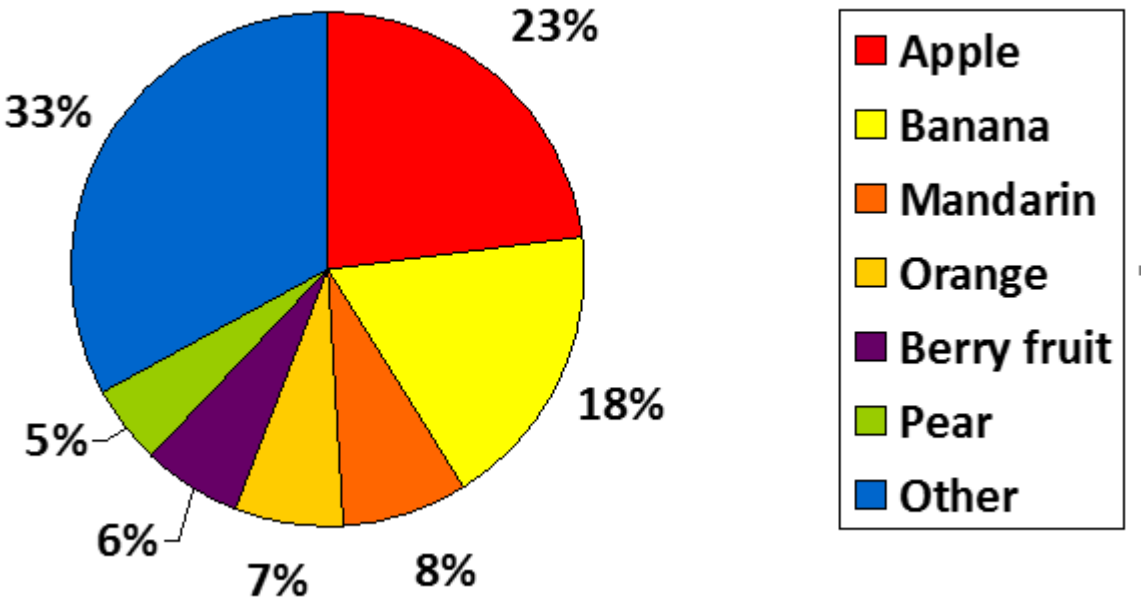


Figure 3: Most commonly consumed fruit by the Australian population (Results from the 2011-12 Australian Health Survey [16]).

From the one-day 24-hour recall data while fruit was consumed by six out of ten people overall in the day before interview, the proportion of consumers varied considerably across age groups and by sex (Figure 4).

Teenage and young adult males were the least likely to eat fruit with 45% of 14-18 year olds and 39% of 19-30 year olds reporting any fruit consumption the previous day, while children aged 2-3 and 4-8 years had the highest rate of fruit consumption with 84% and 80% respectively. Females were more likely to consume fruit beyond the 4-8 years group, contributing to the overall higher rate of fruit consumption among females (65%) than males (55%). Taken together this indicates that there is significant room for improvement in fruit consumption in Australians in order to meet the dietary guideline recommendations, with adolescents and adults potential target groups for improving fruit intake, as they currently have the lowest levels of consumption, below 60% of recommended intake. Currently pears are the 6th most consumed fruit based on this snapshot of Australian intakes.

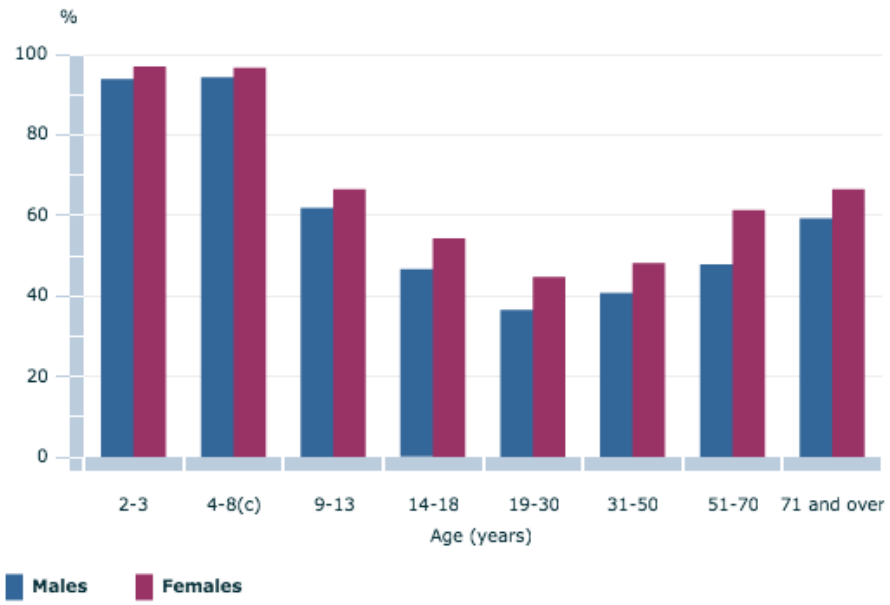


Figure 4: The proportion of Australians meeting the recommended daily intake of fruit stratified for age and gender (Australian Health Survey 2011-12 [16])

As discussed, one of the stand-out features of pears is its high fibre content (4.1g total fibre/medium pear). Pears therefore have the potential to make an important contribution to the daily fibre requirements. Australian adult males (19 years and over) are achieving 83% of the recommended fibre intake (adequate intake (AI) = 30g/day) with an average intake of 24.8g/day; and adult women are achieving 84% of the recommended intake (AI=25g/day) with an average intake of 21.1g/day. The shortfall could be bridged by adding a pear to the diet every day.

One medium pear per day could make an important contribution to achieving daily fibre recommendations.

6 Key summary points

- Pears surpass all other fruits for its high content of digestive regulating nutrients including fibre, fructose and sorbitol. The fibre content of a medium size pear (4.1g) meets the FSANZ criteria for a nutrient content claim that pear is a "good source" of fibre. Furthermore, pears, particularly the peel, are rich in several phytonutrients, especially phenolic acids which has been associated with multiple health benefits related to diabetes, cardiovascular disease and obesity.
- Because of their unique composition of fibre, sorbitol and fructose pears have the potential to play an important role in regulating normal bowel function. However, to date no human study has been performed to substantiate this benefit. Based on the fibre content of pears (≥2 g/serving) a general level health claim can be made for its contribution to laxation. It is important to note that these same features of pear may result in discomfort in a small proportion of the population who inadequately absorb fructose.
- One small intervention study indicated that the addition of pears to a weight reducing diet may contribute to weight loss through its low energy density resulting in reduced energy intake. However, further intervention studies are needed to confirm this effect.
- Consumption of pear juice prior to alcohol consumption have been shown to reduce blood alcohol levels, particularly in individuals with a genetic variant associated with a reduced ability to metabolise alcohol, while in normal individuals hangover symptoms and severity were reduced. The key component proposed to stimulate alcohol metabolism is arbutin, found in the skin of Korean pear. These effects have only been tested in one animal and one human intervention study in a Korean population and only using a Korean pear variety. Hence a general recommendation regarding pear consumption and alcohol hangover cannot be made at present. Human intervention studies in an Australian population are needed to confirm these effects and other potential pear varieties should also be investigated.
- Pears have earned their reputation as a low allergenic food and are often one of baby's first foods or used in elimination diets (used to identify food allergies and intolerances) due to is low allergenic potential.
- Prospective observational studies (association type studies which cannot proof causality, but compared to other association studies are highest in the hierarchy of proving causality) have consistently shown that the consumption of apples and pears (combined) are associated with reduced risk of stroke. Some evidence is also available to show that apples and pears are associated with a reduced risk of coronary heart disease.
- Prospective observational studies have also consistently shown that apples and pears (combined) are associated with a reduced risk of type 2 diabetes. Pears have a low glycaemic index (GI) which may assist in the prevention and managing of type 2 diabetes. Further support for pear's anti-diabetic potential is provided from three animal studies that showed favourable effects on blood glucose from pear extracts, potentially related to insulin-like activity of various bioactive compounds in pear, in particular blocking of carbohydrate digestion by certain phenolic acids.
- Consumption of pear pulp, peel and wild pear leaf extract improved metabolic health markers such as glucose levels and cholesterol/lipid profiles in animal models. Pears contain several bioactive components such as polyphenols and fibre that may contribute to these effects. However, intervention studies in humans are needed before recommendations can be made.
- Consumption of pear or pear components increases *in vivo* antioxidant activity in animal models. The effect is greater with pear peel extract than pear pulp, which is consistent with greater levels of polyphenols in the peel, compared to the pulp. Thus, to obtain all the benefits of pear it should be consumed with the peel. Animal studies suggest the antioxidant mechanisms of pears may be at play in wound healing and liver protection.
- Evidence from association type studies (prospective and case-control studies) showed that increased consumption of apples and pears (combined) were associated with reduced risk of cancer including

lung, bladder, oral, pancreatic and breast cancer. However the number of studies per type of cancer have been limited.

- Evidence from cross-sectional studies (association studies low in the hierarchy of proving causality) suggests some benefit of consuming pears (and apples) for asthma and other respiratory diseases and a limited number of animal studies support these findings. However, further research is required before any recommendations can be made regarding pears role in allergic and respiratory conditions.

7 Recommendations and conclusion

Pears have some unique nutritional features that could have important health benefits. However, human studies to substantiate these health benefits are scarce which limits conclusions or recommendations regarding their health attributes. Based on the nutritional properties and current available evidence on pears, recommendations are made regarding the attributes of pears that can be promoted at present whereas other potential health attributes of pears or pear-based products needs further substantiation in human studies before promotion.

Potential health messages regarding pears based on current evidence:

- Pears are unequalled compared to other fruit for its content of fibre, sorbitol and fructose. Pear may therefore offer a natural package of digestive regulating nutrients and may well be our "daily prescription for digestive health". Consuming pears may be a more preferred method for alleviating constipation than taking medications, particularly in children who may be averse to taking medications and older adults who are often already taking several medications.

  It is surprising that, to date, no human studies have been conducted to substantiate the potential digestive benefits of pears. However, in the absence of human studies, a general level health claim promoting the laxative effects of pears can be made based on its fibre content (≥2g fibre/serving).

  It is important to note that in a small proportion of the population (i.e. FODMAP malabsorbers) the high content of fructose and the combination of fructose and sorbitol may result in gastrointestinal discomfort.

- Pears also meet the FSANZ criteria for a nutrient content claim that pear is a "good source" of fibre (≥4g/serve). Adding one medium pear per day to the daily diet could make a significant contribution to achieving daily fibre recommendations. In fact, one pear per day could bridge the shortfall between Australian women's fibre intakes (21g/d) and recommended intakes (25g/d).

- Pears have a low GI and may therefore be included in a diabetic diet to assist with managing glucose levels.

- Pears are low in energy density and may therefore play a role in weight reducing diets by adding weight to the diet without increasing calories.

- Pears, particularly the skin of pears, are rich in several phytochemicals, especially phenolic acids, which have been associated with multiple health benefits. Thus, to gain the most benefit from consuming pears it needs to be consumed with the peel.

- Apples and pears combined are associated with reduced risk of stroke, coronary heart disease, type 2 diabetes and cancer. Unfortunately, studies investigating these relationships have always combined apples and pears hence the independent effects of pears cannot be elucidated. Any messages regarding these associations should thus be for apple and pear combined. In addition, since these results are based on association type studies any messages should refer to these health benefits as associations and not causal effects.

Health attributes of pears requiring further research:

The following potential health attributes of pears or pear-based products are worth further investigation within human intervention studies before specific recommendations can be made:

- The phenolic acid arbutin, found in high concentrations in the peel of Korean pear has the potential to stimulate alcohol metabolism and decrease blood alcohol levels and hangover symptoms. Identification

of an Australian pear high in arbutin (potentially Nashi), development of products containing high arbutin pear peel (e.g. beverages, ciders) and subsequent human intervention studies is recommended.

- The high content of soluble fibre and polyphenols in pears, previously shown to have hypoglycaemic and hypolipidaemic effects, may contribute to metabolic health by improving lipid profiles, glycaemic control and reducing chronic inflammation. The fruit itself may not contain these compounds in sufficient amounts to have a clinical benefit, but pear peel and pulp extracts may be effective, as shown in some animal studies. Novel products containing these extracts could be developed and substantiated in human intervention studies.
- There is limited evidence from cross-sectional studies and animal studies suggesting some benefit of consuming pears for managing and treating asthma and other respiratory and allergic diseases such as rhinitis. Human interventions studies are recommended to substantiate and investigate this mechanism further.
- While research has quantified some nutritional components of pear waste, namely oil and fibre, further analysis of other aspects such as phytonutrients and sugars e.g. sorbitol, could provide indications of other potential uses for pear by-products.
- Waste products of pear including the peels and seeds have potential to be further processed to seed oil, or a fibre product which could be used to fortify low fibre foods e.g. baked goods, medical nutritional therapy products or commercial fibre supplements. The feasibility of this would depend on current levels of waste produced and processing costs, however it is recommended that this is explored.

In conclusion, pears have some unique features that could have important health benefits, but studies in humans have been limited which restricts specific health recommendations. The most unique feature of pears compared to other commonly consumed fruit is its high content of digestive regulating nutrients, namely fibre, sorbitol and fructose. Hence, the daily consumption of pear may be an effective natural strategy for ensuring normal bowel function across all life stages. Pears may well be our “daily prescription for digestive health”. Pears are rich in several phytonutrients, mainly found in the skin of the pear, which may contribute to multiple health benefits. Thus, to gain the most benefit from consuming pears it should be consumed with the peel. Only half of the Australian population consume the recommended two serves of fruit per day of which pears are the 6th most consumed fruit in Australia. It may be beneficial for all Australians to increase their intake of pears in order to capitalize on its high fibre content; consumption of one pear a day will make an important contribution to achieving daily fibre recommendations and in some individuals one pear a day may bridge the gap between low and recommended fibre intakes.

8 Appendix

8.1 About the authors

Genevieve James-Martin

Genevieve graduated with a Masters in Nutrition and Dietetics from Flinders University in 2011 and is an Accredited Practising Dietitian. Her varied work experience includes clinical dietetics in many of Adelaide's major public hospital, food service and private consulting. In 2014, Genevieve took up the position of Research Dietitian at CSIRO where she is responsible for preparation and delivery of the dietary interventions of clinical trials, analysis of dietary data, and the preparation of scientific publications and systematic reviews.

Gemma Williams

Gemma completed her Masters of Nutrition and Dietetics in 1997 and since then has had a diverse range of experience in clinical, health promotion and community dietetics. Her role in research dietetics at CSIRO extends from 2003 where she has been involved in the preparation and delivery of the dietary interventions of clinical trials, analysis of dietary data, and the preparation of scientific publications and systematic reviews.

Welma Stonehouse

Dr Welma Stonehouse (previous surname Oosthuizen) (BSc Hons, MSc, PhD Nutrition) is a senior research scientist in clinical nutrition and Team Leader of the Nutrition Interventions Team at CSIRO Food and Nutrition Flagship. She started her career >20 years ago as a scientific researcher and university lecturer and was later promoted to Associate Professor in Human Nutrition at North-West University, Potchefstroom, South Africa. She then joined Massey University in Auckland as Associate Professor in Human Nutrition in 2006 until 2013 when she jointed CSIRO. Her research focusses on the substantiation through human clinical trials and systematic reviews of nutritional interventions for the prevention of cardiovascular disease, enhancement of metabolic health, reduction and maintenance of healthy body weight and enhancement of cognitive function. She has published a total of 77 papers in the peer-reviewed scientific literature and has an H-index of 16. She has also successfully supervised a total of 32 MSc and PhD students in Nutrition & Dietetics. In recognition of her outstanding contribution to nutritional science, she was recently presented with the Muriel Bell Award from the Nutrition Society of New Zealand at the Nutrition Society of Australia and Nutrition Society of New Zealand Joint Annual Scientific Meeting, 4-6 December 2013, Brisbane, Australia.

Nathan O'Callaghan

Nathan holds a PhD in medical genetics from the John Curtin School of Medical Research at ANU and has a broad experience in nutritional science; with a focus on developing biomarkers for use in Clinical Nutrition Science. Nathan currently leads the Diet, Lifestyle and Health Substantiation group This portfolio focuses on obesity and metabolic health through a broad array of disciplines from clinical biochemistry, physiology and molecular biology through clinical nutrition and dietetics, consumer and health behaviour, epidemiology and psychology pre-clinical animal models, human clinical and community studies. This group aims to deliver innovative diet and lifestyle solutions for improved metabolic health and well-being.

Dr O'Callaghan has a current focus on developing and validating emerging markers for use in Nutritional and Health Science and is working to reduce the impact of non-communicable diseases (e.g. Obesity, type-2

diabetes) and improve health via dietary means in the Australian population. The key aspects of this research is to: (a) develop and validate a scientific 'tool-kit' to measure health and diet; (b) identify, how nutrients, supplements and dietary patterns impact on health in individuals and (c) applying this science and technology into demonstrable improvements in the health and wellbeing of individuals and populations..

Manny Noakes

Professor Manny Noakes, BSc, Dip Nut&Diet, PhD is currently the Research Director for Food, Nutrition and Health in the CSIRO Food and Nutrition Flagship. She has over 35 years of experience in nutrition and is considered a key opinion leader and trusted advisor in nutrition and health both nationally and internationally, particularly in the area of higher protein dietary patterns and weight management. Whilst she has a well credentialed scientific track record having published 197 papers (145 since 2004), cited 6403 times with an 'H' index of 44, her translation of much of this work into highly successful consumer publications has been notable. She was instrumental in the development and release of 5 editions of the CSIRO Total Wellbeing Diet (TWD) (launched in 2004) which has now been translated into 17 languages, sold over 1 million copies in Australia and continues to have a high awareness. In 2007 she published an externally conducted impact assessment of the (TWD in a nationally representative sample of 5000 people which revealed a projected 500,000+ individuals had lost an average of 6kg on TWD and experienced health benefits. The TWD has also won several awards including the World Food Media Award for best health publication for 2007. Professor Noakes is an executive member of the Federal Government Food and Health Dialogue which influences nutrition reformulation targets for manufactured foods in order to improve the nutritional quality of the Australian Food supply. She is also a member of the Heart Foundation Food and Nutrition Advisory Committee, the Food Standards Australia New Zealand (FSANZ) Health Claims Advisory Committee, and the Woolworths Healthier Australia Taskforce amongst other industry bodies. She is the recipient of 3 CSIRO Medals, is a Distinguished Alumni of Flinders University, holds a research excellence award from the University of Adelaide and is a recipient of the Zonta Club Woman of International Achievement award.

8.2 NHMRC Criteria for hierarchy of level of evidence in humans

Table 8: NHMRC criteria for hierarchy of level of evidence in humans [17]

Level of evidence	Human Study design
I	Evidence obtained from a systematic review of all relevant randomised controlled trials.
II	Evidence obtained from at least 1 properly-designed randomised controlled trial.
III-1	Evidence obtained from well-designed pseudo-randomised controlled trials.
III-2	Evidence obtained from comparative (non-randomised and observational) studies, including systematic reviews of such studies, with concurrent controls and allocation not randomised, cohort studies, case control studies, or interrupted time series with a control group.
III-3	Evidence obtained from comparative studies with historical control, two or more single arm studies, or interrupted series with a parallel control group.
IV	Evidence obtained from case series, ether post-test or pre-test/post-test.

8.3 NHMRC Body of evidence matrix

Table 9: NHMRC body of evidence matrix [17]

	A Excellent	B Good	C Satisfactory	D Poor
Evidence base	Several level I or II studies with low risk of bias	One or two level II studies with low risk of bias or a systematic review/multiple level III studies with low risk of bias	Level III studies with low risk of bias, or level I or II studies with moderate risk of bias	Level IV studies, or level I to III studies with high risk of bias
Consistency	All studies consistent	Most studies consistent and inconsistency may be explained	Some inconsistency reflecting genuine uncertainty around clinical question	Evidence is inconsistent
Clinical impact	Very large	Substantial	Moderate	Slight or restricted
Generalisability	Population/s studied in body of evidence are the same as the target population for the guideline	Population/s studied in the body of evidence are similar to the target population for the guideline	Population/s studied in body of evidence differ to target population for guideline but it is clinically sensible to apply this evidence to target population	Population/s studied in body of evidence differ to target population and hard to judge whether it is sensible to generalise to target population
Applicability	Directly applicable to Australian healthcare context	Applicable to Australian healthcare context with few caveats	Probably applicable to Australian healthcare context with some caveats	Not applicable to Australian healthcare context

8.4 Characteristics of included studies

Table 10: Characteristics of human intervention studies on the health effects of pears

Reference (Country)	Health outcome	Study design and duration	Participant characteristics[1]	Intervention	Control	Adverse effects	Results[2]	Quality score[3]
Chronic studies								
De Oliveira, 2003 (Brazil)	Weight control; Metabolic markers	RCT, parallel, 12wk	Overweight, HC, n=49 (35), 100% women, 30-50yr; BMI=>25kg/m^2	3 pears (William) or 3 apples (Fuji)/d as part of hypocaloric diet (designed to reduce body weight with 1kg/mo)	60g oat cookie as part of hypocaloric diet	NR	Results for apples and pears combined: ↓ body weight (-0.33 kg, P=0.003) ↓ glucose (-4.45 mg/dL, P=NR) ↑ TG (0.74 mmol/L, P=NR) ↔ insulin, cholesterol	9
De Oliveira, 2008 *secondary analysis of De Oliveira 2003 (Brazil)	Weight control	RCT, parallel, 10wk	Overweight, HC, n=49 (49, ITT using mixed models), 100% women, 30-50yr; BMI=>25kg/m^2	3 pears (William) or 3 apples (Fuji)/d as part of hypocaloric diet (minus 250 kcal/day for modest weight reduction)	60g oat cookie as part of hypocaloric diet (similar fibre, protein, carbohydrate, energy content; higher energy density [3.7 vs. 0.64 for pears and 0.63 for apples])	NR	Mean changes during 7 (or 10?) wk follow-up. Pear vs. Oat cookies (adjusted values): ↓ body weight (-1.05 kg, P<0.05 ↓ BMI (-0.34 kg/m^2, P<0.05) ↓mid-arm circumference (-0.49 cm, P<0.05) ↓ energy density (-1.29 kcal/g, P<0.05, P<0.05) ↓ Energy intake (-20.4 kcal/day, P<0.05) Apple vs. Oat cookies: similar results as above. Apple vs. Pear: no	9

							differences	
Acute studies								
Lee, 2013 (Korea)	Alcohol hangover symptoms	Randomised single blind crossover, 2d	Healthy males, mean 25.8yr, n=20 (14)	220ml pear juice	220ml placebo drink (artificial pear flavour + fructose)	NR	The total and average of hangover severity were alleviated to 16% and 21% by Korean pear juice at 15 h after the alcohol consumption, respectively ($p < 0.05$). Particularly, 'trouble concentrating' was significantly improved by the pear juice treatment ($p < 0.05$). In addition, the pear juice treatment lowered levels of blood alcohol ($p < 0.01$)	9
Rodruigez, 2000 (Spain)	Allergy	Double-blind, placebo-controlled food challenges	34 consecutive patients referred to the allergy division of a hospital complaining of adverse reaction to one or more of seven foods from the Rosaccea family, age 14 to 62yr (median 24.5yr)	Skin prick testing (SPT) and CAP FEIA (fluorenzymeimmunoassay) (i.e. RAST) and open food challenges (OFCs)	Saline solution and histamine dihydrochloride	NR	231 SPT were performed. 126 were positive in 26 patients, 18 were to pear. 226 OFCs were performed in 28 patients, only one patient has a positive reaction to pear. Clinical reactivity was 6% for positive SPTs in pear and 10% for positive RAST tests making it one of the least reactive fruits in the Rosaccea family	NA

BMI, body mass index; GI, glycaemic index; HDL-C, high density lipoprotein cholesterol; HC, hypercholesterolaemic; ITT, intention-to-treat; NR, not reported; PII, peak incremental indices; RCT, randomised controlled trial; TC, total cholesterol; TG, triacylglycerol; TAC, total antioxidant capacity; T2DM, type 2 diabetes mellitus

[1]n=number enrolled (number completed); BMI=mean (SD) kg/m^2

[2]Results are for the effects of the intervention compared to control unless otherwise stated.

[3]Health Canada Quality appraisal tool for intervention studies (ref) (see Table 11). A score of ≥8 is considered higher quality.

Table 11: Critical appraisal of human intervention studies (Health Canada ref)

Study reference	1) In- exclusion criteria	2) Group allocation				3) Blinding		4) Attrition		5) Intervention		6) Health effect	7) Stat analysis		8) Confounders	Potential confounders	Total
		Randomized	Method reported	Method appropriate	Allocation concealed	Subjects	Researchers	Numerically reported	Reasons provided	Type described	Amount described	Methods reported	Between-groups	Intention-to-treat			
De Oliveira, 2003	1	1	1	1	0	0	0	1	0	1	1	1	1	0	0	Energy intake significantly reduced in apple & pear groups but not in oat cooking group. Attrition higher in oat cooking group.	9
De Oliveira, 2008	1	1	1	1	0	Not clear	Not clear	1	1	1	1	1	1	1	0	As above.	11
Alvarez-Parrilla, 2010	1	0	1	0	0	0	0	1	1	1	1	1	1	1	0	No reporting on baseline characteristic of groups or compliance to intervention	9
Lee, 2013	1	1	0	0	0	1	0	1	0	1	1	1	1	0	1	Not reported if placebo energy matched with pear juice	9

Table 12: Characteristics of observational studies investigating associations between pears and health benefits

Reference Name (Country)	Health outcome	Study design & years of follow-up	Sample characteristics	Fruit	Method to assess intake	Confounders adjusted for	Results	Quality score[1]
Prospective cohort								
Mink, 2007 Iowa Women's Health Study (USA)	CVD, CHD, stroke	Prospective, 16yr	Postmenopausal women, n=34 489, free of CVD, 55-69yr,	Apples and pears	FFQ at baseline	Age, energy intake, marital status, education, blood pressure, diabetes, BMI, waist-to-hip ratio, physical activity, smoking, estrogen use	Intake of apples and pears >1x/wk vs. <1x/wk associated with reduced mortality from CHD and CVD: RR (95%) Stroke: 0.85 (0.68, 1.07), P=0.28 CHD: 0.85 (0.75, 0.98), P=0.05 CVD: 0.87 (0.78, 0.96), P=0.02	9
Botterwerk et al 1998 Netherlands Cohort Study (Netherlands)	Stomach cancer	Prospective, 6.3yr	Men and women 55-69yr, n=3405 (282 cases, 3123 controls)	Apples and pears	150-item FFQ at baseline	Age, sex, smoking, education, stomach disorders, family history of stomach cancer, total vegetable consumption (g/day)	Intake of apples and pears with stomach cancer risk was non-significant in multivariate analysis: RR (95%) Q1 vs Q5 0.76 (0.47-1.123), p=0.18	10
Buchner, 2009, EPIC (Europe)	Bladder cancer	Prospective, 8.7y	478,533 men and women aged 25-70 from Europe	Hard fruit (apples & pears)	Various assessment methods used at baseline including semi-quant FFQs, diet interviews, food records and	Smoking, duration and intensity of smoking, energy, vegetable intake. Height, weight, red and processed meat, alcohol, milk consumption, PA,	Hard fruit consumption with increments of 25 g/day was associated with a 7% protective association on bladder cancer risk among never	8

					non-quantitative FFQs with some countries using a combination of methods	education showed no effect on the model so were not adjusted for.	smokers (HR=0.93 95% CI: 0.89–0.98; calibrated HR= 0.90 95% CI: 0.82–0.98)	
Larsson, 2013, Swedish Mammography Study and Cohort of Swedish Men (Sweden)	Stroke	Prospective cohort, 10.2yr	74,961 men and women aged 45-83yr	Apples and pears	96-item FFQ	Age, sex, smoking status and pack-years of smoking, education, body mass index, total physical activity, aspirin use, history of hypertension, diabetes, family history of myocardial infarction, and intakes of total energy, alcohol, coffee, fresh red meat, processed meat, and fish. Apples/pears, banana, citrus fruits, and berries were mutually adjusted and adjusted for total vegetable consumption.	Intake of apples and pears 1.0 serving/d vs 0.1 serving/d associated with reduced total stroke: RR (95% CI) 0.89 (0.80, 0.98), P=0.02	9
Linseisen, 2007, EPIC (Europe)	Lung cancer	Prospective cohort, 6.4yr	Men and women from 10 European countries aged 25-70yr at baseline n=478,590	Apples and pears	Various assessment methods used at baseline including semi-quant FFQs, diet interviews, food records and non-quantitative FFQs with some countries using a combination of methods	Age, sex, tobacco smoking (status and duration), education, physical activity at work, intake of red meat, intake of processed meat, height, weight, non-fat energy intake, energy intake from fat, ethanol intake at baseline.	Each 100g increment intake of apples and pears was inversely associated with lung cancer All: HR, 0.861; 95% CI 0.751-0.987 calibrated model	8
Muraki, 2013, Nurses' Health Study, Nurses Health Study II	Type 2 diabetes	Prospective cohort, 3,464,641 person-years	N=187,328 men and women free of diabetes (type 1, 2 or gestational),	Apples and pears	118-item FFQ	Adjusted for age, ethnicity, BMI, smoking status, or missing), multivitamin use, PA,	Intake of apples and pears >1x/d vs. <1x/wk inversely associated with type 2 diabetes: HR	10

and Health Professionals Follow-up Study (USA)		of follow up	CVD or cancer at baseline			family history of diabetes, menopausal status and post-menopausal hormone use, oral contraceptive use, total energy intake, fruit juice consumption and the modified alternate healthy eating index score. Individual fruit consumption was mutually adjusted.	(95%) 0.83 (0.76-0.90) p<0.001 Replacing each three servings /week of fruit juice consumption with the same amount of total or individual whole fruits, the risk of T2DM in the pooled analysis was 14% (11% to 18%) lower for apples and pears	
Oude Griep, 2011, MORGEN study (Netherlands)	Stroke	Prospective cohort, 10yr	Men and women aged 20 to 65yr n=20,069	Apples and pears	178-item FFQ	Age, sex, total energy intake (kcal), smoking alcohol intake, educational level, dietary supplement use, use of hormone replacement therapy, family history of acute myocardial infarction, BMI, intake of whole grain foods, processed meat, and fish, sum of intake of the other fruit and vegetable colour groups or subgroups. PA in subgroup enrolled since 1994.	Each 25-g/d increase in intake of apples and pears was inversely associated with stroke (HR, 0.93; 95% CI, 0.86 – 1.00).	7
Wedick, 2012, Nurses' Health Study, Nurses Health Study II and Health Professionals Follow-up Study, (USA) *similar data set as Muraki	Type 2 diabetes	Prospective cohort, 3,645,585 person-years of follow up	N=200,894 men and women free of diabetes (type 1, 2 or gestational), CVD or cancer at baseline	Apples and pears	118-item FFQ	Adjusted for age (continuous), BMI category, smoking, alcohol intake, multivitamin use, PA, family history of diabetes, postmenopausal status and hormone use, oral contraceptive use, ethnicity, total energy,	Pooled results for all three studies, random-effects model for ≥5x/wk vs <1x/month, HR (95% CI) 0.77 (0.65,0.93) p<0.001 This was the strongest and most consistent association observed for	11

2013						polyunsaturated:saturated fat ratio and intakes of red meat, fish, whole grains, coffee, high-calorie sodas, and trans fat (all in quintiles).	anthocyanin-rich foods (blueberries, strawberries and apples/pears)	
Cross-sectional & case-control								
Hung, 2005, Nurses Health Study (USA)	Tooth loss	Cross-sectional	59,467 female registered nurses aged between 30-55yr	Hard fruit (apples & pears)	116-item FFQ	Total energy, age, PA, BMI and smoking	Women with more teeth were more likely to consume fresh apples or pears at least one time a week, 77% for women with 25-32 teeth vs 64% for edentulous women, however test for linear trend across the five categories of number of teeth did not show statistical significance	NA
Rosenlund, 2011, BAMSE cohort, (Sweden)	Allergy	Cross-sectional	2,447 children who had completed an FFQ, and parental questionnaire about symptom and diagnosis of allergic diseases	Apples and pears	98-item FFQ filled out at age 8	Adjusted for sex, parental socioeconomic status, maternal smoking during pregnancy and/or at baseline, iso-BMI, maternal age at baseline, and parental history of allergic disease	Highest versus lowest tertile of intake of apples and pears were inversely associated with rhinitis, asthma and atopic sensitization OR (95% CI) Rhinitis: 0.46 (0.35-0.62) p=<0.01 Asthma: 0.63 (0.42-0.94) p=0.38 Atopic sensitization: 0.69 (0.54-0.87) p=0.07 However when children who reported allergic symptoms related to	NA

							fruit or vegetables were excluded from analysis (as they might have changed their diet as a result of the allergic symptoms) the associations disappeared	
Rossi, 2011 (Italy)	Pancreatic cancer	Case-control	326 cases and 652 frequency – matched controls (admitted to same hospital for acute non-neoplastic conditions) matched by gender, age and study centre	Apples and pears	78-item FFQ assessing usual diet 2yr before diagnosis/hospital admission	Estimates from conditional logistic regression models conditioned on gender, age and center of study, and adjusted for year of interview, education, history of diabetes, tobacco smoking, alcohol drinking, and non-alcohol energy intake.	For apples and pears the OR for three or more portions versus less than half portion per day was 0.35 (95% CI 0.15–0.82) P<0.001, and the continuous OR per one portion per day was 0.73 (95% CI 0.60–0.90).	NA
Woods, 2003 (Australia)	Asthma	Cross-sectional	1601 young adults mean age 34.6±7.1yr recruited randomly from Federal election roll, Melbourne	Apples and pears	Validated semi-quantitative FFQ assessing intake over previous 12mo	Age, sex, smoking, BMI, region of birth, family history of asthma, and the specified food variable. The reference categories were those without current asthma, asthma, doctor-diagnosed asthma, bronchial hyperreactivity (BHR), or atopy, respectively.	The consumption of apples and pears was negatively associated with current asthma, asthma and BHR OR (95% CI) Current asthma: 0.83 (0.71,0.98) p<0.05 Asthma: 0.88 (0.78,1.00) P<0.05 BHR: 0.88 (0.77, 1.00) P<0.05	NA
Cassidy, 2015, Framingham Heart Study (USA)	Anti-inflammatory effects	Cross-sectional	2375 men and women	Apples and pears	Validated semi-quantitative FFQ	Age, sex, smoking, energy intake, nonsteroidal anti-inflammatory drug use, BMI, cardiovascular disease, diabetes, and saturated fat and trans fat intakes.	An inverse association was seen between anthocyanins and flavonol intake from apples and pears and a combined IS (sum of a range of inflammatory	

							biomarkers combined). Adjusted mean IS; (95% CI) ≥7 servings/wk and <1 serving/wk, -0.74 (1.49, 0.01) vs 0.28 (-0.16, 0.72) with across quintile category differences of -1.02 (65% decrease; P=0.06)	
Zheng 1993 (China)	Oral cancer	Case-control	404 hospital cases aged between 18 and 80yr with histologically confirmed oral cancer and 404 hospital controls	Pears	63-item FFQ requested for two time periods- before 1976 and 1 year before the onset of symptoms (cases)/interview (control)	Tobacco smoking, alcohol drinking, inadequate dentition, years of education, Quetelet Index, sex and age	Consumption of pears was associated with a significant inverse association with oral cancer risk OR (95% CI) 0.27 (0.15,0.49) for one serve ≥2.wk vs <1/month	NA
Vaud 1993 (Switzerland)	Breast cancer	Case-control	107 cases with histologically confirmed breast cancer and 318 hospital controls	Pears	Food frequency questionnaire	Adjusted for age only	RR for pear highest vs lowest tertile of pear intake =0.5 (P<0.05)	NA
Meta-analysis								
Hu, 2014 (China)	Stroke	Meta-analysis of prospective cohort studies, mean duration of follow up 3.09-37yr	29 prospective cohort studies including n=760,629 (only 2 studies n=4558 looking specifically at apples and pears)	Apples and pears	Various methods	NA	Inverse association seen with apples and pears and stroke RR; 95% CI, 0.88; 0.81-0.97	NA

CHD, coronary heart disease; CVD, cardiovascular disease, FFQ, food frequency questionnaire, GC, gastric cancer, NOC, N-nitroso compounds, PA, physical activity, GAE gallic acid equivalent, BHR, bronchial hyperreactivity, IS, inflammation score

[1]Health Canada Quality appraisal tool for observational studies (ref) (See Table 13). A score of ≥7 is considered higher quality.

Table 13: Critical appraisal of observational studies (health Canada ref)

Study reference	In- exclusion criteria reported	Attrition		Exposure		Health outcome		Blinding	Baseline comparability of groups	Statistical analysis	Confounders		Total	Potential confounders not adjusted for in study
		Numerically reported	Reasons provided	Method reported	Measured more than once	Method reported	Health outcome verified	Outcome assessor blinded	Exposure groups compared at baseline	Significance of trend reported	Demographics	Other confounders		
Botterweck, 1998	1	1	1	1	1	1	1	0	0	1	1	1	**10**	Could not adjust for *H. pylori* as not tested for at baseline
Buchner, 2009	1	0	0	1	0	1	1	0	1	1	1	1	**8**	
Larsson, 2013	1	0	0	1	1	1	1	0	1	1	1	1	**9**	
Linseisen, 2007	1	0	0	1	1	1	1	0	1	0	1	1	**8**	
Mink, 2007	1	0	0	1	1	1	1	0	1	1	1	1	**9**	No mutual adjustment for other fruits or vegetable intake
Oude Griep, 2011	1	0	0	1	1	1	1	0	0	0	1	1	**7**	Trend reported for white fruit but not apples and pears
Muraki, 2013	1	1	0	1	1	1	1	0	1	1	1	1	**10**	
Wedick, 2012	1	1	0	1	1	1	1	1	1	1	1	1	**11**	

Table 14: Characteristics of animal studies investigating the health benefits of pears

Reference (Country)	Disease condition	Animal model	Description of Pear intervention and control	Observation/results
Wang et al 2015 China	Type 2 diabetes	Streptozocin-induced type 2 diabetic Kunming mice	8 Asian pear varieties analysed. The highest content of polyphenol pear (Yaguang pear) was then used to compare the diabetic potential in its peel and pulp. a) Diab mice fed high fat diet + pear peel b) Diab mice fed high fat diet + pear pulp c) Diab mice fed high fat diet d) Control mice fed normal pellet diet	**Composition measures:** Total phenolics, flavonoids and triterpenes higher in peel than pulp (Figure 1) Chlorogenic acid, coumaric acid, gallic acid, vanillic acid composition (phenolic acids), rutin, catechin, epicatechin (flavonoids) [rutin main anti-inflam activity] Oleanolic acid and ursolic acid (triterpene compounds) **Animal/in vitro testing:** Antidiabetic function shown. a) FBG ↓ 13.35 to 8.24mmol/L (P≤0.01) after 3 weeks b) FBG ↓ 13.32 to 12.44 c) FBG 13.55 to 14.74 d) FBG 5.81 to 5.56 Lipids: Pear peel had signif reduced serum TC, TG, LDL compared with ctrl α-glucosidase inhibitory activity in pear peel Conclusion: Genetic selection of pear cultivars may be indicated
Lee et al 2015 Korea	Antioxidative activity	25 Sprague-Dawley rats	Peel and flesh extract of 2 Asian pear cultivars (P pyrifolia) administered to rats plus a control.	**Composition measures:** Pear peel more often consumed in European pears than Asian pears (skins thinner; less pectin, stone cells). Ascorbic acid, tocopherol, phenolic acid and flavonoids values analysed (higher in peel than flesh). Tocopherol same. **Animal/in vitro testing:** Antioxidative activity in blood plasma measured (CE-OOH

				formation in copper ion-induced rat plasma peroxidation). Antioxidative activity in rat blood highest in both peel groups. Peels showed higher free radical scavenging activities than flesh
Li et al 2013 China	Antioxidant and anti-inflammatory activities	Kunming mice	10 Asian pear cultivars compositions analysed then AO and anti-inflam testing on mice	**Composition measures**: total phenolics, total flavonoids, triterpenes of the different pears Table1 **Animal/In vitro testing:** Antioxidant activities (reducing power, DPPH assay) and anti-inflammatory capacity (xylene induced ear oedema and carageenan induced paw oedema) tested on all cultivars Figure 1 & 2, Table 2 Four pear cultivars incl Yaguang, Hongpi, Qingpi and Jinqiu have the highest concentration of active chemicals and bio-activities
Chinnasamy et al 2014 India	Wound healing effects	Wistar albino rats, given sutured wounds	Phytochemical screening of extracts of European pear (ethyl acetate extracts and ethanol extracts) 4 groups: a) Control, 2ml of 1%v/v tween 80 b) Standard drug, 5% povidone iodine ointment applied topically c) 200mg/kg ethyl acetate pear extracts orally d) 200mg/kg ethanol extract pear extracts orally	Polyphenolic flavonoids and tannins are reported to facilitate wound healing Tissue breaking strength signif better in pear gps ($p<0.01$) Wound area smaller ($p<0.01$) and scar area smaller ($P<0.01$) Pear could be natural drug for wound healing
Azuma et al 2013 Japan	Acute IBD	Acute IBD mouse model (C57BL/6 mice)	6 gps: a) Cellulose nanofibers from Asian pear (P-CNF) b) Cellulose nanofibers from wood (W-CNF)	Shortening of colon lengths suppressed in P-CNF gps ($p<0.01$) P-CNF inhibits colonic inflammation by ↓ MPO activation of inflammatory cells such as leucocytes. P-CNF suppresses fibrosis in IBD mice Therefore P-CNF is a potent new dietary fiber (contain

			c) Control (-) admin tap water d) Control (+) admin 3% dextran sodium e) Pear juice f) Hydrothermally treated pear juice	pectin matrix, phenolic polymer lignin)
Wakuda et al 2012 Japan	Ulcerative colitis	Dextran sodium sulphate (DSS)-induced ulcerative colitis mouse model	Pear vinegar specially brewed for enhanced galacturonic acid content administered to mice + water as a control.	No other studies assessing effect of vinegar from fruit on IBD. Pear vinegar improved clinical symptoms and histological tissue injury in this mouse model. PV improved inflammation caused by acute UC by suppressing MPO-mediated activation of inflammatory cells such as leucocytes and decreasing IL-6 concentration. More research needed before PV used as a functional food
Valmurugan et al 2013 India	Diabetes. Hypoglycaemic and hypolipidaemic activity	Swiss Albino mice and Wistar rats – dexamethasone induced with diabetes	European pear (P communis) extracts a) Normal ctrl b) Diabetic ctrl c) Glibenclamide(5mg/kg) d) Ethyl acetate (200mg/kg) of P communis (EAEPC) e) Ethanolic extracts (200mg/kg) of P communis (EEPC) Glucose tolerance and lipids tested	Pear used in folk medicine – pectin helps maintain acid balance in body GTT - Extracts showed signif hypoglycaemic effect after 90 mins of treatment ($p<0.01$) Blood glucose level – signif reduced BGL from day 3-11 (more signif $p<0.01$ than standard drug, glibenclamide in lowering BGl in diabetic ctrl) Lipids signif lower in both pear extract gps compared with diab ctrl, HDL ↑er, $p<0.05$ (table 5, details) P communis could be useful in Mx of diabetes assoc with abnormalities in lipid profiles
Ma et al 2013 Inner Mongolia, China (no paper available – read online only)	Liver damage. Hepatoprotective effects	Kunming mice with CCl_4-induced acute liver damage (oxidative stress-induced liver injury)	Asian pear composition analysed Animal RCT: a) Ctrl (saline) b) Silymarin (reference drug) c) Ethanol extracted pear at 1.4g, 2.8g and 5.6g	Polyphenols and triterpenes (oleanolic acid and ursolic acid) esp high in peel. Some phenolic compounds exhibited strong free radical scavenging capacity (table 2 eg catechin, chlorogenic acid, rutin, glucoside); Significant protective effect against chemically induced liver damage of mice (the elevated ALT and AST were signif reduced in most gps pre-treated with EHASP or EASP, EASP

				slightly superior, p<0.01 Histopathological examination of liver showed marked amelioration in pre-treated gps
Cho et al 2013 Korea	Anti-oxidative activity	Sprague-Dawley rats	Asian pear (P pyrifolia) composition analysed Antioxidative activities analysed by copper ion-induced oxidation of diluted rat blood plasma, caffeic acid as control In vitro studies: Free radical scavenging activities of compounds by a DPPH radical-scavenging assay, caffeic acid as control	**Composition measures:** 6 triterpenes incl 3 caffeoyl triterpenes isolated from peel. 4 compounds identified for first time. **Animal/in vitro studies:** The triterpenes containing caffeic acid moiety showed superior antioxidative activities.
Li et al 2012 China	Composition studies + antioxidant and anti-inflammatory effects	Kumming mice	8 Asian pear cultivars Polyphenol, flavonoid, anthocyanins, total triterpenes composition Controlled trial: Anti-inflam of all cultivars + ctrl via mouse ear oedema and paw oedema	**Composition measures**: Arbutin and catechin were dominant polyphenols **Animal/in vitro testing**: Oleanolic and ursolic acid highly correlated to anti-inflam activity Gallic acid, caffeic acid, rutin correlated with anti-oxidant activity
Li et al 2012 China	Anti-inflammatory and anti-microbial effects of phytochemicals isolated from P bretschneideri Rehd	Kumming mice	Asian pear (P bretschneideri) analysed for composition, anti-inflammatory and anti-microbial activities (tested in mice)	Phenolic compounds had anti-inflammatory and anti-microbial effect Ursolic acid, quercitrin, phthalate and amarin inhibited mice ear oedema cf with control Above plus sitosterol, daucosterol showed activity against various bacterial strains
Lee et al 2012 Korea	Alcohol detoxification	Mice (Aldh2 +/+ and Aldh2-/-)	a) Asian pear (P pyrifolia Shingo) administered to Aldh2 normal mice b) Control Aldh2 mice c) Asian pear administered to Aldh2	Pear treatment ↓ blood ethanol in both genetic gps but more evident in the aldh2 -/- mice (16.26±1.90mM vs 11.2±2.43mM; p<0.05) Tmax showed no diff between tr and ctrl so the time of absorption and elimination are equal

			deficient mice d) Control Aldh2 deficient mice All mice administered 1g of ethanol per kg bw 30 min after treatment with or without pear	 In vitro: pear tr ↑ADH (R2, 0.57; p<0.01 by regression analysis) and ALDH (R2, 0.45, p<0.05) Individual diff in response to pear tr for detoxification of alcohol is likely due to genetic variations of aldh2
Shahaboddin et al 2010 Iran	Antihyperglycaemic, antihyperlipidemic and antioxidant effects of wild pear leaf extract	Wistar rats	Wild pear leaf extract 3 groups treated orally for 4 days with: 1) Control (fed water) 2) 500mg/kg/day of P biossieriana Buhse extract 3) 1000mg/kg/day extract	Antioxidant activity in groups 2 & 3 signif higher (p<0.05) TG signif ↓ in groups 2 & 3 (p<0.02) Glucose conc induced by alloxan signif ↓ (p<0.05) in both gps compared with ctrl Serum insulin levels signif ↑ Serum cholesterol signif ↓ in both gps but only at 72 hrs for 1000mg gp Could be due to arbutin content and other phenolic glycosides but not conclusive. More studies to determine action and clinical benefit of leaf extract in DM
Li et al 2011 China (a)	Antioxidant and anti-inflammatory activities	Mice (no details)	5 Asian pear cultivars (Xuehua, Xiang, Ya, Fengshui, Shuijiug) 11 groups of 8 mice incl a control gp	Table 1: pear cultivars details + total phenolic acid content and total flavonoid content Table 2 details 5 pear cultivars and their phenolic compounds: gallic acid, catechin, chorogenic acid, caffeic acid, epicatechin, rutin Highest anti-inflam activity was not correlated with the highest total phenol content due to high level of phytosterols and triterpenes Therefore anti-inflammation activity may be due to compounds other than antioxidants
Li et al 2011 China (b)	Anti-inflammatory and antioxidant activity	Sprague-Dawley rats and Kunming mice	Asian pear (P bretschneideri Rehd) 11 gps of 8; ctrl gp + various crude extracts from PBR	PBR inhibits inflammatory reaction compared with dexamethosone Free radical scavenging and antioxidant activities shown in concentration dependent manner. Most effective extracts were EtOAc and n-BuOH fractions

				Table 1: carageenan induce paw oedema results
Survay et al 2010 Korea	Type 2 diabetes	Hyperglycaemic Sprague-Dawley rats	European pear (P communis) Groups incl ctrl and fruit extracts (10)incl pear and vegetables (20)	Table 1: Glucose AUC, phenolic content and anti-oxidant activity Pear in top 4 for effectively ↓ing BGL and AUC in hyperglycaemic rats ($p<0.05$) – more than apples! Apricots and European blackberries had far more TPC. Euro blackberries and pineapples had far more AOA
Huang et al 2010 China (a)	Anti-inflammatory effects	Kunming mice and Sprague Dawley rats	Asian pear (P bretschneideri Rehd) Crude extract administered at diff doses + ctrl	**Composition measures:** Active ingredients in of the ethanol extract from the pear - beta-sitosterol, daucosterol (sterols), oleanolic acid, ursolic acid (triterpenes) **Animal/in vitro testing:** Signif inhibition of ear oedema of all ingredients ($p<0.01$) Crude extract signif reduced paw oedema in dose dependent manner ($p<0.01$) Capillary permeability ↓ ($p<0.01$) These compounds have potential as novel lead compounds for future development of therapeutic interventions in treatment of inflammatory disorders.
Huang et al 2010 China (b)	Respiratory disease – anti-inflammatory and synergistic activities of bulb of Fritillariae ussuriensis (BFU) and P bretschneideri Rehd (PBR)	Sprague Dawley rats	Animal studies: 11 gps; ctrl received saline, standard received dexamethasone, others were combo + individual extracts in varying doses.	Combo gp best performing (comparable with standard drug at 30ml), but the pear extract improved the test 1 (oedema test) too in a dose dependent manner ($p<0.05$) In tests 2 and 3 the combo showed inhibition at a more significant level ($p<0.01$) but pear extracts alone showed inhibition. Synergistic effect between BFU and PBR, useful in treating throat and lung diseases
Hamauzu et al 2005	Gastric lesions. Effect of	Wistar rats	European pear (P communis) Antiulcer test: HCl/ethanol induced ulcers	1) Negative effect on ulcer (↑ulcer index, $p<0.05$ 2) Protective effect on ulcer (↓ulcer index, $p<0.01$) 3) Protective effect on ulcer (↓ulcer index, $p<0.01$)

Japan	polyphenols		(varying concentrations of ethanol and diff times of exposure) Looked at chlorogenic acid and procyanidin, the most abundant proanthocyanidin which are polymers of flavan-3-ol or catechin units 1) Chlorogenic acid dense pear extract 2) Procyanidin dense pear extract 3) Combined 4) Ctrl (water)	
Lee et al 2004 Korea	Asthma	Mice with ovalbumin induced respiratory disorder resembling human allergic asthma	Prior to sensitization, mice were administered a) High dose (100ug) of Asian pear pectin-sol b) ctrl	The pectin-sol gp significantly inhibited sensitivity of airway smooth muscle to electrical field stimulation and acetylcholine ($p<0.05$) Histologically the pectin-sol gp recovered the ovalbumin-induced abnormal signs to nearly normal state. IgE production significantly ↓ in pectin-sol gp ($p<0.05$) Administration of Asian pear pectin-sol in presensitized mice suppressed allergic asthmatic reaction therefore recommendable fruit for asthma sufferers This animal study could lead to respiration related study to control the production of cytokines (T_H1 and T_H2 type)
Leontowicz et al 2003 Poland	Antioxidant activity and antihyperlipidaemic activity of pear and apple peel and pulp	Wistar rats	European pear and apple composition analysed 5 gps 1) Chol gp – basal diet and non-oxidised cholesterol (NOC) 2) Chol/Apulp – BD+ 10% apple pulp + NOC 3) Chol/Apeel – BD + 10% apple peel + NOC	Table 1: Dietary fibre in apple and pear peel and pulp (insoluble fibre ↑er than soluble; ↑er in peel an pulp in both fruits) Table 2: Phenolic acids - ferulic acid, p-coumaric and caffeic acid (↑est) in apple and pear peel and pulp; highest content in apple peel Table 3 Flavonoids, polyphenols and total antioxidants; apple peel has highest content

			4) Chol/Ppulp – BD + 10% pear pulp + NOC 5) Chol/Ppeel – BD + 10% pear peel + NOC	Antioxidant potential (DPPH method) signif higher in apple peel, pear pulp showed smallest activity Good correlation between antioxidant potentials and total polyphenols (by DPPH – R^2=0.9207; by NO - R^2=0.9453; B-carotene – R^2=0.9350). Flavonoids showed lower correlations (by DPPH - R^2=0.6325) Apple and pear peel supplemented diets have a signif higher positive effect of plasma lipids and plasma antioxidant capacity of rats (details p5782) Concl: use the peels in industrial processing
Leontowicz et al 2002 Poland	Antioxidant activity and antihyperlipidaemic activity of peaches, pear and apple peel and pulp	Wistar rats	European pear composition analysed Rats fed diets with and without 1% cholesterol and with and without peach, apples and pears	Dietary fibre was high in all 3 fruits without signif differences Polyphenols, phenolic acids and TRAP values are higher in peeled apples and their peels than in peaches and pears; higher in peels than peeled fruits Correlation very poor (R^2=0.3267) between fibre and antioxidant capacity (TRAP), AO potential dependent on total polyphenols All fruit diets had hypocholesterolic effect in rats fed chol but mostly apples All diets positively infl plasma antioxidant potential in rats with and without chol

Table 15: Characteristics of studies investigating the composition of pears

Reference (Country)	Pear variety	Compositional analysis	Method	Observation/results
Flavanol & polyphenols				
Bilia 1994 (Italy)	*Pyrus bourgaeana* (Iberian pear)	Flavanoids including a new glycoside	The structures of the compounds were determined with spectroscopic methods including 2D NMR techniques.	A new flavanol glycoside, isorhamnetin 5-O-β -D-galactopyranoside, was isolated from the aerial parts of *Pyrus bouroaean.*
Chen 2007 (China)	8 commercial Asian pear cultivars: Yali, Kuerle Fragrant, Dangshan, Nanguo, Jingbai, Ninomiyahaku, Niitaka and Wujiuxiang	Sugar, organic acid, amino acid, fatty acid	Sugars-Dolenc and Stampar method Organic acids- HPLC Fatty acids- gas chromatography Amino acids- AccQ.Tag system Minerals- wet oxidation procedure	Table 2. Sugars- fructose, glucose, sucrose- fructose was the major sugar and almost always was greater than glucose content. Table 3- organic acids- Malic, citric, quinic and shkimic acids were the major organic acids identified Table 4- fatty acid composition- all eight pear varieties were rich in linoleic acid (70-80% of total fatty acids) Table 5- amino acid composition- the major amino acids in the eight pear varieties were asparagine and serine Table 6- Mineral composition- potassium is the most abundant mineral in the eight pears followed by magnesium and calcium
Cho, 2014 (Korea)	Asian pear *(Pyrus pyrifolia* Nakai cv. Chuhwangbae)	An ether and three ester derivatives of phenylpropanoid from pear peel and their radical-scavenging activity	Sephadex LH-20 column chromatography and octadecylsilane-HPLC	The four isolated compounds were identified as 2-O-(trans-p-coumaroyl) glyceric acid (1), 2-O-(cis-p-coumaroyl) glyceric acid (2), guaiacylglycerol-β-ferulic acid ether (3), and 2-O-(cis-caffeoyl) malic acid (4), based on the one- and two-dimensional nuclear magnetic resonance spectroscopic data. The isolated compounds 1-4 were identified for the first time from pear. Compound 4 showed higher DPPH radical-scavenging activity than 1-3.
Galvis Sanchez, 2003 (Spain)	Six Chilean pear cultivars (Coscia, Red D'Anjou, D'Anjou, Bosc, Packams, Forelle)	Phenolic and vitamin C content and antioxidant capacity	HPLC-DAD and HPLC/ESIMS	Chlorogenic acid was detected as the major hydroxycinnamic acid derivative and was higher in the peel than skin of all varieties. Epicatechin was the major flavan-3-ol compound found in the peel, highest in Packams, followed by Bosc, while Forelle showed only half this content. Flavonols were only found in the peel and high variability was noted with the highest content in Forelle and Red D'Anjou (55.9 and 54.7mg k g−1 peel respectively). Anthocyanin pigments were found only in the peel of Red D'Anjou and

				Forelle (12.0mg 100 g−1 and 1.2mg100 g−1 peel). Arbutin (hydroquinone 1-*β*-D-glucoside) was found only in the peel and was highest in Bosc and Red D'Anjou (1158 and 1055mgkg−1 peel respectively). Ascorbic acid (AA) and dehydroascorbic acid (DHA) - Forelle showed the highest vitamin C (AA + DHA) content in both the flesh and the peel. Range 5.4- 8.4mg/100g edible fruit. Antioxidant capacity- mainly located in peel. The peel of the red pears generally showed higher antioxidant capacities than that of the yellow cultivar (Coscia). The antioxidant capacity was correlated with the content of chlorogenic acid (r = 0.46), while ascorbic acid made only a small contribution to the total antioxidant capacity of the fruit.
Huang, 2013 (China)	Asian pear (*Pyrus pyrifolia* Nakai cv. Aikansui)	Distribution and metabolism of ascorbic acid	Kampfenkel method	Ascorbate contents increased with the fruit development, and reached the highest titers in 30 days after anthesis (DAA), then decreased and maintained a level. The higher contents of ascorbate in the peel of pear fruit were observed. Exogenous feeding of ascorbate synthesis precursors demonstrated that the peel had stronger capability of *de novo* ascorbate biosynthesis *via* Smirnoff-Wheeler pathway and uronic acid pathway whereas the flesh and core had lower capability for ascorbate synthesis. These results suggest that the pear fruit is able to cause *de novo* ascorbate biosynthesis and the peel had higher capability for ascorbate biosynthesis than the flesh and core.
Hudina, 2012 (Slovenia)	Concorde' pear (*Pyrus communis* L.) European pear	Phenolic compounds profile, carbohydrates and external fruit quality after bagging	HPLC and physical characteristics	Bagging ↓ content of phenolic compounds in skin (catechin, chlorogenic acid, epicatechin, p-coumaric acid, quercetin 3-O-galactoside, quercetin 3-O-glucoside, quercetin 3-O-rhamnoside). The removal of bags 7 d before harvest significantly ↑ glucose, shikimic and fumaric acids.
Lee, 2011 (Korea)	Asian pear (*Pyrus pyrifolia* Nakai cv. Chuhwangbae)	Isolation and identification of phenolic compounds from Asian pear peel	Electronic spray ionization (ESI)-MS and NMR spectroscopic data	The isolated compounds were identified to be arbutin (1), 4-(O-β-D-glucopyranosyl)-3-(3'-methyl-2'-butenyl)benzoic acid (2, malaxinic acid), 3,4-dihydroxybenzoic acid (3), trans-chlorogenic acid (4), cis-chlorogenic acid (5), isorhamnetin 3-O-β-D-glucopyranoside (6), 3,5-dicaffeoylquinic acid (7), and (-)-epicatechin (8). The first study to identify compound 2 and 5 in pear. Malaxinic acid (2) may act as antifungal, antibacterial, and anticancer active substance although the biological effects of 2, glucoside, has not yet been investigated.
Lin, 2008 (USA)	16 pear varieties- Fresh Asian, Asian brown, Korean, Korean Shinko,	Phenolic compounds in the skins of pears	Liquid chromatography with diode array and electrospray	Arbutin and chlorogenic acid were the main phenolic compounds. The pattern of distribution of the remaining phenolic compounds suggested that the tested pears could be divided into four groups. Group 1- The Asian, Asian brown, Korean, and Korean Shinko (*Pyrus* spp.)

	fragrant, Yali, red, Packham, Beurre, Forelle, Bartlett, Seckel, Bosc, D'Anjou, red D'Anjou, and Comice pears		ionization/mass spectrometric detection (LC-DAD-ESI/MS)	pears. They contained only arbutin and chloregenic acid with only trace amounts of the other flavonoids. Group 2- Yali pears (*P. bretschneideri*). They contained greater quantities of 3,5-dicaffeoylquinic acid than chlorogenic acid, and they also contained significant quantities of caffeic acid. Group 3-Fragrant pear (*P. serotina*) formed group 3 and contained significant amounts of rutin, quercetin 3-*O*-2''-xylosyl- 6''-rhamnosylglucoside (peak 13), and isorhamnetin 3-*O*-rutinoside as the main flavonoids. This pear also contained detectable amounts of the glycosides of luteolin, apigenin, and chrysoeriol. Group 4-The remaining 10 pears, all cultivars or varieties of *P. communis* L. They contained significant quantities of isorhamnetin glycosides, including the malonyl forms, and lesser quantities of quercetin glycosides.
Nassar, 2011 (Egypt)	The aqueous alcoholic extract of *Pyrus calleryana* Decne. leaves	Phenolic metabolites from Pyrus calleryana leaves	Spectroscopic analysis, including UV, IR, HRESI-MS, and 1D/2D NMR	Identified two new phenolic acids glycosides, namely protocatechuoylcalleryanin-3-O-b-glucopyranoside (1) and 30-hydroxybenzyl-4-hydroxybenzoate-40-O-b-glucopyranoside (2), together with nine known compounds among them lanceoloside A and methylgallate, which have been isolated for the first time from the genus Pyrus. Free radical scavenging activity was measured, the total alcoholic extract showed strong antioxidant activity while the two new compounds showed weak antioxidant activity
Ozturk, 2014 (Turkey)	17 cultivars of *Pyrus Communis* L. (European pear)	Phenolic compounds and chemical characteristics (vitamin C, weight, firmness, skin colour)	HPLC analyses of phenolic compounds Vitamin C-spectrophotometric procedure	Arbutin and chlorogenic acid were detected as the major phenolic compounds in the peel and flesh of pear. Catechin: range 40.0 to 543.8 mg kg−1 (flesh), 42.4 to 695.2 mg kg−1 (peel) Epicatechin: range 11.47 to 243.1 mg kg−1 (flesh), 12.6 to 315.4 mg kg−1 (peel) Vitamin C: range 9.1 to 29.7 mg 100 g−1 (flesh), 9.5 to 35.9 mg 100 g−1 (peel) Pear peel indicated higher contents of phenolics than pear flesh, confirming the health benefit of the consumption of pears together with peel.
Pyo, 2014 (Korea)	Asian pear (*Pyrus pyrifolia* Nakai)	Phytochemicals contents and antioxidant capacity of typical Korean kernel fruit juices	Antioxidant capacity-determined by Ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) assays	Summary of results for phytochemical and atinoxidant capcity of a 250mL serve of juiced and blended Korean pear respectively Total phenolics (mg GAE): 250.2±1.7vs 90.1±1.1 (P<0.05) Flavanoids (mg QE): 30.2±0.4 vs 17.5±0.1 (P<0.05) Ascorbic acids (mg): 4.7±0.1 vs nd TEAC(mM): 90.3±0.4 vs 59.5±0.3 (P<0.05)
Salta, 2010	Rocha pear, a	Phenolic profile and the	Phenolic composition-	Rocha pear (peel and flesh) presented the highest content of total phenolics

(Portugal)	Portuguese pear cultivar compared with Comice, Abate, General Leclerc and Passe Crassane	antioxidant activity	HPLC-DAD Antioxidant activities- three complementary test systems: DPPH radical scavenging activity, FRAP and b-carotene/linoleic acid bleaching assay.	(164.3 mg/100 g FW). chlorogenic, syringic, ferulic and coumaric acids, arbutin and (-)-epicatechin were detected as major components.
Schieber, 2001 (Germany)	European pear *Pyrus communis* cv. Alexander Lucas, Anjou and Red Williams	Phenolic acids and flavonoids of apple and pear	HPLC mass spectrometry	Contents of 7 phenolic compounds (Arbutin, Chlorogenic acid, Epicatechin, Quercetin-3-rutinoside, Quercetin-3-galactoside, Quercetin-3-glucoside, Isorhamnetin-3-glucoside) in three pear cultivars were reported (Table 3).
Siddiq, 2000 (USA)	Two European pear cultivars *d 'Anjou* and *Bartlett*	Polyphenol oxidase (PPO) and phenolics	Total phenolics and chlorogenic acid were extracted and determined by the Folin-Ciocalteau colorimetric method (Coseteng and Lee 1987)	D'Anjou pears had 51.36% of Bartlett pear PPO activity (P≤0.05). Total phenol concentration differed significantly (P≤0.05) with 426 and 780 pg/g fruit tissue in d'Anjou and Bartlett pears, respectively. Heat inactivation- Bartlett pear PPO lost more than 40% of its activity during first 5 min of heating while heating for another 25 min resulted in only 13% additional loss, for a total loss of about 60%. PPO from d'Anjou pears lost its activity (about 33%) slowly during first 20 min, however, it rapidly lost activity (an additional 37%) between 20 and 30 min.
Silvia, 2010 (Portugal)	European pear *Pyrus Communis* L. Rocha	Antioxidant properties and fruit quality during long term storage	Free radical scavenging activity-method of Brand-Williams (1995)	Fruit-free radical scavenging activity at harvest was highly dependent on the harvest date (Fig. 3). The highest value (160 mg/kg) was observed in fruits from the early and optimal harvest dates, whereas in the late harvest date, the activity was 34% lower (102.8 mg/kg). The initial differences, however, did not persist during storage. After the initial adjustment during the first 60 days in storage, free radical scavenging activity remained stable for the remaining storage period. Neither DPA nor 1-MCP affected the free radical scavenging activity.
Tanrioven, 2005 (Turkey)	Seven different pear cultivars of European pear grown in Turkey (Akça, Şeker, Williams, Santa Maria, Starkrimson, Passa Crassane,	Phenolic compounds	HPLC	Total amount of polyphenol of pear juice samples varied between 196 and 457 mg/L. The main phenolics determined in pear juice were chlorogenic acid, epicatechin, caffeic acid and coumaric acid. The descriptive values of major phenolics in pear juice Presented as mg/L min, max, mean, SD, CV^c (%) Chlorogenic acid: 73.1, 249, 151, 57.0, 37.9 Epicatechin: 11.9, 81.3, 32.4, 23.4, 72.2 Caffeic acid: 2.4, 9.2, 7.4, 3.9, 52.7 p-Coumaric acid: 0.0, 3.0, 0.8, 1.0, 125.0

	Ankara)			The effects of clarification (phenolics contribute to the formation of haze): Phenolics decreased by 22.5–39.6% (29.7% average) after clarification. The reduction levels differ from phenolic to phenolic.
Fibre				
Gorinstein, 2002 (Spain)	European pear *(Pyrus communis* L var Blanquilla)	Dietary fibre, total polyphenols and phenolic acids in Spanish pears were analysed and compared with their TRAP)	Polyphenols- Folin-Ciocalteu method Pheonlic acid- Garcia-Sanchez	The content of total polyphenols was 2.1±0.3g kg^{-1} in peeled fruits and 4.5±0.4kg^{-1} in their peels. The contents of dietary fibre, total polyphenols, caffeic, p-coumaric and ferulic acids and the TRAP values were significantly ($P<0.05$) higher in peels than in peeled fruits. Dietary fibre was 22.8±2.2, 8.9±0.7 and 13.9±1.3 for TDF, SDF and IDF respectively in peeled pears and 29.7±0.3, 11.8±1.1, 17.9±1.6 for TDF, SDF and IDF in pear peels. Dietary fibre content of peels was significantly higher than in peeled fruit ($P<0.05$). There was a very good correlation between total polyphenol content and TRAP values ($R^2=0.9505$) and a poor correlation between TRAP values and total dietary fibre content ($R^2=0.2969$).
Martin-Cabrejas, 1995,	Pear pomace (consisting of the entire insoluble portions of the fruits, including seeds, skins, and cores)	Dietary fibre content of pear and kiwi pomaces to assess the suitability of the fiber-rich waste material as alternative sources of DF	Fibre-AOAC procedure of Prosky, and we have subsequently determined the Mason lignin and nonstarch polysaccharide content of the residues.	Soluble fiber contents of both pomaces are comparable and are approximately 7%, but the IDF content of the pear pomace (36.3%) is twice that of kiwi reflected in the much higher content of TDF in pear, 43.9%. The marked difference in the IDF content can be inferred to be due to the presence of significant amounts of stone cells (sclereids) in the pear pomace which are rich in glucuronoxylans, cellulose, and lignin. Although other plant foods such as runner bean pods and asparagus stems (Selvendran and King, 1989; Waldron and Selvendran, 1992) have the potential to lignify after a certain stage of growth, these vegetables, unlike pear fruit, are not palatable after vascularisation and supporting tissues have lignified because they become very tough. In the case of pear fruit, the stone cells are not "fibrous".
Sugars				
Hudina, 2000 (Slovenia)	Seventeen European pear cultivars (*Pyrus communis* L.) and four Asian pear cultivars (*Pyrus serotina* Rehd.)	Free sugar and sorbitol content	HPLC	Great differences were noted in the individual sugar content of various cultivars with Asian pear cultivars having more sugar. Glucose range: 4.29 - 25.32g/kg Fructose range: 35.13 - 65.61g/kg Sucrose range: 3.70 - 37.13g/kg Sorbitol range: 10.38 - 43.20g/kg.

Hudina, 2000b (Slovenia)	18 European (*Pyrus communis* L.) and 4 Asian (*Pyrus serotina* Rehd.) cultivars	sugars (glucose, fructose, sucrose, sorbitol) and organic acids (citric, malic, fumaric, tartaric)	HPLC	Fructose-in European pears highest in cv. Clapp Favorite (66.1 g kg.1) and lowest in cv. Conference (23.7 g kg.1). In Asian pears ranged from 27.9 g kg.1 in cv. Shinseiki to 45.7 g kg.1 in cv. Koshui. Sorbitol- European pears contained from 12.5 g kg.1 of sorbitol in cv. Conference to 25.8 g kg.1 in cv. Concorde and in Asian pears cv. Hoshui contained the highest amount of sorbitol (17.6 g kg.1) and the cv. Shinseiki contained the lowest amount, only 5.0 g kg.1. Sucrose- the highest in the European pears (21.1 g kg.1) in cv. Beurré Bosc and the lowest in cv.Princess Mariane (2.2 g kg.1). The Asian pears cvs .Koshui and Hoshui contained only 2.6 g kg.1 or 2.9 g kg.1, cvs Kumoi and Shinseiki on the other hand, contained significantly more sucrose (15.4 g kg.1 or 10.8 g kg.1). Total sugar- In the European pears was from 52.3 g kg.1 in cv. Conference to 99.0 g kg.1 in cv. Beurré Bosc and in the Asian pears from 58.5 g kg.1 in cv. Shinseiki to 80.7 g kg.1 in cv. Kumoi
Jovanovic-Malinovska, 2012 (Macedonia)	Pear (European)	Low molecular weight carbohydrates including sugar alcohols and mono-, di- and oligosaccharides, in particular fructooligosaccharides and raffinose-family oligosaccharides	HPLC	Pear: mean ± standard deviation (*n* = 3), moisture 83±0.01, fructose 4.50±0.193, glucose, 4.21±0.243 sucrose, 2.44±0.180 sorbitol 2.45±0.192, mannitol nd, xylitol 0.12±0.012, $GF_2$0.15±0.004, $GF_3$0.32±0.012, GF_4 0.09±0.007, Total FOS 0.56±0.023, Cluster analysis was used to identify the similar groups according to the oligosaccharides content within the fruit and vegetable samples: Blueberry, pear, watermelon, and nectarine which belong to cluster B are distinguished with the significantly highest concentration of total oligosaccharides as well as of GF3.
Li, 2002 (USA)	Pear (assumed European)	Individual sugars, soluble and insoluble dietary fibre contents of 70 high consumption foods	Sugars- HPLC Fibre-AOAC method	Pears, raw, ripe with skin Sugars (g/100g) - fructose 5.3, glucose 4.2, sucrose 1.2, total fibre 10.7 Soluble- 0.92, insoluble- 2.25, total 3.16
Muir, 2009 (Australia)	Packham and Nashi pear varieties	Measurement of short-chain carbohydrates (FODMAPs)	HPLC with ELSD	FODMAP content of pears (g/100g of fresh weight sample) Pear, Packham- firm, peeled % moisture 81, fructose 9.32, glucose 4.35, excess fructose 4.97, sorbitol 5.99, manitol, raffinose, stachyose, nystose, kestose all nd Pear, Packham- ripe, peeled % moisture 83, fructose 3.40, glucose 1.11, excess fructose 2.29, sorbitol 2.30, manitol, raffinose, stachyose, nystose, kestose all nd Nashi pear % moisture 80, fructose 4.35, glucose 2.58, excess fructose 1.77, sorbitol 1.01, manitol, raffinose, stachyose, nystose, kestose all nd

Park, 2015 (Korea)	European pear (*Pyrus communis*)	Quantitative assessment of the main antioxidant compounds, antioxidant activities and FTIR spectra from commonly consumed fruits, compared to standard kiwi fruit	Fibre- Prosky method	Dietary fibre (g/kg fresh weight)- total 21.2, insoluble 12.9, soluble 8.4
Stone cells				
Tao, 2009 (China)	Two Asian pear species (*Pyrus bretschneideri* cv. 'Jingaisu' and *Pyrus pyrifolia* cv. 'Kousui')	Anatomy, ultrastructure and lignin distribution of Stone cells	Light microscopy (LM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) as well as autofluorescence analysis	There were no obvious differences in stone cell structure between the two varieties, but stone cell size and content was much greater in 'Jingaisu' than in 'Kousui'. Further, lignin accounted for 29.8% of stone cell composition in 'Jingaisu', a significantly higher proportion than in 'Kousui' (24.6%). Several factors influence the formation of stone cells, including cultural practices, post-harvest handling, but the most important factor is genetic variability, different species even different varieties show variation in stone cell content with various size. Sometimes, stone cells are not a major constituent of the edible portion, however in some varieties, such as 'Jingaisu' (Pyrus bretschneideri), they impart a very gritty texture. Part of a research program aimed at improving pear quality by reducing stone cell content.
Seed oil				
Yukui, 2009 (China)	Asian Pear *(cv. Dangshan Suli)*	Fatty acid composition of pear seed oils	Fatty acid analysis by gas chromatograph	Oil content in pear seeds (179 g/kg seeds) was similar to that in soybeans. There are 11 kinds of fatty acids in pear seed oil. Saturated fatty acids: 9.732 g/100g pear seed oil Unsaturated fatty acids: 77.846 g/100g pear seed oil Monounsaturated fatty acid: 20.675 g/100g pear seed oil
Matthaus 2015 (Turkey)	European pear (*Pyrus Communis*)	Seed oil content and vitamin E-active compounds	Fatty acids by gas chromatography and Vitamin E by HPLC	Oil content in pear seeds 31.7g/100g oleic acid: 31.8g/100g linoleic acid: 53.6g/100g Distribution of vitamin E-active compounds in pear (due to antioxidant properties vit E is an important feature) α-T=5.4mg/100g y-T=55.6mg/100g Seeds containing more than 30g/100g oil are interesting as valuable sources for oil production "From an economical point of view, this high oil content would justify oil extraction of the seeds, whereas for seeds with oil contents below 20 g/100 g

				an economical extraction of oil is only meaningful by solvent when the meal contains valuable protein, e.g., soybean or if the oil can be marketed as high-quality cold-pressed edible oil"
Fromm 2012 (Germany)	European pear (*Pyrus Communis*)	Seed oil content	Gas chromatography analysis	The pear cultivar "Gelbmostler" only yielded 1.4g seeds/kg fruit. The fruits of this cultivar only contained few seeds (3.4 per fruit) most of which were also incompletely developed, resulting in low average seed weight (36.7 mg) and oil content. In a preliminary screening of other pear cultivars, seed yields have been even lower (data not shown). Therefore, a more extensive investigation of seeds from a broader selection of pear cultivars was not feasible.
Glycaemic index				
Lunetta, 1995 (Italy)	Asian pear	Glycaemic index	Pear containing 50g carbohydrate compared to 78g white bread (containing 50g carbohydrate)	61 type 2 diabetics (n=8 in pear group) Glycaemic index of pear 60 ± 4.9 which was significantly lower than white bread (reference food), PII value of pear 3.48±0.55
Chen, 2011 (Taiwan)	European Pear	Glycaemic index	Used standard GI testing protocol. One edible portion of pear containing 25g carbohydrate compared to 25g glucose	20 healthy non-diabetics, mean age 21.9yr and 17 type 2 diabetics, mean age 57.5yr GI of Asian pear, mean ± SEM 18.0 ± 5.4 in healthy subjects and 25.9 ± 2.9 in T2DM. PII, 0.26±0.06 in healthy and 0.35±0.04 in T2DM. No significant difference was found between healthy and T2DM subjects in GI or PII

CV[c,] coefficient of variance, DPA, diphenylamine, FRAP, ferric reducing antioxidant power, GAE gallic acid equivalents, GF2: 1-kestose; GF3:nystose; GF4: 1F-β fructofuranosylnystose, HPLC, High Performance Liquid Chromatography, HPLC-DAD, high performance liquid chromatography with diode array detection, HPLC/ESIMS, HPLC/electrospray ionisation mass spectrometry, IDF, insoluble dietary fibre, PII, post-prandial insulin index, PPO, polyphenol oxidase, QE, quercetin equivalents, SD, standard deviation, TDF, total dietary fibre, TEAC, Trolox equivalent antioxidant capacity, TRAP, total radical-trapping anti-oxidative potential, ND, not detected, 1-MCP, 1-methylcyclopropene.

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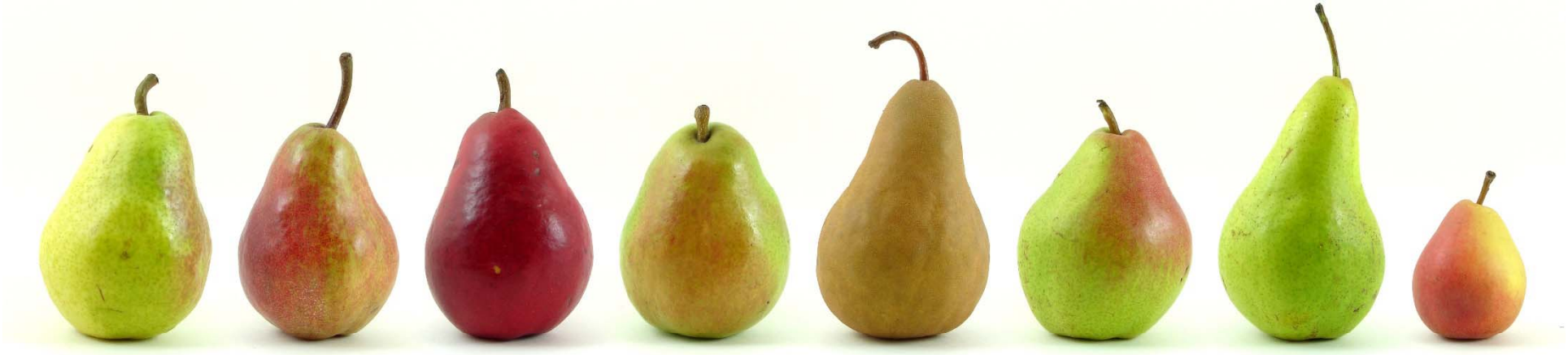

Health and Nutritional Properties of Pears

A Literature Review for APAL & HIA

Genevieve James-Martin, Gemma Williams, Welma Stonehouse, Nathan O'Callaghan, Manny Noakes

25 October 2015

FOOD AND NUTRITION FLAGSHIP
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Outline

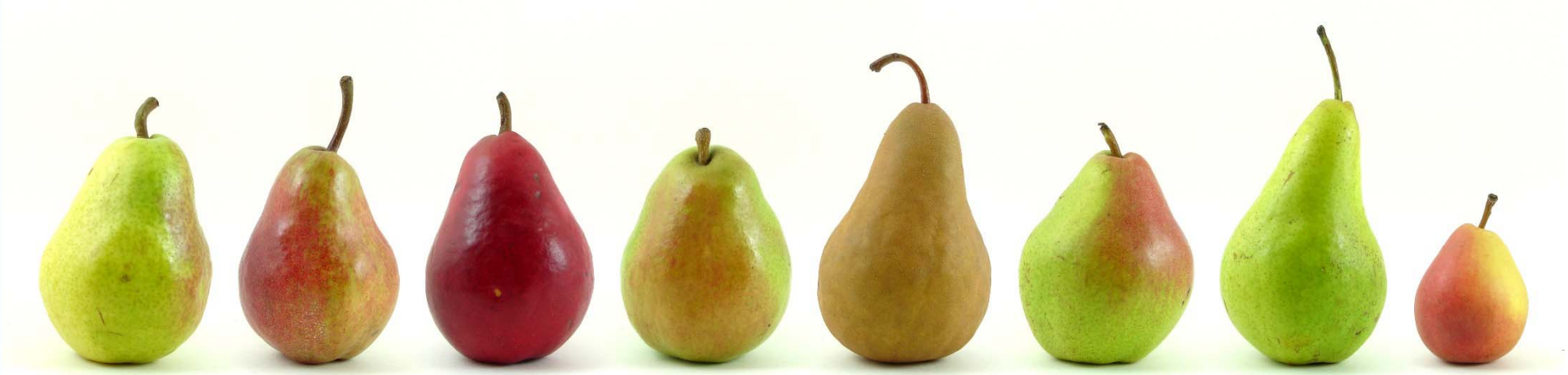
- Background
- Aim of Review
- Methods
- Nutritional Composition of Pears
- Results
- Pears as Part of a Healthy Diet
- Recommendations
  - Potential health messages regarding pears based on current evidence
  - Health attributes of pears requiring further research
- Conclusion

Background

- Pears are enjoyed throughout the world and are one of the oldest human cultivated plants.
- The European pear (*Pyrus communis*) is the major pear of commerce in Australia with eight varieties available.
- While the Asian pear (*Pyrus pyrifolia*) or “Nashi” is mostly grown in Asia it has been produced commercially in Australia for over 25 years.
- Pears have been used as a traditional folk remedy in China for more than 2000 years because of their supposed anti-inflammatory, antihyperglycemic, diuretic activities, cough relief and as a prophylactic agent for alcohol hangover.

Aim of Review

- To conduct a comprehensive systematic literature review investigating the health benefits and nutrition properties of pear and pear components to provide APAL and HIA with an up-to-date understanding of the current scientific evidence in order to promote the health benefits of pears.



Methods

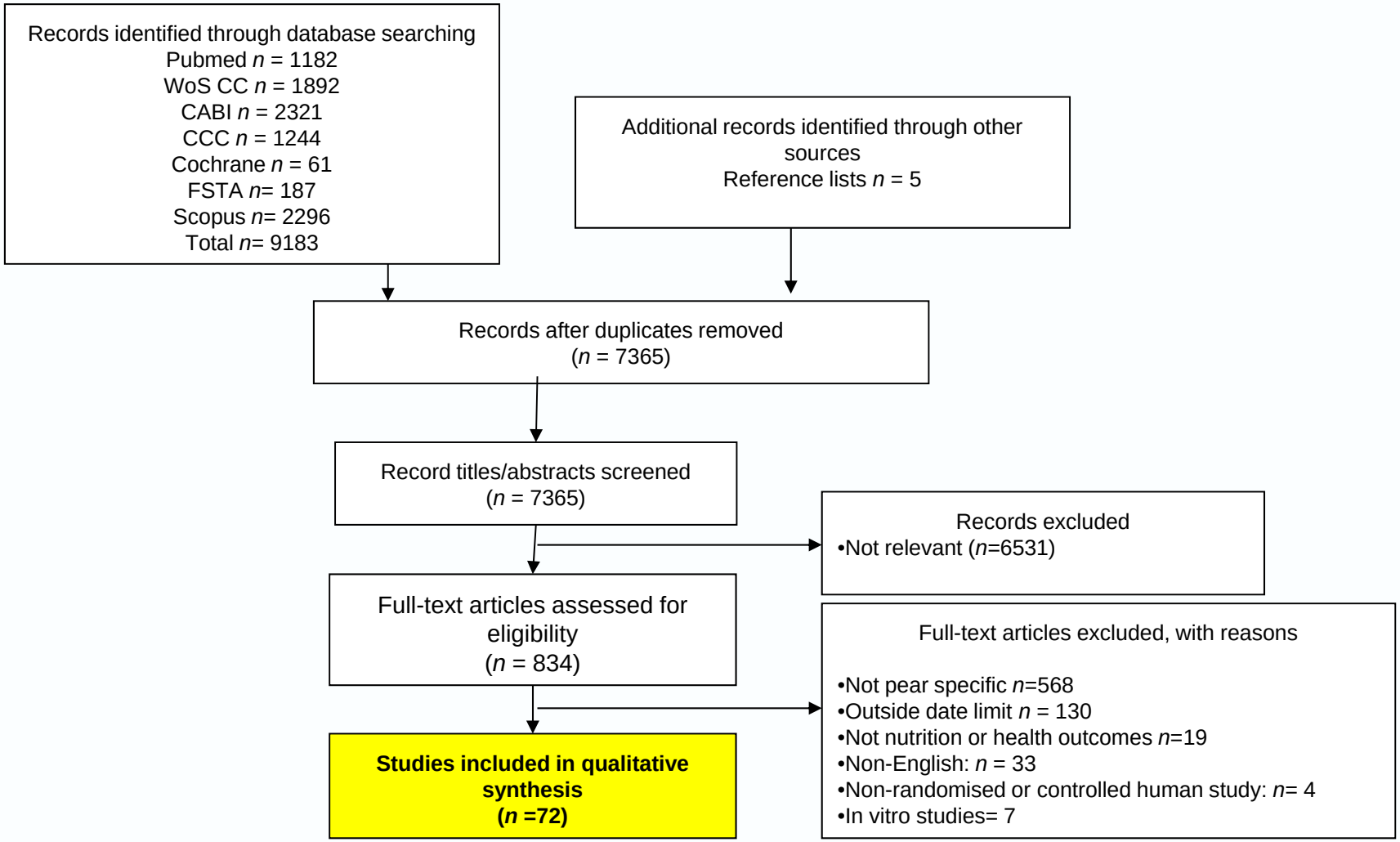
- Relevant original research reports published in English up to 10 July 2015 were identified by a comprehensive systematic search of seven scientific journal databases.

- Search restrictions were limited in order to capture all studies related to health benefits of pears and pear components conducted in humans (including intervention and association studies), animal studies and studies reporting nutritional composition information on pears.

- The strength of the scientific evidence were evaluated using the National Health and Medical Research Council (NHMRC) criteria.

- Although animal studies are useful to inform the body of scientific evidence, recommendations can only be based on evidence from human studies.

Literature search results

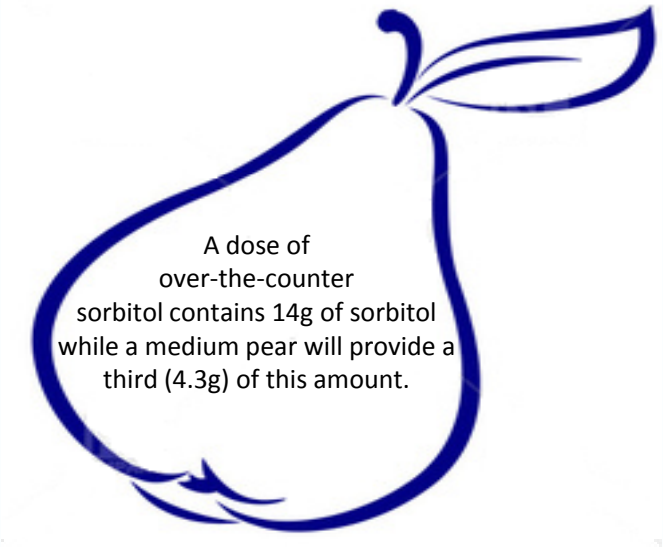


Nutritional Composition (per 100g edible portion)

	PEAR AVERAGE, UNPEELED, RAW	APPLE, RED SKIN, UNPEELED, RAW	BANANA,CAVENDISH PEELED, RAW	ORANGE, NAVEL, PEELED, RAW	STRAWBERRY, RAW
Energy (kJ)	233	236	385	175	108
Protein (g)	0.3	0.3	1.4	1	0.7
Total fat (g)	0.03	0.2	0.3	0.1	0.2
Carbohydrate avail (g)	12.4	12.4	19.6	8	3.9
Sugars (g)	9.8	11.6	12.8	8	3.8
Glucose (g)	2.4	2.2	5.38	3.28	NR
Fructose (g)	**6.5**	6.4	2.45	2.09	NR
Sucrose (g)	0.9	3.0	NR		NR
Dietary Fibre (g)	**3.1**	2.21	1.79	2.35	2.07
Sorbitol (g)	**3.3**	0.4	ND	ND	NR
Vitamin c (mg)	4	4	4	53	45
Potassium (mg)	112	96	346	147	158
GI (mean)	33-42 (38)	28-44 (36)	47	33-40	NA

- Pears stand out for their combination of digestion regulating nutrients including fibre, sorbitol and fructose.
- Pears, particularly pear peel, contain a number of health benefitting phytonutrients especially phenolic acids, in particular chlorogenic acid, arbutin, ferulic and citric acid.

Digestive Effects



- Pears surpass all other fruits for their high content of digestive regulating nutrients including fibre, fructose and sorbitol.
- At 4.1g of fibre per medium pear, it is one of the highest fibre containing fruits.
- Due to their unique composition of fibre, sorbitol and fructose pears have the potential to play an important role in regulating normal bowel function

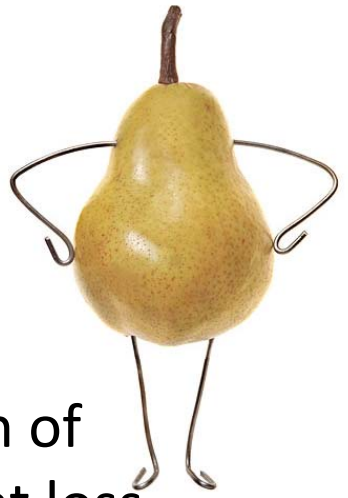
The fibre content of pears meets the FSANZ criteria for a nutrient content claim that pear is a "good source" of fibre. A general level health claim can also be made "Contributes to regular laxation".

- It is important to note that in a small proportion of the population, FODMAP mal-absorbers, the high content of fructose and the combination of fructose and sorbitol may result in gastrointestinal discomfort.

Alcohol Hangover Symptoms

- Consumption of pear juice prior to alcohol consumption reduced blood alcohol levels, particularly in individuals with a genetic variant associated with a reduced ability to metabolise alcohol, while in normal individuals hangover symptoms and severity were reduced.
- The key component proposed to stimulate alcohol metabolism is arbutin, found in the skin of Korean pear.
- These effects have only been tested in one animal and one human intervention study in a Korean population using a Korean pear variety.
- Hence a general recommendation regarding pear consumption and alcohol hangover cannot be made at present.
- Human intervention studies in an Australian population are needed to confirm these effects and other potential pear varieties should also be investigated.

Weight Management



- One small intervention study indicated that the addition of pears to a weight reducing diet may contribute to weight loss.
- The authors suggested that the weight loss was due to pears low energy density resulting in reduced energy intake.
- Further intervention studies are needed to confirm this effect.

Cardiovascular disease

- Prospective observational studies have consistently shown that the consumption of apples and pears (combined) are associated with reduced risk of stroke.
- Some evidence is also available to show that apples and pears are associated with a reduced risk of coronary heart disease.

Type 2 Diabetes

- Prospective observational studies have consistently shown that apples and pears (combined) are associated with a reduced risk of type 2 diabetes. Pears have a low glycaemic index (GI) which may assist in the prevention and managing of type 2 diabetes.

Pears are a low GI food (Low <55)

Whole pear	38
Canned pear in natural juice	43
Canned pear in syrup	25
Dried pear	43

- Further support for pear's anti-diabetic potential is provided from three animal studies that showed favourable effects on blood glucose from pear extracts, potentially related to insulin-like activity of various bioactive compounds in pear, in particular blocking of carbohydrate digestion by certain phenolic acids.

Metabolic Health Markers and Antioxidant Effects

- Consumption of pear pulp, peel and wild pear leaf extract improved metabolic health markers such as glucose levels and cholesterol/lipid profiles in animal models.
- Pears contain several bioactive components such as polyphenols and fibre that may contribute to these effects. However, intervention studies in humans are needed before recommendations can be made.
- Consumption of pear or pear components increases *in vivo* antioxidant activity in animal models.
- The effect is greater with pear peel extract than pear pulp, which is consistent with greater levels of polyphenols in the peel, compared to the pulp.
- Animal studies suggest the antioxidant mechanisms of pears may be at play in wound healing and liver protection.

To obtain all the benefits of pear it should be consumed with the peel.

Cancer

- Evidence from association type studies (prospective and case-control studies) showed that increased consumption of apples and pears (combined) were associated with reduced risk of cancer including lung, bladder, oral, pancreatic and breast cancer.
- However the number of studies per cancer type are limited.

Allergy and Respiratory Disease

- Pears are used in elimination diets (used to identify food allergies and intolerances) due to their low allergenic potential

- Evidence from cross-sectional studies (association studies low in the hierarchy of proving causality) suggests some benefit of consuming pears (and apples) for asthma and other respiratory diseases and a limited number of animal studies support these findings.

- However, further research is required before any recommendations can be made regarding pears role in allergic and respiratory conditions.

Pears as Part of a Healthy Diet

>80% CORE FOODS

<20% NON CORE FOODS

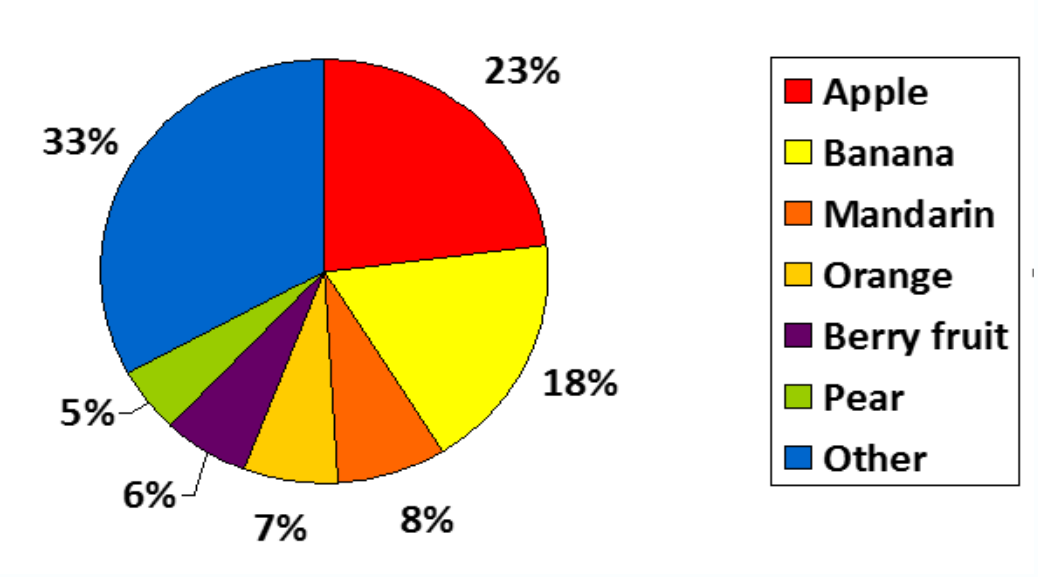
Only occasionally and in small amounts

2 fruits serves per day

Pears as Part of a Healthy Diet

- The latest National Health Survey 2011-12 showed just over half (54%) of Australians reported consuming the recommended serves of fruit (2 serves a day for adults).

- Apples were most commonly consumed the day before the survey while pears were consumed by 5% of Australians.



Recommendations: Potential health messages regarding pears based on current evidence

Pears – your daily prescription for digestive health.

- Consuming pears may be a more preferred method for alleviating constipation than taking medications, particularly in children who may be averse to taking medications and older adults who are often already taking several medications.

- Adding one medium pear per day to the daily diet could make a significant contribution to achieving daily fibre recommendations.

- One pear per day could bridge the shortfall between Australian women's current fibre intakes (21g/d) and recommended intakes (25g/d)

Recommendations: Potential health messages regarding pears based on current evidence

Pears, particularly the skin of pears, are rich in several phytochemicals, especially phenolic acids, which have been associated with multiple health benefits. Thus, to gain the most benefit from consuming pears it needs to be consumed with the peel.

Pears have a low GI and may therefore be included in a diabetic diet to assist with managing glucose levels.

Pears are low in energy density and may therefore play a role in weight reducing diets by adding weight to the diet without increasing calories.

Recommendations: Potential health messages regarding pears based on current evidence

Apples and pears combined are associated with reduced risk of stroke, coronary heart disease, type 2 diabetes and cancer.

- Studies investigating these associations have always combined apples and pears hence the independent effects of pears cannot be elucidated.
- Any messages regarding these associations should therefore be for apple and pear combined.
- As these results are based on association type studies any messages should refer to these health benefits as associations and not causal effects.

Recommendations: Health attributes of pears requiring further research

The following potential health attributes of pears or pear-based products are worth further investigation within human intervention studies before specific recommendations can be made.

1. The phenolic acid arbutin, found in high concentrations in the peel of Korean pear has the potential to stimulate alcohol metabolism and decrease blood alcohol levels and hangover symptoms.

   - **Identification of an Australian pear high in arbutin (potentially Nashi), development of products containing high arbutin pear peel (e.g. beverages, ciders) and subsequent human intervention studies is recommended.**

Recommendations: Health attributes of pears requiring further research

2. There is limited evidence from cross-sectional studies and animal studies suggesting some benefit of consuming pears for managing and treating asthma and other respiratory and allergic diseases such as rhinitis.

   ❖ **Human interventions studies are recommended to substantiate and investigate this mechanism further.**

3. The high content of soluble fibre and polyphenols in pears, previously shown to have hypoglycaemic and hypolipidaemic effects, may contribute to metabolic health by improving lipid profiles, glycaemic control and reducing chronic inflammation. The fruit itself may not contain these compounds in sufficient amounts to have a clinical benefit, but pear peel and pulp extracts may be effective, as shown in some animal studies.

   ❖ **Novel products containing these extracts could be developed and substantiated in human intervention studies**

Recommendations: Health attributes of pears requiring further research

4. Research has quantified some nutritional components of pear waste, namely oil and fibre

   ❖ **Analysis of pear waste for other bioactive components such as phytonutrients and sugars e.g. sorbitol, could provide indications of other potential uses for pear by-products.**

5. Waste products of pear including the peels and seeds have potential to be further processed to seed oil, or a fibre product which could be used to fortify low fibre foods e.g. baked goods, medical nutritional therapy products or commercial fibre supplements.

   ❖ **The feasibility of this would depend on current levels of waste produced and processing costs, however it is recommended that this is explored.**

Conclusion

- Pears have some unique features that could have important health benefits.
- Studies in humans have been limited which restricts specific health recommendations.
- It may be beneficial for all Australians to increase their intake of pears in order to capitalize on its high fibre content.
- One pear a day will make an important contribution to achieving daily fibre recommendations and regulating normal bowel function.

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