



FOOD STANDARDS
Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

Systematic review of the evidence for a relationship between pectin and peak postprandial blood glucose concentration

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Executive Summary

Does pectin intake reduce peak postprandial blood glucose concentration?

Food-health relationship	Pectin consumption reduces peak postprandial blood glucose concentrations.
Proposed degree of certainty (GRADE rating)	1.4 to 5.2 g pectin has no effect on peak postprandial blood glucose concentration: Very low ⊕ 10–14.5 g pectin reduces peak postprandial blood glucose concentration: Very Low ⊕

Component	Notes
<i>Body of evidence</i>	Sixteen cross-over studies testing doses ranging from 1.4 to 30 g of pectin consumed with food or a glucose drink were found. The meta-analysis was limited to the lower doses of 1.4 to 14.5 g pectin reported in nine studies (10 strata) testing a total of 99 subjects. In adults with normal blood glucose levels, there was a non-significantly higher peak postprandial glucose concentration (0.22 mmol/L) in those who consumed 1.4 to 5.2 g pectin together with 53–74 g of carbohydrate compared with control food. In studies testing 10–14.5 g pectin together with 49–106 g of carbohydrate there was a mean overall effect of -0.41 mmol/L glucose concentration (95%CI: -0.78, -0.04). No studies tested doses between 5.3 – 9.9 g pectin.
<i>Consistency</i>	There was no consistency in effect between the two dose ranges ($p = 0.02$) for sub-group differences. In the 10–14.5 g pectin dose range, there was moderate heterogeneity as the effect sizes varied markedly across the studies, which tested different pectin-types in various food vehicles containing 49–106 g of carbohydrate. Therefore it was not possible to determine if the variation in results reflects effects due to these study differences or random variation around a common value.
<i>Causality</i>	Randomised controlled trials (RCTs) are a strong study design for causal evidence when sufficiently powered. With one exception, the sample size in each study was small, 5–15 subjects. The conclusions that there is no effect for the lower doses and that there is an effect at the higher doses are based on few subjects with some indirectness of the association and also most studies did not describe some important features of their design. Therefore, causality is not established.
<i>Plausibility</i>	High-molecular weight pectin increases viscosity and so could delay gastric emptying and, thereby, decrease or delay glucose uptake in the gastrointestinal tract. Low-molecular weight pectin does not have this property. Most studies did not state what type of pectin they tested.
<i>Generalisability</i>	Most studies tested healthy adult subjects and took acute postprandial glucose measurements only, so results should not be influenced by usual dietary patterns and therefore should be generally applicable to New Zealand and Australia. Studies which used purified pectin in amounts which might be found in a single serving of food found no effect on post-prandial blood glucose concentration.

FSANZ has conducted a systematic review on pectin consumption and peak postprandial blood glucose concentrations. In doing this review, FSANZ has followed the required elements of a systematic review given in the mandatory information requirements in Part 3 of the FSANZ *Application Handbook* and Schedule 6 – Required elements of a systematic review in the *Australia New Zealand Food Standards Code* except where it is clear that a provision is irrelevant because the relationship was not substantiated.

The claim permitted in the European Union specifies a minimum quantity of 10 g pectin per portion consumed with a meal and that consumers should be warned of a choking hazard associated with the high swelling property of pectins. Therefore, FSANZ believes that this claim relates to the consumption of a supplement because an intake of 10 g of pectin is unlikely to be achieved in a serving of food. However FSANZ has conducted a review to determine whether an effect occurs with lower amounts of pectin that might be obtained from a serving of food. The amount of pectin in a serving of food containing pectin that has been added according to good manufacturing practice (GMP) is likely to be less than 1 g. Pectin is found naturally in foods, mainly in certain fruits and some vegetables, in variable amounts.

Sixteen RCTs described in 17 articles met the selection criteria for the systematic review. FSANZ decided not to include six studies which used 15–30 g pectin in the meta-analysis. Pectin doses in that range are approximately 10–20 times more than could be expected to be consumed from a serving of food.

The studies included in the meta-analysis tested up to 14.5 g pectin. All used a cross-over design and tested a total of 99 adults. The included studies used purified pectins; some used food-grade pectins and others used pharmaceutical-grade pectins. A reduction in postprandial glucose concentration can only be achieved if there is concurrent consumption of substances which raise blood glucose concentration. Therefore the amount of carbohydrate consumed concurrently in the meal is relevant. The amount of carbohydrate given with the pectins ranged from 49–106 g and appeared to be mostly glucose or digestible starch. There was a non-significant increase in peak postprandial blood glucose following the consumption of pectins compared to control (0.22 mmol/L, 95%CI: -0.15, 0.58) when the lower doses (1.4–5.2 g pectin) were tested. FSANZ regards this as showing no effect. There was an effect on postprandial blood glucose for doses in the range of 10–14.5 g (-0.41 mmol/L; 95%CI: -0.78, -0.04). The one high-quality study (Wanders et al. 2014a) tested 10 g pectin with 49 g carbohydrate in 29 adults and found an effect of -0.30 mmol/L blood glucose (95%CI: -0.54, -0.06) for food-grade pectin compared to controls.

FSANZ concludes that the data do not support an effect of pectin on peak postprandial blood glucose concentrations at the usual quantities of pectin found in a serving of food. The relationship is not established.

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1 Introduction

In 2012, the European Union (EU) authorised the health claim that *Consumption of pectins with a meal contributes to the reduction of the blood glucose rise after that meal* (European Commission 2012). FSANZ notes that the EU claim *may be used only for food which contains 10 g of pectins per quantified portion* because the beneficial effect is obtained by consuming 10 g pectins as part of the meal. The EU claim also has the following condition:

Warning of choking to be given for people with swallowing difficulties or when ingesting with inadequate fluid intake - advice on taking with plenty of water to ensure substance reaches stomach

While the conclusions of the European Food Safety Authority (EFSA) were drawn from the scientific literature, a systematic review of the literature was not performed (EFSA 2010).

FSANZ is considering whether a relationship between intake of pectin and peak postprandial blood glucose concentration can be incorporated into Schedule 4 – Nutrition, health and related claims in the *Australia New Zealand Food Standards Code* (the Code). FSANZ considers that 10 g of pectin (i.e. the minimum quantity of pectin attached to the EU claim) is unlikely to be obtainable from a single food on a single eating occasion and that it would need to be consumed as a dietary supplement. Supplements are not regulated by the Code. However, FSANZ has examined the literature to determine whether a food-health relationship might be substantiated and whether a qualifying amount of pectin could be achievable a serving of food in the normal diets of the Australian and New Zealand populations.

No relevant systematic reviews were identified. FSANZ notes that while the EU claim refers to 'contributes to the reduction of' postprandial glycaemic responses', the EU relationship refers to a lowering of blood glucose concentrations after eating or drinking. Therefore, the purpose of this report is to systematically review the evidence for the relationship between consumption of pectin in a meal and peak postprandial blood glucose concentrations.

1.1 Food or property of food

Dietary carbohydrates are frequently classified into two distinct groups, depending on whether they are digested or fermented in the gastrointestinal tract. Since only monosaccharides (i.e. simple sugars) are readily absorbed in the upper part of the gastrointestinal tract, the chemical configuration and intramolecular linkage of the monosaccharides are important determinants of enzymatic digestion of saccharides. Mammalian enzymes can only cleave saccharides that contain monosaccharides that are linked by α 1,4 glycosidic bonds. Therefore all other saccharides having different glycosidic linkages (with the exception of lactose) will pass undigested into the colon. Resistant starch is also an exception because, although the linkages are α 1,4 glycosidic, most resistant starch passes undigested into the colon.

A second group of dietary carbohydrates is the branched carbohydrates. These fermentable carbohydrates are frequently components of plant cell walls and can be subdivided into two groups based on their water solubility. The more soluble ones, such as pectins, β -glucans or inulin-type fructans, form viscous gels in water and are relatively easily fermented to short-chain fatty acids by microflora of the large intestine. Those that are less soluble in water include lignin, cellulose and some hemicelluloses, and do not form viscous gels and so fermentation by microbiota in the large intestine is more limited.

Pectin collectively refers to a group of polysaccharides that are rich in galacturonic acid, although they contain other monosaccharides as well. Around 80% of the galacturonic acids in naturally occurring pectin are esterified with methanol. This proportion decreases during extraction, leading to high- versus low-ester pectins (also known as high-methoxyl versus low-methoxyl pectins).

The average daily intake of all types of fibre among men and women aged 15 years and older was 22.8 g and 17.9 g respectively in New Zealand in 2008–9 (University of Otago and Ministry of Health 2011). In 2011–12, Australian men and women aged 19 years and older, consumed 24.8 g and 21.1 g total fibre per day respectively (Australian Bureau of Statistics 2015). Total fibre includes a range of fibres in addition to pectin. Pectin consumption in 'typical' Western countries is estimated to be around 5 g per day, i.e. when all eating occasions are combined (Srivastava and May 2011). However, in the current context, the amount of pectin in a serving of food, not the total daily intake, is the relevant amount.

Pectin is mostly obtained from fruits (Table 1), where it can be found in significant amounts in pome fruits, berries, and citrus fruits (especially the peel). The pectin content of fruit decreases naturally as the fruit ripens. Pectin does not have a single molecular weight but rather a very wide distribution of molecular weights that reflects the heterogeneous mixture of pectins that naturally occur in fruits and vegetables. The viscoelastic property of pectin is directly related to its molecular weight (Yamaguchi et al. 1995). It also appears that the degree of esterification influences the viscosity of pectin solutions through metal ion-mediated aggregation of pectinic polysaccharides (Yoo et al. 2006).

Table 1: Amount of pectin naturally contained in some fruits and vegetables

Part of fruit	Fruit	% pectin substances (wet weight)
Edible component	Apple	0.5–1.6
	Banana	0.7–1.2
	Carrot	0.2–0.5
	Lemon pulp	2.5–4.0
	Mango	0.26–0.42
	Passion fruit	0.5
	Peaches	0.1–0.9
	Pineapple	0.04–0.13
	Strawberries	0.6–0.7
	Tamarind	1.71
Peel	Orange	3.5-5.5

(source: Table 1 in Thakur et al. (1997), p 50)

1.2 Health effect

Blood glucose rise after a meal is a normal physiological response as glucose is liberated from food and then absorbed or generated from the carbohydrate contained in the food (Venn and Green 2007). This rise in plasma glucose promotes insulin release from the islet cells of the pancreas into the bloodstream, which in turn facilitates uptake into muscle and fat cells. When blood glucose concentrations fall too low, the peptide hormone glucagon is released from alpha cells in the pancreas, which stimulates the liver to convert stored glycogen into glucose. Thus the interplay between insulin and glucagon keeps blood glucose concentrations tightly controlled.

However, in the case of insulin insensitivity, the glucose present in the blood is inefficiently transported into cells, most likely due to a lipid-induced breakdown in insulin initiated signal

transduction (Samuel and Shulman 2012). Therefore it is relevant to examine whether the dietary intervention causes unexpected changes in insulin concentrations.

There are a number of ways of measuring changes in blood glucose concentration after a meal. Researchers report fasting serum values and then following an intervention, typically every 10, 15 or 30 minutes for anywhere between 120 minutes to five hours. These serial clinical measures are taken using an indwelling catheter under laboratory conditions. In the literature, commonly reported serum measures of postprandial blood glucose concentrations include: time to peak, rate of rise, peak, incremental peak, mean, incremental mean, 2-hour glucose concentration, area under the blood glucose concentration curve (AUC) (which may be over differing time points), and incremental area under the blood glucose concentration curve (iAUC).

The highest value measured is often referred to as 'peak glucose' even though most studies measure glucose intermittently and so cannot determine the true peak. In addition, the true peak might occur at different times in people consuming different types of food or in people with normal as compared to those with abnormal glucose metabolism. There is no agreement among researchers as to which of these various outcome measures is the most relevant for assessing the physiological impact of changes in postprandial blood glucose concentrations.

After consultation with FSANZ's Health Claims Scientific Advisory Group peak glucose was chosen as the most appropriate measure of postprandial blood glucose concentrations because this is the most uniformly reported measurement and also measures immediate postprandial effect. FSANZ has selected the highest reported blood glucose concentration measurement after ingestion of a meal or glucose drink as the parameter to quantitatively evaluate in the meta-analysis. This will hereafter be referred to as the peak. FSANZ notes that the true peak may not have been measured or reported.

Normal fasting glucose concentration was defined as ≤ 5.5 mmol/L, impaired glucose tolerance was defined as 5.6–6.9 mmol/L and diabetes was defined as ≥ 7.0 mmol/L (Diabetes Australia 2012).

1.3 Proposed relationship

The food-health relationship assessed in this report is:

- pectin consumption reduces peak postprandial blood glucose concentrations.

2 Evaluation of evidence

A systematic review of the literature was performed to assess the proposed food-health relationship. The effect of pectin on peak blood insulin concentrations was also assessed because an increase in postprandial blood insulin concentration that occurred with a decrease in blood glucose concentration would be considered an adverse effect.

2.1 Methods

2.1.1 Search strategy

A search was conducted in Embase® (OVID) on 11 November 2015 for literature published from 1974 to that point in time. The search was repeated in PubMed and Cochrane CENTRAL on 17 November 2015 without time limits around the publication date. Detailed search strategies are presented in Appendix 1.

2.1.2 Inclusion and exclusion criteria

The eligibility criteria are summarised in Table 2. All animal studies were excluded. Only human controlled trials were included. To be included in the systematic review, the trial must have stated that it was randomised or described an allocation method that suggested randomisation (such as Williams Latin Square) and included an appropriate control group. Sequential designs were excluded. Trials with a concomitant intervention were excluded also, unless this intervention did not differ between control and test groups. Parallel and cross-over designs were acceptable. The absence of double-blinding was not treated as an exclusion criterion because the outcome (postprandial blood glucose concentrations) is measured within an hour or two of the test by standard laboratory methods and there is no opportunity for non-compliance or other participant factors to affect the results.

Study populations could be adults or children (≥ 2 years of age), and could include those with chronic non-communicable diseases such as diabetes, hyperlipidaemia or hypertension. Studies of people with insulin dependent diabetes who had not taken insulin were excluded because these people were considered to be acutely ill. Trials in other acutely ill populations were excluded, as were trials in people with gastro-intestinal conditions that would affect gastric emptying, such as dumping syndrome or any prior gastric surgery.

The pectin intervention had to occur at a single meal, with postprandial blood glucose levels measured after that meal to test the effect. The pectin could be given in various ways as long as an appropriate control was available. For example: pectin-rich food versus equivalent food without pectin; pectin incorporated into food (e.g. pectin powder mixed in marmalade spread on bread versus the marmalade and bread without additional pectin); packets of pectin powder consumed with food (e.g. sprinkled on breakfast cereal) versus no powder; or pectin supplements given as capsules versus placebo capsules. Studies testing pectin in a mixed fibre (such as testing guar and pectin together or using apple pomace/powder that was not purified pectin) but without an appropriate control were excluded because it would not be possible to attribute the results to pectin alone.

Table 2: PICOTS criteria for study inclusion

Population	Non-acutely ill adults or children ≥ 2 years (without gastro-intestinal conditions affecting gastric emptying); participants with diabetes must have taken regular insulin or oral medications prior to the intervention
Intervention	Increased consumption of pectin in foods or as a supplement at a single meal
Comparator	Placebo or same foods without pectin
Outcome	Sequential measurements of blood glucose concentration after a meal
Time	At least 90 minutes of postprandial assessment reported
Study design	Randomised controlled trial

2.1.3 Additional material

The World Health Organization International Clinical Trials Registry Platform was also searched to identify potentially unreported or impending clinical trials on pectin and postprandial blood glucose concentration (World Health Organization 2015). No unreported or impending trials were found.

Forty-three additional papers were identified for screening by searching the reference lists of all the articles screened on full text.

2.1.4 Study selection, data extraction and quality assessment

Records identified during the search process were imported into EPPI-Reviewer 4 (<http://eppi.ioe.ac.uk/cms/er4>). The forty-three papers identified through hand-searching were manually entered. Following removal of duplicates, records were screened on title and abstract. Candidate full-text articles were retrieved and assessed against the inclusion and exclusion criteria. Screening was conducted by two investigators.

Peak postprandial blood glucose concentration data were extracted by one investigator and cross-checked by at least one other investigator. Numerical data were extracted when available. If the data were present only in graphs, the means and standard deviations or standard errors were extracted using the online program WebPlotDigitizer Version 3.6¹. Where the true peak blood glucose concentration was given (via continuous measurement using an indwelling catheter), this was extracted. However, most studies tested blood glucose concentration at intervals of 15 or 30 minutes or longer (from fasting until a final postprandial time point of either 120, 180, or in one case, 300 minutes) and so the peak was defined as the highest blood glucose concentration measured during the observed period. The peak might have occurred at a different time point for the intervention and the control groups. If some data (e.g. means) were presented numerically and other data only available in a graph, then the best data (i.e. the numerical value) were extracted whenever possible; even when this meant that a reported mean was used with an error digitised from a graph. Comparison of instances where both numerical and graphical data were available showed that it was possible to achieve a close match between the two types of data. Where error bars for several arms overlapped and it was not clear which mean the bar related to, the widest error was selected for extraction. Results from the two graphical data extractions were averaged. Data were extracted from trials presenting absolute values at each time point as well as those presenting incremental increases in blood glucose concentrations from baseline. Blood glucose concentrations reported in mg/dL were converted to mmol/L by multiplying by 0.0555.

Some studies had several intervention arms. For example, studies may have measured different types or forms or amounts of pectin. To prevent double counting of the control group by using it to calculate more than one difference (Higgins and Green 2011), only one intervention group was chosen from multi-arm studies using the following criteria:

- If the same form of pectin was tested in different test meals then the arm most closely resembling a true meal would be chosen, providing the control was appropriate.
- If multiple forms of pectin were tested, the form most commonly found in food was chosen.
- If different quantities of pectin were tested, and both the other criteria were satisfied, then the arm with the lowest dose of pectin was chosen, owing to the focus of this review.
- Finally, if one study was a subset of another part of that same study, then the larger set of results was used.

Some papers reported studies in more than one group of adults, or where a second control arm had been given for a different dose of pectin. These papers were regarded as having more than one stratum.

Trials were assessed for risk of bias according to the Cochrane Handbook (Higgins and Green 2011) and were collated using Review Manager (RevMan) Version 5.3 the systematic

¹ <http://arohatgi.info/WebPlotDigitizer/index.html>

review software developed by The Cochrane Collaboration (The Nordic Cochrane Centre 2014).

FSANZ used the Grading of Recommendations Assessment, Development and Evaluation system (GRADE) to assess the quality of the body of evidence to determine the degree of certainty in the food-health relationship (Guyatt et al. 2011a; Guyatt et al. 2011b; Guyatt et al. 2011c; Guyatt et al. 2011d; Guyatt et al. 2011e; Guyatt et al. 2008) (refer section 3.1 and Appendix 4).

All data concerning insulin were examined to assess whether glucose lowering was not effected through increased insulin secretion. Insulin secretion in the intervention group that is in excess of the control group would be considered an adverse effect. All other adverse effects mentioned by study authors were also extracted (Table 3).

2.1.5 Statistical analyses

Following data extraction, the difference in peak blood glucose concentration between the intervention and control groups was calculated if it was not reported. Because all included studies used a cross-over design, the difference was calculated as:

$$\text{Difference} = \text{Glucose}_{(\text{peak in intervention})} - \text{Glucose}_{(\text{peak in control})}$$

and its standard error (SEM) as:

$$\text{SEM} = \sqrt{[(\text{SEM}_{(\text{peak in intervention})})^2 + \text{SEM}_{(\text{peak in control})}^2] - 2r(\text{SEM}_{(\text{peak in intervention})})(\text{SEM}_{(\text{peak in control})})}$$

The correlation coefficient (r) was imputed as 0.6 based on the intra-class correlation coefficient obtained from a linear mixed model fitted on 150 people with between one and 12 replicate measurements of capillary blood glucose concentration taken at baseline and after 30 minutes after consuming 50g glucose in a fasting state (data supplied by Sydney University's Glycaemic Index Research Service, personal communication, 2015).

Meta-analysis was performed using a random effects model and the generic inverse variance method using RevMan version 5.3 (The Nordic Cochrane Centre 2014).

I^2 was used to assess heterogeneity among the strata. It describes the “percentage of total variation across studies that is due to heterogeneity rather than chance” and 0%, 25%, 50% and 75% could be interpreted as indicating no, low, medium and high heterogeneity respectively (Higgins et al. 2003).

2.1.6 Subgroup analyses

Two subgroup analyses were carried out:

- Dose of pectin (1.4 – 5.2 g versus 10-14.5 g).
- High-quality compared with low-quality studies (in view of the short-term nature of the tests, items such as blinding were not used to assess quality; rather the focus was on whether the authors described giving subjects instructions about diet and exercise prior to testing (as variation in these can alter blood glucose response) and on whether there were a priori sample size calculations).

The decision about how to group the studies to examine the dose of pectin was decided post-hoc after examining the scatterplot, but reflects the consideration of the amount of pectin which could be obtained from food, rather than a supplement.

The following subgroup analyses were identified *a priori* to explore differences in effect sizes but were not carried out as the number of included studies was too small:

- Pectin type, e.g. high- vs low-methoxyl pectins.
- Use or not of concomitant glucose-lowering medication among trials of hyperglycaemic subjects.
- Parallel or cross-over study design (no parallel studies have been reported).
- Sex of subjects (the majority of subjects in the included studies were male).
- Adults compared to children (no studies involving children have been reported).
- Funding source, i.e. industry funded vs non-industry funded studies. (The following studies declared their funding source (Jones et al. 2015; Siddhu et al. 1989; Siddhu et al. 1990; Siddhu et al. 1991; Wanders et al. 2014a; Williams et al. 1980). Ranganathan et al (1994) noted cellulose was a gift from Servier Company (Paris).
- Populations with normal vs abnormal fasting glucose concentrations (Williams et al. (1980) was the only reported study involving people with non-insulin dependent diabetes (n=7)).

In addition, the planned sub-group analysis comparing studies which tested pectin administered in a meal (including liquids which contained protein or fat in addition to carbohydrate) or glucose drink was not carried out because the two studies testing pectin in a glucose drink used 14.5 g but none of the meal studies tested this quantity of pectin. Consequently any comparison by vehicle type might be confounded by difference in dose of pectin tested. A full description of the test product used for the intervention in each study is provided in Table 3 below.

2.2 Results

2.2.1 Search results

The screening of articles retrieved from the search strategies is detailed in Figure 1. Of the total 142 records screened (after 44 duplicates had been removed), 104 records were excluded on title/abstract and another 21 after reading the full text (Figure 1). Studies excluded after full-text examination are listed in Appendix 2 where FSANZ generally reported one reason for the exclusion of each study only, even though studies may have been able to satisfy more than one exclusion criteria.

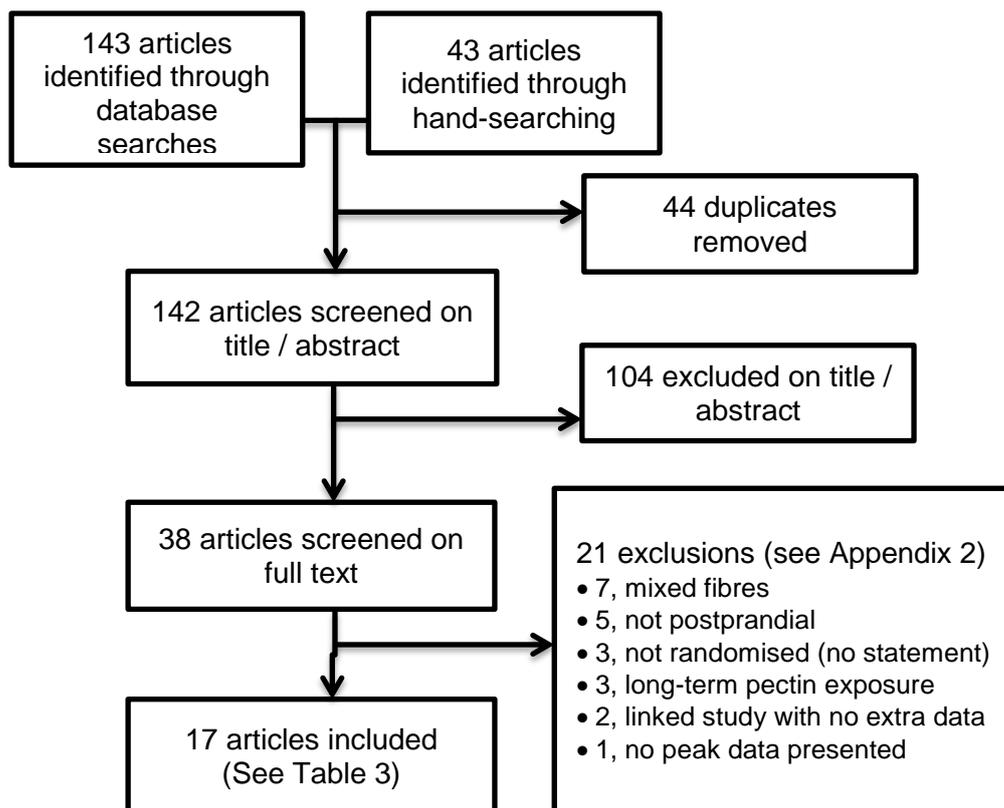


Figure 1. PRISMA diagram of study filtering process

2.2.2 Included studies

Table 3 lists the 16 studies (17 articles) included in the systematic review (Flourie et al. 1985; Holt et al. 1979; Iftikhar et al. 1994; Jenkins et al. 1977; Jenkins et al. 1978; Jones et al. 2015; Ranganathan et al. 1994; Sahi et al. 1985; Sanaka et al. 2007; Sandhu et al. 1987; Shimoyama et al. 2007; Siddhu et al. 1989; Siddhu et al. 1990; Siddhu et al. 1991; Villaume et al. 1988; Wanders et al. 2014a; Williams et al. 1980). Villaume et al. (1988) and Flourie et al. (1985) publish results from the same study: Villaume et al. published in French and Flourie et al published in English.

The 16 studies described results from testing 152 adult subjects (see Table 3), assuming that the four Indian studies (Sahi et al. 1985; Siddhu et al. 1989; Siddhu et al. 1990; Siddhu et al. 1991) describe results from non-overlapping studies. Table 3 is listed by increasing dose of pectin given in the studies. Some used lower doses (1.4 – 5.2 g per meal) than referred to in the EU claim, some used similar doses (10-14.5 g per meal) and the remainder used larger doses.

Data were extracted from nine of the 16 studies (10 strata) for the purpose of a meta-analysis. The remainder were not included in the meta-analysis for the following reasons. Sandhu et al (1987) tested 15 g pectin but did not any provide numerical or graphical data which could be used; they only reported that there was “no effect” of pectin on glucose rise. Five papers tested doses of pectin of 20 g or 30 g, which is approximately 10–20 times more than can be expected to be consumed from food per serving and therefore well outside the pectin intakes of any potential relevance to this review (Ranganathan et al. 1994; Sahi et al. 1985; Siddhu et al. 1989; Siddhu et al. 1990; Siddhu et al. 1991). Four of these papers reported an overlapping set of studies (Sahi et al. 1985; Siddhu et al. 1989; Siddhu et al. 1990; Siddhu et al. 1991) and contain some discrepancies. For example, Siddhu (1992),

which summarises the overall study but does not provide any additional extractable data, reports that the test described in Sahi et al. (1985) tested pectin with 100 g glucose whereas the paper by Sahi et al. (1985) state that 60 g was given. Even without this decision to exclude the studies testing the high doses, Sahi et al. (1985) did not report standard errors or standard deviations and the values for outcome measures plotted in figures by Ranganathan et al. (1984) were not clear enough to be extracted. The final exclusion was Jones et al. (2015), a conference abstract that did not specify the dose of pectin used or give details of the results.

2.2.3 Extracted data

Data were extracted from 10 strata (nine studies described in 10 articles) for inclusion in the meta-analysis. These strata tested between 1.4 g and 14.5 g pectin per test food or glucose drink. One study (Villaume et al. 1988; Flourie et al. 1985) provided two separate strata in the quantitative meta-analysis. One of the strata further compared both 10 g and 15 g pectin to the same control group. FSANZ included the 10 g arm only because it was the smaller amount and so it was more relevant to the focus of this review (FSANZ noted that the results of the 15 g arm were identical to those of the 10 g arm). A number of decisions had to be made during data extraction from the included studies and are described in Appendix 3.

Most studies described the source of their pectin and some used pharmaceutical-grade products rather than food-grade products (Table 3). Only one study tested more than one type or form of pectin (Wanders et al. 2014a). These investigators tested three different pectins in a randomised, Williams Latin Square designed cross-over study with thirty unique orders generated by computer. The choice of arm was not clear. FSANZ chose the CU901 arm (i.e. food-grade pectin) for the main analysis (see Appendix 3). Compared to the control meal, there was little difference among the three pectins delivered in the same meal format and the impact of choosing one of the other arms was explored in a sensitivity analysis.

2.2.4 Quality assessment of individual studies

FSANZ assessed trials for risk of bias using GRADE (Figure 2, Appendix 4). Most studies did not provide enough information to assess the risk of bias with much confidence, especially in the areas of selection bias (random sequence generation and allocation concealment), as well as blinding of outcome assessment.

The risk of attrition, reporting and other bias was considered to be low in the body of evidence. FSANZ concluded that the overall risk of bias in the body of evidence was low for the usual criteria relating to randomisation, allocation and blinding. Most studies reported the number in the analysis but not whether there had been any attrition during the cross-over experiment. One study could not be included because the author did not provide any numerical details but simply stated 'not significant' and another did not provide any measure of variance. Test results are affected by diet and exercise on the days leading up to the test. Only one author described giving subjects instructions concerning exercise, and standardising the meal on the night before the test (Wanders et al. 2014a). This was also the only study to describe the basis of their sample size, albeit for an outcome other than glucose concentration and had twice as many subjects as the next largest study. FSANZ considers this study to be a much higher quality study within the body of evidence.

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Table 3: Properties of the 16 studies (17 articles) included in the review analysis, ordered by dose of pectin tested

Reference & study location	Study design*	Objectives	Participants & sample size	Methods	Interventions	Pectin dose, pectin source, & reported adverse effects (AE) from pectin	Statistically significant results reported by authors
Shimoyama 2007 Japan	Cross-over	To investigate how the increased viscosity of an elemental formula could prevent gastro-oesophageal reflux in healthy volunteers.	11 healthy adults (5 male and 6 female) aged 22–35	Venous blood taken fasting, 15, 30, 45, 60, 90, 120, 150, 180 & 210 mins. Method to measure plasma glucose not described	400 mL enteral formula (K-3S, Kewpie Corporation, Japan: 52.8 g glucose) labelled with 100 mg sodium ¹³ C acetate vs same with 90 mL REF-P1 solution (Kewpie Corporation) containing 1.4 g pectin	1.4 g Kewpie Corporation: pectin (1.4 g) in REF-P1 viscosity regulating solution (total 90 g) AE: not reported	Glucose: Significantly higher with pectin than control at 60 & 90 minutes (p<0.05). Insulin: Higher with pectin than control at 60 & 120 minutes (p<0.1).
Iftikhar 1994 UK	Double-blind cross-over	To evaluate the effect of pectin given in a palatable form on the gastric emptying rates of the solid and liquid phases of a test meal and to ascertain whether pectin affected blood glucose levels	10 healthy male and female volunteers	Venous blood taken fasting and every 15 minutes for six hours. Method of blood glucose analysis not stated.	Scrambled eggs [2 eggs (60 g), 30 mL milk, 25 g butter], 2 slices toast and 300 mL Lucozade (61.5 g glucose) with microcrystalline cellulose placebo vs same with 2 g pectin instead of cellulose placebo	2 g Farma Food A/S (Denmark) AE: not reported	Glucose: No significant difference
Villaume 1988 France (linked to Flourie 1985) (Stratum B also tested with 15 g pectin but data not shown)	Cross-over	To study the effect of pectin in a solid-liquid meal on carbohydrate metabolism in healthy people.	2x6 healthy volunteers (10 male and 2 female) aged 19–51.	Blood taken fasting, 30, 60, 90, 120, 180, 240 & 300 mins. Plasma glucose measured by glucose oxidase technique. (blood was centrifuged, therefore a venous sample)	Blended meal of beef, white bread, & olive oil, with pear sorbet & water taken throughout meal (approximately 65 g carbohydrate) vs same but with pectin added to pear sorbet	5 g (Stratum A) 10 g (Stratum B) High-methoxy powder type apple pectin: 'Brun NF Pomme', Laboratoires Unipeptine, Paris AE: not reported	Glucose: Stratum A (5 g): no significant differences. Stratum B (10 g): significantly higher than controls at 180 mins only (p<0.05). AUC not significantly different. Insulin: no significant differences

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Reference & study location	Study design*	Objectives	Participants & sample size	Methods	Interventions	Pectin dose, pectin source, & reported adverse effects (AE) from pectin	Statistically significant results reported by authors
Sanaka 2007 Japan	Cross-over	To investigate the effects of agar and pectin on gastric emptying and postprandial glycaemic profiles	10 healthy male volunteers aged 21–33	Venous blood taken fasting, 30, 60, 90 & 120 mins. Glucose measured by enzymatic glucosidase method. Graph labelled plasma glucose	Ready-made nutritive drink (EN-Otsuka, Iwate, Japan) (17.6 g protein; 9 g fat; 5.2 g glucose; 59.6 g maltodextrin per 400 mL) vs same with pectin added; thus described as “pudding like” and eaten with spoon). All control & test drinks given as 500 mL in total	5.2 g EASYGEL; Otsuka Pharmaceutical, Tokushima, Japan AE: not reported	Glucose: no significant differences.
Wanders 2014a The Netherlands (linked to Wanders <i>et al</i> (2012), see Appendix 2)	Cross-over	To study the effect of different physicochemical properties of dietary fibre on appetite and energy intake	30 (29 completed) healthy males (aged 18–30). Power calculation: To detect a difference in energy intake of 10% between pairs (CV = 13%, $\alpha = 0.05$, $1-\beta = 0.8$), a sample size of 30 subjects was calculated, given an anticipated dropout rate of 10%.	Venous blood taken fasting, 15, 30, 45, 60, 90, 120, 150 & 180 mins. Plasma glucose measured by hexokinase method. Insulin measured by commercial ELISA; all samples from a subject were analysed in the same run	Liquid test product of: soft cheese (quark), milk, apple juice, & strawberry syrup (49 g carbohydrate) vs same with added pectin (N.B. type of pectin & method of supplementation differed across five test products)	10 g Tested both non-viscous pectin, non-gel forming (bulking) pectin; viscous pectin and gel forming pectin. All manufactured by Herbstreith & Fox, Germany AE: One dropout after three days due to intestinal problems. No differences between test products at any time for any of the side-effects asked.	Glucose: significantly lower peak for viscous pectin only compared to control ($p=0.024$) but the three pectins were not different from each other. Insulin: mean insulin levels significantly lower with viscous ($p=0.002$) and gelled pectin ($p=0.0001$) only.
Williams 1980 England (Part 1 only,	Cross-over	To test the effect on post prandial glucose and insulin concentrations of	Part 1: 7 healthy but with non-insulin dependent	Blood taken fasting, 15, 30, 45, 60, 90 & 120 mins. Plasma glucose measured by glucose	Meal of cornflakes, milk & sugar, then 100 ml diabetic orange squash, then	10 g Hercules Powder Company Ltd.	Glucose: Part 1: No significant differences. AUC no sig differences.

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Reference & study location	Study design*	Objectives	Participants & sample size	Methods	Interventions	Pectin dose, pectin source, & reported adverse effects (AE) from pectin	Statistically significant results reported by authors
with pectin in powdered form) Results for pectin in hydrated form not shown		adding one of four fibre compounds in powder form to a test breakfast given to maturity onset diabetics	diabetes from a pool of 13 (10 male, 3 female) aged 39–64	oxidase method. Insulin measured by radio-immunoassay	white bread & butter with marmalade followed by 150 ml tea (84.9 g carbohydrate) vs same meal with 5 g pectin stirred vigorously in squash and 5 g pectin sprinkled on butter	AE: Excessive flatus, mild abdominal discomfort (n = several). Some nausea (n = 1) & diarrhoea (n = 1).	Insulin: no significant differences
Jenkins 1977 England	Cross-over	To test if pectin as part of a meal reduces postprandial insulin and glucose concentrations.	8 healthy volunteers (6 included for insulin studies) drawn from pool of 13 (11 male, 2 female) aged 19–33.	Venous blood taken fasting, 15, 30, 45, 60, 90 & 120 mins. Glucose measured by glucose oxidase method. Insulin measured by radio-immunoassay.	White bread with butter & marmalade & milk tea (106 g carbohydrate) vs same meal with pectin added to the marmalade	10 g NF pure, HP Bulmer Ltd Hereford) AE: not reported	Glucose: significantly lower glucose after pectin at 15 mins only (p<0.01). No other sig differences. Insulin: significantly lower insulin levels with pectin at 15 & 30 (p<0.01), and 45 mins (p<0.05).
Holt 1979 Scotland	Cross-over	To test if pectin affects glucose absorption through modifying gastric emptying	7 (6 completed) healthy volunteers (2 female, 5 male) aged 25–32. One dropped out (gender not stated) = 6 analysed	Venous blood taken fasting, 15, 30, 45, 60, 120, 150 & 180 mins. Plasma glucose measured by glucose oxidase method.	Glucose drink (50 g glucose) in 200 mL, vs same drink with pectin added, stirred, left to form gel.	14.5 g NF pure, HP Bulmer Ltd Hereford) AE: Glucose drink with pectin induced vomiting in one subject, the dropout	Glucose: significantly lower mean peak during first hour after pectin (p <0.025). No other significant differences.
Jenkins 1978 England	Cross-over	To test various fibres to see if viscosity correlates with glucose tolerance.	6 healthy volunteers drawn from pool of 11 (10 male, 1 female) aged 20–40.	Venous blood taken fasting, 15, 30, 45, 60, 90 & 120 mins. Glucose and insulin methods not given.	Glucose drink (50 g glucose, 40 g lactulose & xylose, 40 g lemon juice) in 400 mL vs same drink with pectin added	14.5 g Hercules Powder Company Ltd. AE: not reported	Glucose: significantly lower glucose after pectin at 15 mins only (p<0.05). No other sig differences. Insulin: significantly lower insulin after pectin at 15 mins only (p<0.02). No other significant differences.

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Reference & study location	Study design*	Objectives	Participants & sample size	Methods	Interventions	Pectin dose, pectin source, & reported adverse effects (AE) from pectin	Statistically significant results reported by authors
Sandhu 1987 USA	Cross-over	To (a) re-examine the effects of pectin on gastric emptying of both a liquid and a solid meal in normal human subjects and (b) to clarify the possible mechanisms of action of pectin by observing its effects on gastroduodenal motility, blood levels of glucose, and release of insulin and glucagon after the meals.	6 healthy non-obese males aged 26–44	Venous blood taken fasting, 15, 30, 45, 60 & 90 mins after liquid meal. Venous blood taken fasting, 15, 30, 45, 60, 90, 120, 150 & 180 mins after solid meal. Plasma glucose measured by oxidase method and insulin measured by radio-immunoassay.	Liquid meal: 400 mL of 10% glucose with 1 mCi of ^{99m} Tc-dithiopropylthiamine, vs same with pectin added. Solid meal: two slices white bread, one fried egg with 1 mCi ^{99m} Tc-dithiopropylthiamine and 100 mL water vs same with pectin added to egg sandwich.	15 g Pectin powder source not stated. AE: not reported	Glucose: no effect after either liquid or solid meal (neither numerical nor graphical results given). Insulin: Liquid meal: significantly lower at 15, 30 and 45 mins (p<0.05). Solid meal: no significant effect (results not shown).
Sahi 1985 India (linked to Siddhu 1989, 1990 & 1991)	Cross-over	To investigate the effect of “isolated nutrients” on glycaemic response	5 healthy male volunteers aged 19–42	Blood taken fasting, 30, 60, 90 & 120 mins. Glucose measured by o-toluidine method and insulin by double antibody radio-immunoassay Graph labelled serum glucose	100 g glucose (no detail provided) vs same 100 g glucose with pectin added	20 g Source not stated in paper. However, see Siddhu 1989 who refer to Sahi 1985 as their previous study that used the same source of pectin. AE: not reported	Glucose: significantly lower at two hours only (p<0.05). AUC significantly lower. Insulin: no significant differences
Siddhu 1989 India (linked to Sahi 1985)	Cross-over	To explore the effect of pectin, singly or in combination with macronutrients, on postprandial glycaemia and insulinaemia.	5 healthy male volunteers aged 19–21	Blood taken fasting, 30, 60, 90 & 120 mins. Serum glucose measured by o-toluidine method and insulin measured by double antibody radio-immunoassay.	400 mL drink containing 100 g glucose vs same drink with pectin added	20 g SISCO Research Laboratories, Bombay. AE: not reported	Glucose: No significant differences. Insulin: No significant differences.

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Reference & study location	Study design*	Objectives	Participants & sample size	Methods	Interventions	Pectin dose, pectin source, & reported adverse effects (AE) from pectin	Statistically significant results reported by authors
Siddhu 1990 India (linked to Sahi 1985)	Cross-over	To examine the effect of casein on postprandial glycaemia when ingested with glucose alone or in combination with corn oil, cellulose or pectin.	10 healthy male volunteers aged 18–42 in two sets: five in isocarbohydrate set and five in isocaloric set	Blood taken fasting, 30, 60, 90 & 120 mins. Serum glucose measured by 0-toluidine method and insulin measured by double antibody radio-immunoassay.	Isocarbohydrate: 400 mL drink containing 100 g glucose & 20 g casein vs same with pectin added. Isocaloric: 400 mL drink containing 60 g glucose & 40 g casein vs same with pectin added.	20 g As per Siddhu 1989 AE: not reported	Glucose (Isocarbohydrate): Significantly lower with pectin than control at 60 min (p<0.05) and at 90 min (p<0.01) Glucose (Isocaloric): Significantly lower with pectin than control at 30 min (p not stated). Insulin (Isocaloric): Significantly lower with pectin than control at 30 min (p not stated).
Siddhu 1991 India (linked to Sahi 1985)	Cross-over	To examine the effect of corn oil on postprandial glycaemia and insulinaemia when ingested with glucose, casein, cellulose and pectin in various combinations	6 healthy male volunteers aged 19–21	Blood taken fasting, 30, 60, 90 & 120 mins. Serum glucose measured by o-toluidine method and insulin measured by double antibody radioimmunoassay.	Fat test: 400 mL drink containing 60 g glucose & 18 g corn oil vs same with pectin added. Fat & protein test: 400 mL drink containing 60 g glucose & 9 g corn oil & 20 g casein vs same with pectin added.	20 g As per Siddhu 1989 AE: not reported	Glucose (fat): Significantly lower than control at 60 min (p<0.05) Glucose (fat & protein): Significantly lower than control at 60 & 90 min. Insulin (fat): Significantly lower than control at 90 & 120 mins (p<0.05) Insulin (fat & protein): Significantly lower than control at 30, 60 & 90 min (p<0.05)
Ranganathan 1994 France	Cross-over	To evaluate the acute effect of ingesting 50 g glucose with a resistant starch (lintner), cellulose or pectin on energy expenditure, colonic fermentation, blood	6 healthy males aged 22–26	Blood taken fasting and every 30 minutes for 6 hours. Blood glucose determined by the glucose oxidase method.	50 g glucose in 20% solution vs same glucose drink with pectin added	30 g (pectin 66–70% methylation) AE: not reported	Glucose: No significant differences. Insulin: significantly lower insulin after pectin for first 90 minutes (p<0.05)

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Reference & study location	Study design*	Objectives	Participants & sample size	Methods	Interventions	Pectin dose, pectin source, & reported adverse effects (AE) from pectin	Statistically significant results reported by authors
		glucose, insulin and free fatty acid concentrations.					
Jones 2015 Location not provided N.B. Abstract only at time of writing	Cross-over	To examine the effects of soy pectin on blood glucose and insulin responses.	15 healthy men	Finger-stick blood samples taken fasting at -15mins and time 0, then 15, 30, 45, 60, 75, 90, 120 & 180 mins. Plasma glucose measured, method not described	Control solution (detail not provided) vs same with added soy pectin.	Dose not stated. Unclear if intervention used soybean seed coats or soy pectin.	Glucose: No specific time interval was significantly different. Mean iAUC ~13.2% lower after pectin. Insulin: No specific time interval was significantly different.

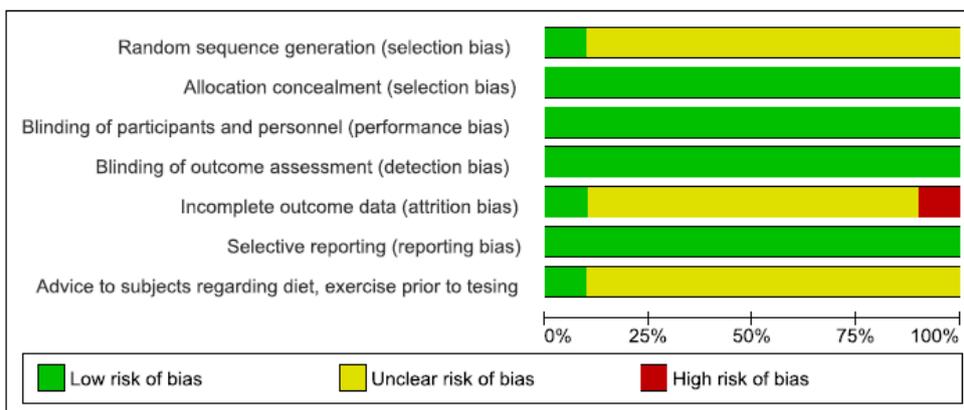
*Confounders: Studies were controlled by cross-over design. Confounding is unlikely because acute measurements were taken, giving no time for change in subjects' diet or behaviour. Wanders et al (2014a) specified being "blinded for subjects".

Most studies (including the abstract by Jones et al. (2015)) stated that they were conducted to test the effect of pectin (and possibly other fibres) on glycaemic response or glucose concentrations (Table 3). Some studies stated other objectives but included blood glucose concentrations in the outcomes they measured: Holt et al. (1979), Sanaka et al. (2007) and Sandhu et al. (1987) studied the effects of pectin on gastric emptying, whilst Wanders et al (2014a) studied effects on appetite and energy intake.

All studies used a cross-over design in which the same individuals receive both intervention and control substances. The difficulty of blinding in dietary trials is acknowledged. As pectin forms a gel, it is likely that subjects might be able to guess which product they were consuming even when the control phase contained identical foods except for the pectin. Blinding is important when participants have to comply with their allocated treatment over time. This would be less important in the current set of trials in which blood glucose was measured in the hours that immediately followed food consumption. Iftikhar et al (1994) state that their study was double-blind and describe an external group who developed the randomisation order. However the graph of results in Iftikhar et al (1994) did not have a legend and FSANZ had to assume that the legend on another graph in the same article also applied when extracting the data. Wanders et al (2014a) stated that their study had been blinded for subjects only, while all of the other authors failed to mention blinding in their study methods. Despite this, it is not likely to have confounded results for the reasons stated above, and therefore FSANZ assessed all studies as having low bias with respect to blinding.

Trials were only included if they lasted at least 90 minutes which is sufficient to see an acute postprandial effect. Because the outcome was measured over a short term in laboratory conditions (peaks in glucose occur in less than 2 hours after consuming digestible carbohydrates), this also limits any bias due to differences in subject compliance or other lifestyle factors that might arise in longer term studies. All studies, except the abstract of Jones et al. (2015), described drawing a venous sample and, therefore, were each rated as having a low risk of bias even though blinding of the phlebotomist was not described because this type of blood sampling is a more standardised technique than taking capillary blood using a fingerprick. As all studies appear to have tested plasma glucose concentrations, no corrections were needed in the analyses to account for the difference in glucose concentration in whole blood and plasma (Kuwa et al, 2001; Colagiuri et al, 2003), or depending on which glucometer was used (Taylor et al, 2016).

Only Wanders et al (2014a) describe giving dietary and exercise instructions to their subjects covering the two days prior to the test and they also provided a standardised meal to their subjects the night before the test. They do not mention whether they also gave instructions regarding physical activity during the test. Williams et al (1980) asked their subjects to follow their customary diet, but other authors do not mention giving subjects any instructions regarding diet, beyond restricting alcohol intake. Although all studies used a cross-over design, three studies do not describe the time interval between tests (Jenkins et al, 1977; Sandhu et al, 1987; Williams et al, 1980). One study states that tests were done on consecutive days (Villaume et al, 1988), one had an interval of at least two days (Jenkins et al, 1978) and the remainder refer to a week or at least a week between tests, except for Wanders et al (2014a) who used an interval of at least 12 days between tests. These details are important as the type of food eaten shortly before a glucose load test affects the results, as does engaging in heavy physical exertion.



	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Advice to subjects regarding diet, exercise prior to testing
Holt 1979	?	+	+	+	-	+	?
Iftikhar 1994	?	+	+	+	?	+	?
Jenkins 1977	?	+	+	+	?	+	?
Jenkins 1978	?	+	+	+	?	+	?
Sanaka 2007	?	+	+	+	?	+	?
Shimoyama 2007	?	+	+	+	?	+	?
Villaume 1988 Stratum A	?	+	+	+	?	+	?
Villaume 1988 Stratum B	?	+	+	+	?	+	?
Wanders 2014a	+	+	+	+	+	+	+
Williams 1980	?	+	+	+	?	+	?

Figure 2. Risk of bias analysis of included studies testing 1.4 to 14.5 g pectin/meal

Randomisation in trials is used to control for confounding. FSANZ included studies where authors stated that the trial had been randomised. All studies used a cross-over design which further reduces confounding between the intervention and control groups. Of the studies that were included in the meta-analysis, only two studies detailed the method of randomisation and it is unclear whether any of them had concealed allocation (Appendix 4). Despite this they were rated as low risk of bias for this component if there was no subject choice in the quantity consumed owing to the shortness of the test phase.

From the above, the methodological rigour and description of methods by Wanders et al. (2014a) mean that it is a much higher quality study than other studies testing the dose range of 10-14.5 g pectin. There were no such studies in the lower dose range.

2.3 Summary of evidence

2.3.1 Peak blood glucose concentration

All studies used a cross-over design. Nine studies (ten strata) were included in the meta-analysis of which five studies (six strata) were published before 1990. Most studies tested the subjects after an overnight fast except for Shimoyama et al. (2007) who had their subjects fast for eight hours after breakfast. Apart from Wanders et al (2014a), which analysed 29 subjects, the sample size of the studies ranged from 5–15 subjects. All studies except that of Williams et al. (1980), tested adults with normal baseline blood glucose concentrations.

Figure 3 shows the doses of pectin tested and the difference in peak blood glucose concentration between the pectin and control phases. The amount of carbohydrate given with the meals varied between 53-71 g for the studies which tested 1.4 – 5.2 g pectin (37 subjects) and 49-106 g for the studies which tested 10 -14.5 g pectin (62 subjects). Most of the carbohydrate appears to have been glucose or starch, although some studies also supplied foods such as marmalade or syrup which contains sucrose (a disaccharide that contains glucose and fructose) as part of their carbohydrate content. Fructose has little effect on blood glucose concentrations.

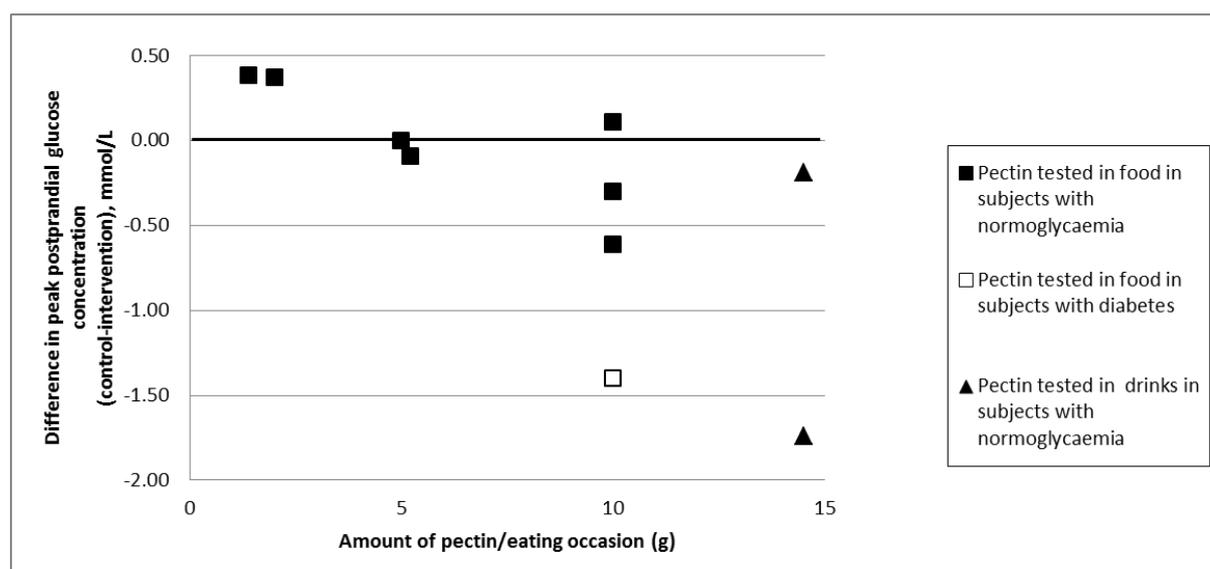


Figure 3. Scatterplot of the dose of pectin consumed and the difference in peak postprandial blood glucose concentrations compared to control

The seven studies that tested 1.4 – 10 g pectin with food (Ifftikhar et al, 1994; Jenkins et al. 1977; Sanaka et al. 2007; Shimoyama et al, 2007; Villaume et al. 1988; Wanders et al. 2014a; Williams et al. 1980) had similar results to each other at the lower doses of pectin but the results for 10 g pectin ranged from no effect to a favourable effect of nearly 2 mmol/L reduction in peak postprandial glucose concentration. Two studies tested 14.5 g pectin in a drink containing 50 g glucose in 12 adults (Holt et al. 1979; Jenkins et al. 1978) and had markedly different results from each other (Figure 3). The glucose drink used in the study with the smaller effect (Jenkins et al. 1978) also contained 40 g of lactulose and xylose and 40 g lemon juice in addition to the glucose.

The results were grouped into two dose groups for the meta-analysis which reflects the focus of the review to assess the effects in food rather than supplements. The results for two dose groups were significantly different ($p = 0.02$). In 37 individuals with normal glucose concentrations who were given 1.4 – 5.2 g pectin, there was a non-significant increase in peak postprandial blood glucose (0.22 mmol/L; (95% CI: -0.15, 0.58) compared to control food (Figure 4). There was no heterogeneity across the four studies ($I^2 = 0\%$).

By contrast, there was a significant decrease of 0.41 mmol/L in postprandial peak blood glucose concentration in the pectin group compared to the control group when 10-14.5 g pectin and 49–106 g carbohydrate was consumed by 62 subjects. There was moderate heterogeneity in this group ($I^2 = 57\%$) which reflects the variable results across the studies which ranged from an increase in blood glucose of 0.1 mmol/L to a decrease of 1.74 mmol/L. This analysis included the one study in seven subjects with non-insulin dependent diabetes mellitus (Williams et al (1980). As is evident in Figure 4, the confidence intervals for this study cover the span of the confidence intervals for all other studies at this dosage level and so no comment can be made about whether the presence of diabetes influences the effect of pectin. Excluding this study would have reduced the overall effect in the 10-14.5 g pectin group to -0.37 mmol/L (95%CI: -0.75, 0.00; $p=0.03$).

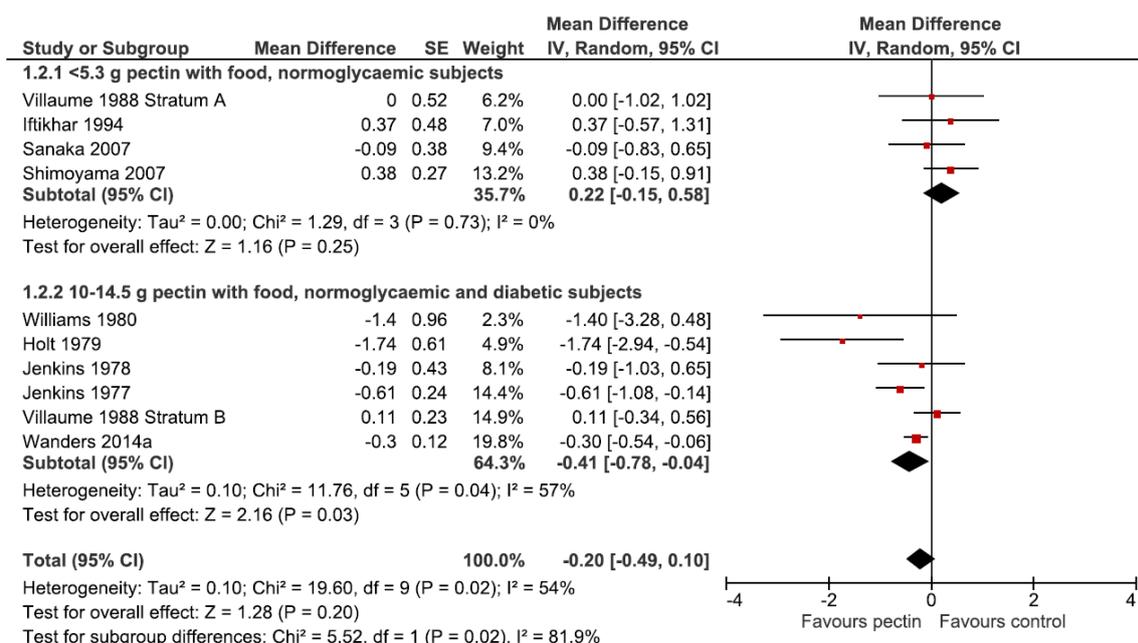


Figure 4. Forest plot of studies measuring peak blood glucose concentration in adults by dose of pectin in the meal or glucose drink

Wanders et al. (2014b) was deemed to be the only high quality study. When their results were excluded, the low quality studies testing 10-14.5 g pectin had a larger overall effect (-0.54 mmol/L; 95% CI: -1.12, 0.05; p=0.07).

Given the difference in the results between the two dose groups, FSANZ believes there is no justification to conclude that there was an effect across the whole range of 1.4–14.5 g pectin on peak postprandial blood glucose concentrations in adults based on the summary results presented in Figure 4. Although an *a priori* analysis by dose had been planned, the division into 1.4 – 5.2 g versus 10–14.5 g was *post-hoc*, having been informed by the scatterplot at Figure 3. FSANZ believes that the results of Wanders et al (2014a) using 10 g pectin, which found a significant decrease in mean blood glucose concentration of -0.30 mmol/L (95%CI: -0.54, -0.06) for the pectin compared to controls, come from the highest quality study but cannot be extrapolated to lower doses given that none of the studies using lower doses found an effect in favour of pectin.

2.3.2 Publication bias

Given the range of pectin doses tested and the amount and type of concurrently consumed carbohydrate, it is difficult to determine whether the asymmetry in the funnel plot for the larger standard errors reflects publication bias or the variability in the methods among the studies (Figure 5).

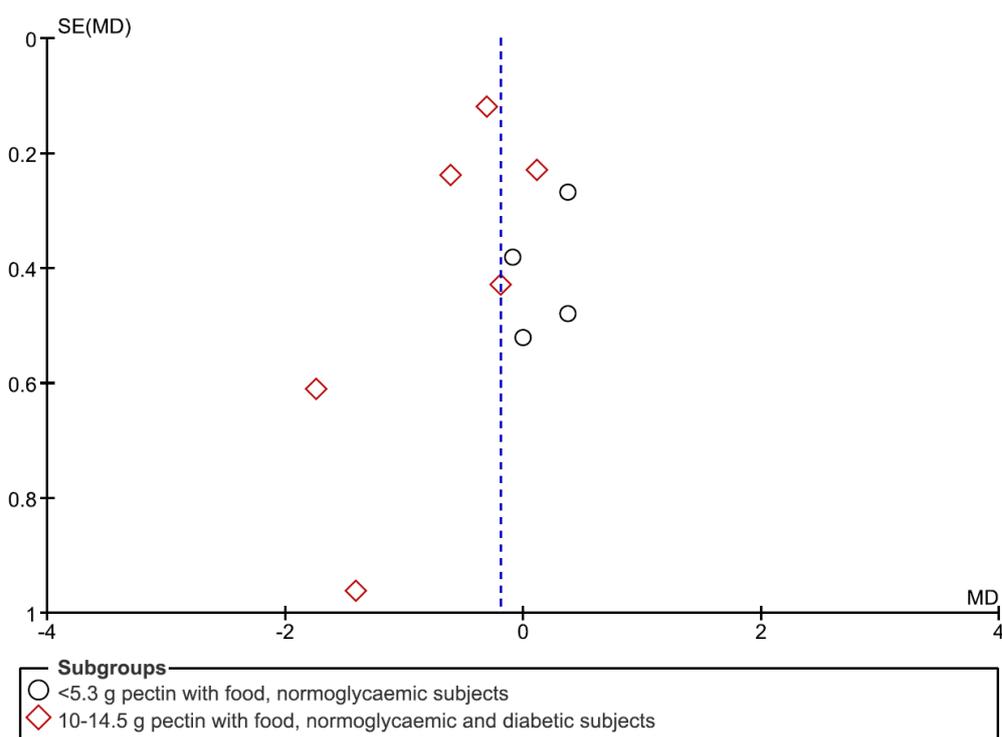


Figure 5. Funnel plot of effect sizes (MD: mean difference in mmol/L) versus standard errors (SE) around the mean effect on peak glucose (Positive numbers favour the control group)

2.3.3 Sensitivity analyses of postprandial blood glucose concentrations

One important assumption in the analysis of the 1.4 – 5.2 g pectin intake group was the direction of the effect in Iftikar et al (1994). As outlined in Appendix 3, the relevant graph did not have a legend and FSANZ assumed that it showed an increase of 0.37 mmol/L with pectin; however it is possible that the result was a decrease of 0.37 mmol/L. If this was,

indeed, the case, then the overall effect for the 1.4 -5.2 g pectin group in Figure 4 would be a non-significant increase of 0.10 mmol/L (95% CI: -0.26, 0.47) in peak postprandial blood glucose concentration after consuming pectin. This result would not alter FSANZ's conclusion that there is no effect at intakes of 1.4 - 5.2 g pectin.

For the dose range 10–14.5 g of pectin, the arm testing 10 g of CU 901 (food-grade) pectin in the Wanders et al (2014a) study was chosen for the meta-analysis. This arm of the trial in which the mean peak postprandial blood concentration was reduced by 0.3 mmol/L (95% CI: -0.54; -0.06) was chosen because the pectin is of a type that is most likely to be used in the commercial manufacturing of foods. Two other types of pectin were also tested in this study: the pharmaceutical-grade AU-201-USP which had a slightly greater effect (-0.4 mmol/L) and the SF 50-A-LV pectin which a slightly smaller effect (-0.2 mmol/L) when given in the food mix. If one of these arms had been chosen instead, then the overall result for the 10-14.5 g pectin intake group would have been -0.49 mmol/L 95% CI: -0.92, -0.06; p=0.02) and -0.38 mmol/L (95% CI: -0.76, -0.00; p = 0.05) respectively. Wanders et al (2014a) also tested the CU 901 (food-grade) pectin in capsules and in a liquid meal containing fruit juice and milk and these had different effects (increase of 0.2 and a decrease of 0.1 mmol/L respectively) compared to the control food meal.

In summary, although various decisions were made during data extraction, the choices described above would not have made a material difference to the results shown in Figure 4.

2.3.5 Postprandial blood insulin concentrations

As stated above, blood glucose concentration reduction by increased insulin excretion would be an adverse effect. Where data on insulin were presented, these were checked to ensure the insulin concentrations in the intervention group did not exceed those in the control group. Of the studies included in the meta-analysis, five (six strata) reported blood insulin concentrations (refer Table 3). Of these, three reported that insulin concentration was lower with pectin than control. In one study (Jenkins et al. 1978), insulin concentration was the same in both phases. Shimoyama et al (2007) reported that insulin was higher with pectin than control phases between 15 and 150 minutes.

3 Weight of evidence

Overall, the evidence base is limited for tests of 1.4–14.5 g pectin conducted in a total of 99 individuals. For a food-health relationship to be substantiated there has to be a consistency of effect across high quality studies. There were no high quality studies at the lower dose level for which no effect was observed. Only one high quality study was available in the body of evidence for the dose range of 10-14.5 g pectin where a reduction in peak postprandial concentration was observed. Thus, based on the current evidence, the relationship between pectin and reduction in peak postprandial glucose concentrations has not been established to a high degree of certainty for either dose range examined.

3.1 Assessment of body of evidence

3.1.1 Consistency

The results differed according to the dose of pectin tested. The four studies testing 1.4 – 5.2 g pectin showed a non-significant increase in peak postprandial blood glucose concentration which FSANZ therefore regards as showing no effect for this dose. There was no inconsistency among these four studies. By contrast, the overall reduction noted in the six

studies testing 10–14.5 g pectin had moderate inconsistency and reflects a wide variation in the results of the individual studies in the analysis.

3.1.2 Causality

Randomised controlled trials (RCTs) are a strong design for inferring causality. However the RCTs in the meta-analysis include only 99 adults. Furthermore, a variety of pectins were tested in a ten-fold range of doses in a variety of food vehicles, which contained varying amounts of available carbohydrate.

It was difficult to assess the indirectness of the evidence because the types of pectin used in the studies were not well-described by the authors. Consequently, it was unclear whether the pectin types used in the included studies are all relevant to those that naturally occur in foods and whether they were of the type that can exert an effect by, in principle, increasing the viscosity of gastrointestinal fluids. Publication bias was difficult to assess and imprecision was very serious. FSANZ considers that the overall small numbers and range of test conditions means that it is difficult to have any certainty in the results.

Based on the foregoing reasons, FSANZ concludes that a very low degree of certainty exists in the relationship between pectin and reduction in peak postprandial blood glucose concentration when 10–14.5 g pectin is consumed with 49-106 g carbohydrate (Appendix 5). However, these doses are unlikely to be achieved in a single serving of food (see Table 1). For the lower pectin intake amounts (1.4-5.2 g/meal), FSANZ concludes that there is no effect on peak postprandial glucose concentrations. However this conclusion is based on only 37 subjects and so future studies may report different results. FSANZ considers that there is very low certainty in the relationship for this dose range (Appendix 5). Causality is not established.

3.1.3 Plausibility

A plausible mechanism exists for high molecular weight pectin to lower blood glucose concentrations due to its viscoelastic properties, possibly through a combination of delayed gastric emptying, reducing macronutrient absorption and preventing diffusion of glucose through the lumen to the epithelium (Ou et al. 2001; Weickert and Pfeiffer 2008; reviewed in Lattimer and Haub 2010). Low molecular weight pectins do not gel to the same extent. Only Wanders et al. (2014a) adequately described the pectin studied and found similar results for high- and low-methoxyl (i.e. high and low molecular weight) pectin, when given in the same food but different results for low-methoxyl pectin when given in different foods. Furthermore, Maruyama et al. (2008) note that the REF-P1 pectin tested by Shimoyama et al. (2007) forms either a hard gel or a semi-solid in the stomach depending on stomach acidity. Consequently, it is unclear whether the type of pectin would be an important factor in future examination of the relationship, and whether the vehicle in which it is given affects the results.

FSANZ further notes that the studies administered between 49-106 g carbohydrate together with the pectin did not describe the sub-types of carbohydrate. There is insufficient data to determine whether any effect of pectin is dependent on the amount of glucose released from foods consumed at the same time.

3.2 Applicability to Australia and New Zealand

3.2.1 Intake required for effect

A specific focus of the review was to examine the effect at intakes that might be achievable in Australia and New Zealand. A wider range of intakes was included, but several studies with very large intake doses were excluded. The studies presented in the meta-analysis all used extracted food-grade or pharmaceutical-grade pectin in doses ranging from 1.4–14.5 g. No effect was seen in the four studies testing 1.4 – 5.2 g pectin in a meal

The amount of pectin found naturally in certain fruits (and some vegetables) is highly variable (Table 1). Even with a fruit serving size of 200 g, less than 5 g pectin would be consumed. Although pectin can be added to foods such as jams and low sugar spreads, the amount added is likely to be less than <0.2 g pectin per 15 g serving². When considering postprandial glucose rise, the relevant quantity is that which can be consumed in the eating occasion that causes the glucose rise, not the total daily intake. Therefore FSANZ concludes that the result for 1.4-5.2 g pectin, i.e. no effect (Figure 4), is the relevant result in the Australia and New Zealand context.

A further consideration is the amount and form of glucose that would need to be consumed at the same time as the pectin to generate any effect, if it exists, on reducing postprandial blood glucose concentration. The studies tested between 49-106 g carbohydrate but did not describe the components of the carbohydrate. Several studies described using breakfast cereals, syrups, marmalade or milk as part of their carbohydrate load but these contain components (fructose, galactose) that have little effect on raising blood glucose concentrations.

3.2.2 Target population

All studies but one (Williams et al. 1980) were carried out on healthy, normoglycaemic adults. Cultural differences are unlikely to be a factor, even though none of the published studies were conducted in New Zealand or Australia. Of the studies included in the meta-analysis, most were from Europe. No studies were found in children.

3.2.3 Extrapolation from supplements

All the studies tested purified pectin, but most did not describe the pectin used. As different pectins have different gelling properties, it is not clear which purified pectins reflect the properties of pectin naturally present in food. In addition, the results indicate that the dose of pectin is important. Owing to the absence of any studies testing pectin in the 5.3-9.9 g dose range, it is not possible to predict the nature of any dose-response curve.

3.2.4 Adverse effects

An abnormal increase in insulin secretion would be considered an adverse effect. All studies were examined to see if the insulin response (where reported) was disproportionate to the glucose response. Only one of the studies reporting insulin data found an increase in insulin in the pectin phase compared to control.

² <http://www.ingredientstop.co.nz/afawcs0153252/Recipes.html>

4 Conclusion

Although intake of 10–14.5 g pectin in a meal significantly reduced peak postprandial blood glucose concentration, FSANZ concludes that there is a very low degree of certainty in this relationship and believes such high doses of pectin cannot be obtained from foods eaten in Australia and New Zealand in a single meal.

The focus of this review was on lower intakes. FSANZ found no effect of consumption of 1.4 to 5.2 g pectin in a meal on peak postprandial blood glucose concentration in normoglycaemic adults. However, there is also a very low degree of certainty in this conclusion.

5 Acknowledgement

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Appendix 1: Search terms

The following search terms were used to identify studies for including in the review:

EMBASE – OVID platform

Timeframe searched: 1974 to 11/11/2015.

Search Strategy:

-
- 1 pectin/ or pectin\$.mp. or peptic polysaccharides.mp. (12046)
 - 2 glucose/ (314112)
 - 3 "disorders of carbohydrate metabolism"/ (2756)
 - 4 glucose intolerance/ (12904)
 - 5 glucose blood level/ (190177)
 - 6 glycosylation/ (29662)
 - 7 glycosylated hemoglobin/ (17595)
 - 8 diabetes mellitus/ (422380)
 - 9 impaired glucose tolerance/ (21342)
 - 10 insulin/ (275465)
 - 11 human insulin/ (4283)
 - 12 insulin resistance/ (90999)
 - 13 metabolic syndrome X/ (56815)
 - 14 hyperglycemia/ (69603)
 - 15 hypoglycemia/ (59697)
 - 16 glucose tolerance test/ (23712)
 - 17 or/2-16 (991371)
 - 18 glucose.tw. (462350)
 - 19 glycosylation.tw. (37186)
 - 20 "glycosylated haemoglobin a".tw. (35)
 - 21 "glycosylated hemoglobin a".tw. (131)
 - 22 "diabetes mellitus".tw. (191745)
 - 23 prediabetes.tw. (3847)
 - 24 insulin.tw. (373556)
 - 25 "metabolic syndrome x".tw. (212)
 - 26 hyperglycemia.tw. (44193)
 - 27 hyperglycaemia.tw. (10686)
 - 28 hypoglycemia.tw. (31732)
 - 29 hypoglycaemia.tw. (12565)
 - 30 "glucose tolerance test".tw. (21497)
 - 31 or/18-30 (852141)
 - 32 17 or 31 (1261731)
 - 33 1 and 32 (1102)
 - 34 randomized controlled trial.sh. (390829)
 - 35 controlled clinical trial.sh. (393413)
 - 36 (randomi?ed or placebo or randomly or trial or groups).ti,ab. (2833587)
 - 37 or/34-36 (2983607)
 - 38 33 and 37 (113)
 - 39 limit 38 to human (43)
 - 40 exp "disorders of carbohydrate metabolism"/ (849373)
 - 41 exp glycosylation/ (52045)
 - 42 exp diabetes mellitus/ (688628)
 - 43 exp hypoglycemia/ (61191)
 - 44 exp glucose tolerance test/ (47677)
 - 45 or/40-44 (908161)

- 46 1 and 45 and 37 (43)
- 47 limit 46 to human (25)
- 48 47 not 39 (3)
- 49 from 39 keep 1-43 (43)
- 50 from 48 keep 1-3 (3)

Cochrane CENTRAL

Searched 17 November 2015

- ID Search
- #1 MeSH descriptor: [Pectins] explode all trees
- #2 #1 or pectin* or pectic polysaccharide*
- #3 glucose or glucose metabolism disorders or glucose intolerance or blood glucose or plasma glucose or glycosylation or hemoglobin a, glycosylated or diabetes mellitus or prediabetes or insulin or insulin, regular, human or insulin resistance or metabolic syndrome X or hyperglycemia or hypoglycemia or glucose tolerance test
- #4 #2 and #3
- #5 MeSH descriptor: [Glucose] 1 tree(s) exploded
- #6 MeSH descriptor: [Glucose Metabolism Disorders] explode all trees
- #7 MeSH descriptor: [Glucose Intolerance] explode all trees
- #8 MeSH descriptor: [Blood Glucose] this term only
- #9 MeSH descriptor: [Glycosylation] explode all trees
- #10 MeSH descriptor: [Hemoglobin A, Glycosylated] this term only
- #11 MeSH descriptor: [Diabetes Mellitus] explode all trees
- #12 MeSH descriptor: [Insulin] explode all trees
- #13 MeSH descriptor: [Hyperglycemia] explode all trees
- #14 MeSH descriptor: [Glucose Tolerance Test] this term only
- #15 #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14
- #16 #2 and #15
- #17 #4 or #16
- #18 randomi*ed controlled trial or controlled clinical trial or randomi*ed or placebo or randomly or trial or groups
- #19 #17 and #18 in Trials

Medline – PubMed portal

Searched 17 November 2015

Query	Items found
#9 Search (#7 not #8)	70
#8 Search ((animals[MeSH Terms] NOT "humans"[MeSH Terms]))	4061492
#7 Search (#5 and #6)	97
#6 Search (("randomized controlled trial"[Publication Type] OR "controlled clinical trial"[Publication Type] OR randomi*ed[Title/Abstract] OR placebo[Title/Abstract] OR randomly[Title/Abstract] OR trial[Title/Abstract] OR groups[Title/Abstract]))	2185198
#5 Search (#1 and #4)	837

FOOD STANDARDS AUSTRALIA NEW ZEALAND — FOR OFFICIAL USE ONLY

#4	Search ((#2 or #3))	892079
#3	Search ((glucose[Text Word] OR "glucose metabolism disorders"[Text Word] OR "glucose intolerance"[Text Word] OR "blood glucose"[Text Word] OR "plasma glucose"[Text Word] OR glycosylation[Text Word] OR haemoglobin a, glycosylated[Text Word] OR hemoglobin a, glycosylated[Text Word] OR "diabetes mellitus"[Text Word] OR prediabetes[Text Word] OR insulin[Text Word] OR insulin, regular, human[Text Word] OR insulin resistance[Text Word] OR "metabolic syndrome X"[Text Word] OR hyperglycemia[Text Word] OR hyperglycaemia[Text Word] OR hypoglycemia[Text Word] OR hypoglycaemia[Text Word] OR "glucose tolerance test"[Text Word]))	892079
#2	Search (((glucose OR glucose metabolism disorders[MeSH Terms] OR glucose intolerance[MeSH Terms] OR blood glucose[MeSH Terms] OR plasma glucose[MeSH Terms] OR glycosylation[MeSH Terms] OR hemoglobin a, glycosylated[MeSH Terms] OR diabetes mellitus[MeSH Terms] OR prediabetes[MeSH Terms] OR insulin[MeSH Terms] OR insulin, regular, human[MeSH Terms] OR insulin resistance[MeSH Terms] OR metabolic syndrome X[MeSH Terms] OR hyperglycemia[MeSH Terms] OR hypoglycemia[MeSH Terms] OR glucose tolerance test[MeSH Terms])) AND ((pectins[MeSH Terms] OR pectin* OR pectic polysaccharides)))	790
#1	Search ((pectins[MeSH Terms] OR pectin* OR pectic polysaccharides))	10344

Appendix 2: Studies excluded at full text review

Reference	Reason
(Asp et al. 1981)	Intervention was a mix of soluble fibres, not pectin alone.
(Bell et al. 1990)	Intervention was a mix of soluble fibres, not pectin alone, plus control was inadequate.
(Di Lorenzo et al. 1988)	Did not measure postprandial blood glucose levels.
(Flourie et al. 1984)	Did not measure postprandial blood glucose levels.
(Gassull et al. 1976)	Intervention was a mix of soluble fibres, not pectin alone. This is a conference abstract of the same study published in full by Jenkins <i>et al</i> in 1976 (see below).
(Gold et al. 1980)	Did not state that the study was randomised.
(Jenkins et al. 1976)	Intervention was a mix of soluble fibres, not pectin alone.
(Kanter et al. 1980)	Intervention was a mix of soluble fibres, not pectin alone.
(Kasper et al. 1985)	Did not measure postprandial blood glucose levels.
(Lawaetz et al. 1983)	Was not randomised, plus four of the six subjects had dumping syndrome.
(Makarova et al. 2015)	Intervention was an apple powder preparation that was not pectin alone.
(Monnier et al. 1978)	Did not state that the study was randomised.
(Poynard et al. 1980)	Only reports postprandial blood glucose concentration at 60 and 90 minutes, without SEMs.
(Ravn-Haren et al. 2013)	Intervention was an apple pomace preparation that was not pectin alone.
(Schwab et al. 2006)	Only measured blood glucose concentration after long-term administration of pectin.
(Siddhu et al. 1992)	Article consolidates data already published in Siddhu <i>et al</i> (1989, 1990 & 1991) and discusses results in terms of glycaemic indices and insulinaemic indices only. No additional postprandial blood glucose measures following pectin interventions are provided in this paper.
(Sirtori et al. 2012)	Only measured blood glucose concentration after long-term administration of pectin.
(Tiwary et al. 1997)	Did not measure postprandial blood glucose levels.
(Wanders et al. 2012)	This is a conference abstract of the included study (Wanders et al. 2014a).
(Wanders et al. 2014b)	Did not measure postprandial blood glucose levels.
(Wolfram et al. 2002)	Long-term intake of prickly pear pulp (not pectin alone).

Appendix 3: Decisions made during data abstraction and analysis

First author, year	Decision and reason
Iftikar, 1994	Figure 2 showing the graphical results did not have a legend although it showed a difference of 0.37 mmol/L between the pectin and control groups. The text did not provide any indication of which way the effect went. The legend shown for Figure 1 was used to decide that the pectin phase had a higher peak glucose concentration than the control phase.
Shimoyama, 2007	<p>Although the pectin used was described as having small amounts of protein, fat and some electrolytes, these quantities were within the purity specifications for pectin. All the other studies also used purified pectins. Therefore the study was included.</p> <p>The vertical axis of the graph showed units of $\mu\text{U mL}^{-1}$ for glucose concentration whereas the text stated that the units were $\mu\text{M mL}^{-1}$. No response was received from the authors in response to an email querying this. Given the numerical values, and that results for a water control in normoglycaemic subjects was also shown, FSANZ decided that the units were mg/dL.</p>
Villaume, 1988 Flourie, 1985	It was not clear whether the error bar given was a standard deviation or standard error. After comparison with other trial results, it was deemed to be a standard deviation.
Wanders, 2014a	One of these was H & F Classic 201-USP, a pharmaceutical-grade product (http://www.herbstreith-fox.de/fileadmin/tmpl/pdf/broschueren/The_Specialists_for_Pectin_09.pdf) referred to as 'viscous' by Wanders. USP pectin is a pure pectin that has not had sugar and possibly buffer salts added to it to standardise its gelling properties (http://www.pharmacopeia.cn/v29240/usp29nf24s0_m61250.html , accessed September 2015) and so would have batch-to-batch variation if used as a food ingredient. Consequently it is not clear whether the lack of standardisation mean that the results in this arm of the trial would reflect the effect of the equivalent food-grade pectin used to set jam. The second pectin was Herbapekt SF 50-A-LV and a general food grade-grade pectin CU901 referred to as 'bulking' and 'gelled' respectively by the authors. The bulking pectin can be used in foods such as instant beverage powders in large quantities without affecting the texture, owing to its low viscosity (http://www.herbstreith-fox.de/fileadmin/tmpl/pdf/awtinfo/AWT_Cholesterol_and_the_Power_of_Pectin.pdf) FSANZ chose the CU901 arm (i.e. food-grade pectin) for the main analysis.
Williams, 1980	This study had two parts. The first part had results for seven subjects while the second had results from a subsequent pectin intervention conducted on a subset of four subjects. FSANZ used the results of the larger set only (see section 2.1.4.

Appendix 4: Risk of bias table for studies in the meta-analysis

Reference	Random sequence generation (selection bias)		Allocation concealment (selection bias)*		Blinding of participants and personnel (performance bias)*		Blinding of outcome assessors (detection bias); type of blood sample drawn and analysed*		Incomplete outcome data (attrition bias)		Selective reporting (reporting bias)		Other (dietary and exercise instructions; testing interval in cross-over studies)
Shimoyama 2007	?	Method not stated	Low	Not described	Low	Placebo used but not known if the participants or personnel were blinded	Low	Not stated	?	Not stated	Low	Expected outcomes reported	Fasted at least 8 hours after breakfast; at least one week between tests
Iftikhar 1994	?	Method not stated	Low	Not described	Low	Double-blind, placebo-controlled	Low	Not stated	?	Not stated	Low	Expected outcomes reported	Overnight fast, no alcohol for 24 hours prior to test; interval between tests not stated
Villaume 1988	?	Method not stated	Low	Not described	Low	Not stated	Low	Not stated	?	Not stated	Low	Expected outcomes reported	Overnight fast; tests done on consecutive days
Sanaka 2007	?	Method not stated	Low	Not described	Low	Not stated	Low	Not stated	?	Not stated	Low	Expected outcomes reported	Overnight fast prior to tests; at least 1 week between tests
Wanders 2014a	Low	Williams Latin Square	Low	'Thirty unique orders were produced by	Low	'Blinded for subjects'	Low	Not stated	Low	1/30	Low	Expected outcomes reported	Sample size calculation provided; Dietary and exercise instructions for the two days

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Reference	Random sequence generation (selection bias)		Allocation concealment (selection bias)*		Blinding of participants and personnel (performance bias)*		Blinding of outcome assessors (detection bias); type of blood sample drawn and analysed*		Incomplete outcome data (attrition bias)		Selective reporting (reporting bias)		Other (dietary and exercise instructions; testing interval in cross-over studies)
				computer generated numbers and allocated by the date upon entering the study'									prior to the test given to subjects; standardised meal provided the night prior to testing; at least 12 days between tests; fasting
Jenkins 1977	?	Method not stated	Low	Not described	Low	Not stated	Low	Not stated	?	Not stated	Low	Expected outcomes reported	14 hour fast prior to tests
Holt 1979	?	Method not stated	Low	Not described	Low	Not stated	Low	Not stated	High	Attrition 1/8	Low	Expected outcomes reported	12 hour fast prior to tests; 1 week between tests
Jenkins 1978	?	Method not stated	Low	Not described	Low	Not stated	Low	Not stated	?	Not stated	Low	Expected outcomes reported	Overnight fast; tests at least 2 days apart

*Because the outcome is measured within hours of the test, and test foods are supplied, there is no opportunity for lack of blinding to affect adherence during the testing phase, studies which did not describe their methods clearly were considered to have low risk of bias for allocation concealment if they used a cross-over design, or low risk of performance bias if they used a cross-over design and there was no choice by subjects in the quantity consumed and low risk of detection bias if they collected a venous blood sample and was analysed using an autoanalyser or a point of care method that could not involve technician variation

Appendix 5: GRADE summary of findings table

Question: *Does pectin intake reduce peak postprandial blood glucose concentration?*

Source: FSANZ systematic review of evidence

Quality assessment of body of evidence							Participants		Mean effect estimate (mmol/L) [95% CI]	Quality (degree of certainty in relationship)
Number of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Considerations	Cross-over studies	Parallel studies		
No effect of 1.4 - 5.2 g pectin on peak postprandial blood glucose concentration										
4	RCTs	Low	None	Some ¹	Serious ²	Lack of description of important test criteria in all studies	37	0	0.22 [-0.15; 0.58]	⊕ Very low
Effect of 10 - 14.5 g pectin and peak postprandial blood glucose concentration – all studies										
5 (6 strata)	RCTs	Low	Serious ³	Some ¹	Serious ⁴	Lack of description of important test criteria in most studies	62	0	-0.41 [-0.78, -0.04]	⊕ Very Low
Effect of 10 - 14.5 g pectin and peak postprandial blood glucose concentration – high quality studies										
1	RCT	Low	N/A	Some ¹	Serious ⁴	The only study to describe allocation procedures and that subjects were given standardised meals prior to each test	29	0	-0.30 [-0.54, -0.06]	⊕ Very Low

¹ Some indirectness owing to variation in types of pectin used and whether they all relate to pectin found in food and whether vehicle affects the results.

² Down-rated owing to the small size of the overall population sample.

³ Down-rated owing to moderate heterogeneity (wide variation among individual study results).

⁴ Although the confidence intervals do not include the null value and exclude small effects, the number of participants was small and so the relationship was down-rated for serious imprecision.