British Journal of Nutrition (2002), **88**, Suppl. 3, S263–S271
DOI: 10.1079/BJN2002716

Pulses and lipaemia, short- and long-term effect: Potential in the prevention of cardiovascular disease

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Cardiovascular disease (CVD) is the leading cause of death in most developed countries. Most CVD deaths are preventable through life-style measures such as diet, exercise and avoidance of cigarette smoking. Decreased intake of saturated fat and cholesterol and increased intake of cholesterol-reducing foods, such as pulses, deserve a high priority for activities designed to prevent CVD. Epidemiological and observational studies indicate that habitual intakes of large amounts of dietary fibre or of vegetables are associated with significantly lower rates of CVD. Studies over four decades document the hypocholesterolaemic effect of pulses and soyabeans. We performed a meta-analysis of eleven clinical trials that examined the effects of pulses (not including soyabeans) on serum lipoproteins. Intake of non-soya pulses was associated with these changes: fasting serum cholesterol, −7·2 %, 95 % CI −5·8, −8·6 %; LDL–cholesterol, −6·2 %, 95 % CI −2·8, −9·5 %; HDL–cholesterol, +2·6 %, 95 % CI +6·3, −1·0 %; triacylglycerols, −16·6 %, 95 % CI −11·8 %, −21·5 %; and body weight, −0·9 %, 95 % CI +2·2 %, −4·1 %. The hypocholesterolaemic effects of pulses appear related, in estimated order of importance, to these factors: soluble dietary fibre, vegetable protein, oligosaccharides, isoflavones, phospholipids and fatty acids, saponins and other factors. Intake of pulses may also reduce risk for CVD by favourable effects on blood pressure, glycaemia and risk for diabetes, and risk for obesity. Overall, the available evidence indicates that regular consumption of pulses may have important protective effects on risk for CVD.

Pulses: Lipaemia: Cardiovascular diseases: Prevention

Introduction

Cardiovascular disease (CVD) is the leading cause of death in most developed countries. CVD accounts for 40·6 % of all deaths in the US, and ≥40 % of all deaths in most European countries (American Heart Association, 2000). Most CVD deaths are preventable through life-style measures such as diet, exercise and avoidance of cigarette smoking (Manson *et al.* 1992). For example, an estimated 37 % of heart attacks in all women are related to excessive body weight; obese women are at even higher risk, with 72 % of CHD being attributed to excess body weight (Willett *et al.* 1995). In addition, hypercholesterolaemia, a major risk factor for CHD (Manson *et al.* 1992), can be managed through dietary measures in an estimated 75 % of individuals (Anderson *et al.* 1990*a*). Thus, decreased intake of saturated fat and cholesterol and increased intake of cholesterol-reducing foods such as pulses should have a high priority for activities aimed at prevention of CVD.

Pulses, commonly defined as 'the edible seeds of leguminous plants cultivated for food, as peas, beans, lentils, etc.', are excellent food choices because of their health-promoting benefits (Messina, 1999). Important components are vegetable protein, complex carbohydrate, dietary fibre, vitamins, minerals and other components (oligosaccharides, isoflavones, phospholipids, antioxidants, etc.) (Anderson & Gustafson, 1988; Sgarbieri, 1989; Geil & Anderson, 1994). In addition to their nutritional value, pulses provide health benefits with respect to cardiovascular disease (Kushi *et al.* 1999), diabetes (Karlstrom *et al.* 1987), bone health (Alekel *et al.* 2000) and weight management (Anderson & Gustafson, 1988). The present paper will focus on the effects of intake of pulses on risk for CHD. Recently the health benefits of whole grains, implying cereal grains, have been recognized and the US Food and Drug Administration has approved a health claim indicating that whole grain use as part of a diet low in saturated fat and cholesterol may reduce risk for CHD (FDA Docket #99P-2209). Recent research indicates that the whole grain may deliver more nutrition and health benefits than the sum of its parts (Anderson *et al.* 2000*b*). Likewise, recent research indicates that the whole soyabean and the protein with intact

Abbreviations: CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; RR, relative risk.

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isoflavones may deliver more health benefits than the sum of the individual components separately (Anderson *et al.* 2000*c*). Most pulses are consumed as 'whole' products and whole pulses may deliver more nutrition and health benefits than the sum of their individual components. We will examine this hypothesis in the present paper.

Epidemiology: pulses and CHD

Habitual intakes of large amounts of dietary fibre or of vegetables are associated with significantly lower rates of CHD (Anderson *et al.* 2000*b*). The effects of intake of pulses on risk for CHD have not been rigorously assessed. In Puerto Rico, starch intake from pulses (beans and peas) was significantly and negatively correlated with risk for CHD (Garcia-Palmieri *et al.* 1980). In Hawaii, the intake of vegetable protein was significantly higher in men who did not develop symptomatic CHD (McGee *et al.* 1984). These observations are supported by our recent review, where vegetable intake was noted to have a negative association with CHD risk in eleven of eleven studies (Anderson *et al.* 2000*b*).

To assess quantitively the effects of plant foods on risk for CHD or CVD, we reviewed and tabulated reports that estimated the risk for CHD associated with intake of various foods or dietary fibre. These data are summarized in Table 1. The greatest protection appeared to be related to dietary fibre intake, with sixteen of seventeen studies reporting a negative association. Thus, intakes of larger amounts of dietary fibre appear to protect from CHD, compared to intakes of smaller amounts; these associations were statistically significant in fourteen of seventeen reports. All eleven reports assessing vegetable intake noted a negative association, with five of these associations being statistically significant. Using data from studies reporting relative risks with variance estimations, we used meta-analysis techniques to calculate the variance-adjusted relative risk (RR) and the 95 % confidence intervals. Dietary fibre intake was associated with the greatest reduction in risk for CHD, with a RR of 0·73. The risk ratio comparing the highest versus lowest intakes of vegetables in seven studies was 0·77, with 95 % CI 0·70, 0·86. Thus intakes of generous amounts of vegetables or of dietary fibre are associated with a 23–27 % reduction in estimated risk for CHD. Since vegetable intake or total dietary fibre intake may serve, in part, as surrogate measures for intake of pulses, these observations are suggestive (Anderson *et al.* 2000*b*).

A 'prudent diet', characterized by higher intakes of vegetables, fruits, pulses (dry beans), wholegrain cereals, fish and chicken, appears to be associated with a 30 % lower risk ($P=0{\cdot}0009$) for CHD in men than a diet with lower intakes of these foods (Hu *et al.* 2000*b*). In a similar manner, women who consume a prudent diet have a significantly lower risk for CHD than women who consume a more typical 'Western' diet (Hu *et al.* 2000*a*). Foods, such as pulses, that have a low glycaemic index compared to many refined grain products provide many health benefits (Jenkins *et al.* 1981; Wolever *et al.* 1987). Recent evidence indicates that diets lower in glycaemic index are associated with a significantly lower risk for development of CHD in women (Frost *et al.* 1999; Liu *et al.* 2000). Additional studies indicate that higher fibre intakes are associated with a significantly decreased risk for developing CHD (Ludwig *et al.* 1999). Thus, while there is not clear epidemiological data specifically documenting that intake of pulses is associated with decreased risk for CHD, the available evidence is strongly supportive of this hypothesis.

Cardioprotective components of pulses

The protein, fibre, starch, vitamins, minerals and other components of pulses (oligosaccharides, isoflavones, phospholipids, antioxidants, etc.) all probably contribute to the cardioprotective effects of pulses (Slavin *et al.* 1997; Anderson & Hanna, 1999*a*). While the effects of dietary fibre on serum lipoprotein levels have received the most attention, it is very likely that other components have an important effect on the cardioprotective effects of pulses. Many pulses are relatively good sources of folic acid and thiamine, vitamins that reduce serum homocysteine concentrations (Sathe *et al.* 1984). Since hyperhomocysteinaemia has been identified as an important risk factor for CHD, increased intake of these vitamins from pulses may reduce this risk (Boushey *et al.* 1995; Welch & Loscalzo, 1998). The minerals provided by pulses may reduce the risk for hypertension (Appel *et al.* 1997) and for stroke (Suter, 1999). The health effects of oligosaccharides are still under exploration, but increased intake of these compounds from pulses may act in several ways to reduce risk for CHD (Anderson & Hanna, 1999*a*). Some pulses,

Table 1. Epidemiological data linking plant foods to risk for coronary heart disease (modified from Anderson *et al.* 2000*b*)

	Qualitative review				Meta-analysis		
	Number of studies						
Category	Total	Protection	Significant protection	No. of studies	Risk ratio	LCI*	UCI†
Whole grains	7	6	5	4	0·74	0·64	0·84
Dietary fibre	17	16	14	6	0·73	0·65	0·83
Fruit	11	9	2	8	0·86	0·77	0·96
Vegetables	11	11	5	7	0·77	0·7	0·86

* Lower 95 % confidence interval.
† Upper 95 % confidence interval.

especially soyabeans, are important sources of isoflavones that have these important actions: improve serum lipoproteins (Anderson *et al.* 1995), antioxidant actions (Anderson *et al.* 1998; Miller *et al.* 2000), antithrombotic and antiplatelet aggregating effects, anti-inflammatory actions and promote vascular health (Anderson *et al.* 2000*c*). While not tested, it seems likely that small quantities of various components (vitamins, minerals, oligosaccharides, isoflavones and other phytochemicals) may have synergistic effects on reducing risk for CHD.

Effects of non-soya pulses on serum lipoproteins

While most of the serum lipoprotein effects of pulses have been attributed to dietary fibre (Anderson *et al.* 1999*a*), other components may make important contributions to their hypocholesterolaemic effects; these effects will be reviewed in the next section. About four decades ago, Groen and associates (1962) suggested that non-soya pulses contributed to the lower serum cholesterol levels noted in Trappist monks compared to values for Benedictine monks. Concurrently, Luyken and associates (1962) observed that consumption of 100 g of pulses (dry beans) daily decreased serum cholesterol concentrations significantly by 8·9 %. Grande and associates (1965) noted that 200 g of pulses daily decreased serum cholesterol values significantly by 9·4 %. Bingwen *et al.* (1981), in a study of subjects with very high serum cholesterol values, reported a significant 16·7 % reduction in values. For normocholesterolaemic subjects, Bingwen *et al.* noted a significant serum cholesterol reduction of 8·8 %. These historical studies, using an average of 107 g of pulses daily over an average study period of 14 weeks, noted significant reductions in serum cholesterol values that averaged 11 %. Subsequent clinical trials have further documented changes in serum cholesterol levels, with a median reduction of 9·7 % (Geil & Anderson, 1994). For the present paper we have performed a quantitative analysis of changes in serum lipoprotein levels from clinical trials reported in the past 20 years.

Description of clinical trials

Eleven clinical trials have reported the effects of intake of non-soya pulses on serum lipoproteins (Jenkins *et al.* 1983; Anderson *et al.* 1984, 1990*b*; Karlstrom *et al.* 1987; Nervi *et al.* 1989; Shutler *et al.* 1989; Cobiac *et al.* 1990; Mackay & Ball, 1992; Duane, 1997; Fruhbeck *et al.* 1997; Oosthuizen *et al.* 2000). This analysis does not include soyabeans and soya protein, which are reviewed elsewhere (Anderson *et al.* 1995). The characteristics of these different studies are summarized in Table 2. We will discuss briefly selected aspects of each study and assess how differences in preparation of pulses, study design and subject characteristics may have contributed to differences in outcomes. Our group has performed two metabolic ward studies evaluating the effects of intake of pulses on serum lipoproteins. Both studies used a fixed-sequence design with a 7 d control diet followed by a 21 d diet rich in pulses (dry beans). Subjects lost small but significant amounts of weight on each study. In the first study (Anderson *et al.* 1984) the intake of 115 g daily of cooked pulses (dry beans) was associated with a significant reduction in serum cholesterol and LDL–cholesterol values (Table 3). In the second study (Anderson *et al.* 1990*b*), subjects consumed an average of 69 g of canned pulses (dry beans) daily. Significant reductions in serum cholesterol and LDL–cholesterol were noted.

Cobiac and colleagues (1990) studied free-living subjects using a crossover design comparing intake of canned pulses (dry beans) to canned spaghetti. Subjects were encouraged to consume six cans of pulses weekly and most complied; one subject reported intake of 4·5 cans of pulses weekly. The intermittent use of pulses and possible over-reporting of the prescribed behaviour may have contributed to the failure to see a significant lipoprotein response in this study. Duane (1997) recruited nine men for a metabolic study of the effects of pulses (dry beans) on serum lipoproteins and biliary lipids. The intake of 120 g of different pulses was associated with significant decreases in serum cholesterol and LDL–cholesterol values.

Fruhbeck and colleagues (1997) performed a clinical trial of particular interest because they compared cooked field-bean flour with raw field-bean flour for healthy young men. This was a metabolically controlled diet that was weight maintaining throughout the 30 d period of study. The diets were well matched for nutrient and fibre intake. The control group and one test group had undesirably high serum cholesterol values (average values of

Table 2. Characteristics of studies

Study	Type of pulse	Preparation	Amount (g/d)*	Type study	Length (weeks)
Anderson *et al.* (1984)	Navy, pinto	Cooked	115	IP	3
Anderson *et al.* (1990*b*)	Pea beans	Canned	69	IP	3
Cobiac *et al.* (1990)	Pea beans	Baked	145	OP	4
Duane (1997)	Mixed	Baked	120	IP	6·5
Fruhbeck *et al.* (1997)	Field beans	Raw/cooked, flour	90	contr OP	4·4
Jenkins *et al.* (1983)	Chickpea, pinto, kidney, lentil	Cooked and canned	140	OP	16
Karlstrom *et al.* (1987)	Brown, white, chickpea, lentil	Dried, cooked	82·5–120	IP	3
Mackay & Ball (1992)	Mixed	Cooked	46	OP	6
Nervi *et al.* (1989)	Mixed	Cooked	120	contr OP	4·5
Oosthuizen *et al.* (2000)	Small white	Extruded	91·9	OP	4
Shutler *et al.* (1989)	Pea beans	Baked	150	OP	2

IP, in-patient; OP, outpatient; contr OP, controlled outpatient.
* Approximate weight on dry (uncooked) basis.

Table 3. Serum lipid and weight responses to intake of pulses

Reference	Date	Number of subjects	Cholesterol		LDL–cholesterol		HDL–cholesterol		Triacylglycerols		Body weight	
			Control value (mmol/l)	Change (%)	Control value (mmol/l)	Change (%)	Control value (mmol/l)	Change (%)	Control value (mmol/l)	Change (%)	Control value (kg)	Change (%)
Anderson *et al.*	1984	10	7·73	−18·50	5·71	−23·12	0·83	−12·05	2·63	−3·04	76·3	−1·31
Anderson *et al.*	1990*b*	24	7·63	−10·75	5·19	−9·44	1·08	−7·41	2·89	−15·22	77	−1·69
Cobiac *et al.*	1990	20	6·32	−0·47	4·63	−0·43	1·26	−3·17	1·25	0·80		
Duane	1997	9	5·27	−4·93	3·57	−8·68	0·84	−4·76	4·45	6·74		
Fruhbeck *et al.*	1997	10	5·81	−9·12	4·03	−9·43	1·02	15·69	1·67	−30·54	68·2	−3·67
Jenkins *et al.*	1983	7	6·95	−7·48	4·88	−6·97	0·97	6·19	3·03	−7·59	70	−2·86
Karlstrom *et al.*	1987	15	4·78	−1·26	3·20	0·63	0·87	−3·45	2·04	9·80	66·8	0·45
Mackay & Ball	1992	39	6·27	−0·80	4·19	0·00	1·15	10·43	1·52	−0·66	76·7	0·39
Nervi *et al.*	1989	20	4·19	−11·69	2·58	−14·73	1·16	−6·90	0·98	2·04	65	1·54
Oosthuizen *et al.*	2000	22	6·15	0·00	4·87	4·52	0·89	−5·62	1·58	10·76	86	−0·58
Shutler *et al.*	1989	11	5·02	−14·54	4·55	−12·09	1·04	10·58	1·31	−12·98		
Unweighted average			6·01	−6·92	4·31	−7·25	1·01	−0·04	2·12	−3·63	73·30	−0·97
Variance weighted average				−7·21		−6·16		2·61		−16·6		−0·93
Lower 95 % CI				−5·82		−2·79		6·31		−11·8		2·24
Upper 95 % CI				−8·6		−9·53		−1·02		−21·5		−4·09

5·36 mmol/l), while two test groups, the cooked bean flour and the raw bean flour, had hypercholesterolaemia (average values of 6·24 mmol/l). Raw and cooked bean flour had similar effects on serum cholesterol and LDL–cholesterol values but the raw bean flour was associated with slightly, but significantly, greater decreases in fasting serum triacylglycerols and VLDL–cholesterol values. The raw bean supplement, showing the greatest effects, was associated with these changes in fasting serum values: glucose, −10·3 %; cholesterol, −7·8 %; LDL–cholesterol, −8·0 %; HDL–cholesterol, +15·0 %; and triacylglycerols, −36·6 %. All of these changes differed significantly from baseline values ($P < 0·0001$) and differed from changes for the control group.

Jenkins and colleagues (1983) replaced starch in the diet of seven hyperlipidaemic patients with 140 g of pulses (dry beans) daily and observed their serum lipid responses over a 4-month period. Karlstrom and colleagues (1987) treated fifteen poorly controlled type 2 diabetic subjects for 3 weeks on a metabolic ward with pulses (dry beans). This was the only study that utilized diabetic subjects and the results are also confounded by the significant baseline hypertriacylglycerolaemia (average initial value of 4·25 mmol/l). The 50 % reduction in triacylglycerols may have affected lipoprotein estimations. Mackay & Ball (1992) examined the effects of diets enriched with pulses in free-living hypercholesterolaemic men and women. They provided only 80 g (cooked weight) or 56 g (estimated dry weight) of pulses (dry beans) daily; this small amount of pulses, coupled with the free-living status of their subjects, may have contributed to the failure to observe significant changes in serum cholesterol and LDL–cholesterol values.

Nervi *et al.* (1989) utilized a controlled metabolic diet to examine the effects of intake of pulses (dry beans) on serum lipoproteins and biliary lipids. These army servicemen ate the controlled diet 6 d/week and were allow free food intake on the seventh day. Oosthuizen and colleagues (2000) examined the effects of baked products, utilizing extruded pulses for free-living hyperlipidaemic men. Their failure to demonstrate serum lipoprotein changes may relate to the preparation of their food products. Shutler *et al.* (1989) examined the effects of canned pulses (dry beans) for free-living normocholesterolaemic male students over a 2-week period.

While the experimental designs of these studies differed greatly, we have included all of them in our analyses. The randomized, controlled studies should be given more weight than the fixed-sequence studies. The metabolic ward and controlled-diet ambulatory studies should be given more weight than the studies of free-living subjects. The one study of diabetic subjects with significant hypertriacylglycerolaemia may not be appropriate for inclusion with the other studies of non-diabetic subjects. However, to avoid bias, we have included all of these studies in our analyses.

Meta-analysis methods

We searched the literature for reports of clinical trials related to the effects of pulses on serum cholesterol levels in humans. We also used the ancestry approach to identify articles cited in research reports and review articles (Anderson *et al.* 1999*b*). After tabulating data, we calculated effect size, expressed as percentage change for each individual study, as described previously (Anderson *et al.* 1995). We calculated unadjusted percentage changes for each variable and then, using the fixed-effects model, we calculated variance-adjusted percentage changes as described previously (Anderson *et al.* 1995, 1999*b*).

Mean effect estimates

Changes in serum lipoprotein values and body weights in clinical trials using non-soya pulses are summarized in Table 3. Desirable serum cholesterol values for healthy individuals are below 5·2 mmol/l, values of 5·2–6·2 mmol/l are considered undesirably high, and values above 6·2 mmol/l are considered to be in the hypercholesterolaemic range (Sempos *et al.* 1993). In three studies, average serum cholesterol values were in the desirable range, in three studies average values were undesirably high and in five studies average values were in the hypercholesterolaemic range. For the entire group of eleven studies, the unweighted reduction in serum cholesterol with intake of pulses was 7·0 % The variance-weighted reduction was very similar, at 7·2 %. These reductions were statistically significant, with 95 % CI 5·8, 8·6 %. We did not analyse the small subgroups, but reductions appear similar across the entire range from initial average values of 4·2 mmol/l to 7·7 mmol/l.

Serum LDL–cholesterol values were reduced to a similar percentage as were serum cholesterol values. The variance-weighted reduction was 6·2 %, with 95 % CI 2·8, 9·5 %. Intake of pulses did not significantly affect serum HDL–cholesterol values. Fasting serum triacylglycerol values were significantly reduced by approximately 17 % with the variance-weighted analysis, but this may represent an overestimation of the effect since the unweighted reduction was only 4 %. Intake of pulses did not have a significant effect on body weight in this analysis, suggesting that weight changes did not significantly affect serum lipid changes.

These studies indicate that regular intake of non-soya pulses is associated with a significant reduction in fasting serum cholesterol and LDL–cholesterol values. Changes in HDL–cholesterol values were not significant. This analysis suggests that intake of pulses tends to decrease serum triacylglycerol values. Since a 7 % reduction in serum cholesterol values reduces estimated risk of CHD by 14–21 % (Manson *et al.* 1992), the habitual intake of pulses is likely to have a significant effect on risk for CHD. The epidemiological support for bean intake as a preventive measure for CHD is not as strong as that for wholegrain cereals (Anderson & Hanna, 1999*b*). The serum cholesterol changes associated with intake of pulses is similar in magnitude to those for oat bran (Ripsin *et al.* 1992), psyllium (Anderson *et al.* 2000*a*) and soya protein (Anderson *et al.* 1995) but there are fewer clinical trials. With several more controlled clinical trials, it seems likely that a health claim for pulses could be established in the US. This claim probably would follow the pattern: 'The daily intake of dry beans as part of a diet low in saturated fat and cholesterol may decrease risk for coronary heart disease'.

Mechanisms for the hypocholesterolaemic effects of pulses

The hypocholesterolaemic effects of pulses appear related, in estimated order of importance, to the following factors: soluble dietary fibre (Anderson, 1995; Brown *et al.* 1999); vegetable protein (Carroll, 1982; Vuksan *et al.* 1999); oligosaccharides (Anderson & Hanna, 1999*a*); isoflavones (Anderson *et al.* 2000*c*); phospholipids and fatty acids (Kirsten *et al.* 1993); phytosterols (Jones *et al.* 2000); saponins (Okubo *et al.* 1994; Milgate & Roberts, 1995; Duane, 1997) and other factors (Fruhbeck *et al.* 1997).

Soluble or viscous fibres have important hypocholesterolaemic effects (Anderson & Gustafson, 1988; Glore *et al.* 1994; Brown *et al.* 1999). Guar gum, extracted from the Indian cluster bean, is one of the most potent soluble fibres for reducing serum cholesterol and LDL–cholesterol levels (Todd *et al.* 1990). In assessing the cholesterol-lowering effects of a number of soluble fibres using human and animal models, we ranked guar gum second only to psyllium for its potency (Anderson *et al.* 1994; Arvill & Bodin, 1995); other fibres from pulses also have hypocholesterolaemic effects (Zavoral *et al.* 1983). The major effects of pulses and other soluble fibres on serum lipoproteins appear related in bile acid binding and decreased reabsorption of bile acids (Everson *et al.* 1992; Marlett *et al.* 1994; Duane, 1999). Fermentation of soluble fibres in the colon with production of short-chain fatty acids appears to contribute to decreased hepatic cholesterol synthesis (Wright *et al.* 1990). Alterations in serum insulin concentrations might also contribute to a lower serum cholesterol level (Jenkins *et al.* 1985).

Isoflavones from some pulses, such as soyabeans, have important and independent hypocholesterolaemic effects (Anderson *et al.* 1995). However, because many pulses have only low concentrations of these important phyto-oestrogens (Mazur, 1998), it seems unlikely that these compounds have a predominant role in the lipoprotein effects observed with the intake of commonly consumed pulses. Other components, such as phytosterols (Jones *et al.* 2000), saponins (Okubo *et al.* 1994) and phospholipids (Kirsten *et al.* 1993) might contribute, somewhat, to the lipoprotein effects.

Non-soya pulses (legume seeds) provide 1–3 % fat with approximately 40–50 % neutral lipids, 25–35 % phospholipids and 9 % glycolipids. Only 12–15 % of the fatty acids are saturated, 7–10 % are monounsaturated and polyunsaturated fatty acids predominate (Sathe *et al.* 1984). It is uncertain whether the favourable distribution of fatty acids would significantly affect serum lipoproteins, because of the low total fat content of pulses. However, phospholipids have fairly potent effects on serum lipoproteins and the phospholipids in pulses could contribute to the lipoprotein effects (Kirsten *et al.* 1993).

Effects of pulses on other CHD risk factors

Hypertension

Generous intake of dietary fibre or fruits and vegetables decreases blood pressure and may have preventive actions (Anderson *et al.* 1999*a*). While vegetarians have lower blood pressures than non-vegetarians, there are many dietary differences and often life-style differences between these groups. Increasing dietary fibre intake is usually associated with a decrease in blood pressure, but the mechanisms are unclear and multiple factors may contribute to the hypotensive effects of high-fibre foods (Anderson *et al.* 1999*a*). The 1997 Dietary Approaches to Stop Hypertension (DASH) clinical trial was a landmark study with respect to prevention and treatment of hypertension (Appel *et al.* 1997). The diet was rich in fruits, vegetables, pulses (dry beans) and wholegrain cereals. The DASH diet, rich in fibre, K and Mg, and poor in Na, was associated with an impressive and significant reduction in blood pressure (Appel *et al.* 1997). The sequel examined the effects of Na intake as part of the DASH diet; a low Na intake as part of the DASH diet decreased systolic blood pressure by 8·9 mmHg and diastolic blood pressure by 4·5 mmHg (Sacks *et al.* 2001). These studies support the suggestion that increased intake of pulses may have a beneficial effect on blood pressure.

Diabetes

Intake of pulses provides benefits in reducing risk for diabetes and in diabetes management. Pulses (dry beans) have a very low glycaemic index (Jenkins *et al.* 1988), indicating that after intake of pulses the blood glucose increase is much less than with most polysaccharide-rich foods. Low glycaemic index foods are associated with a lower risk for developing CHD (Liu *et al.* 1999), higher HDL–cholesterol values (Frost *et al.* 1999) and a lower risk for developing diabetes (Salmeron *et al.* 1997*a*,*b*; Seewi *et al.* 1999; Luo *et al.* 2000) than are high glycaemic index foods. Several studies suggest that the intake of pulses offers important benefits for management of diabetes (Dilawari *et al.* 1987; Luo *et al.* 2000).

Most of the research related specifically to pulses (dry beans) and glycaemic management has involved studies of the effects of intake of pulses on post-prandial blood glucose excursions. Jenkins and colleagues (1981) documented the beneficial effects of pulses on post-prandial blood glucose values. When the blood glucose response to the ingestion of 50 g of carbohydrate from pulses was compared to the response to equal amounts of carbohydrate from bread, pulses produced only 30–40 % the blood glucose response as bread (Jenkins *et al.* 1988). The dampening of the blood glucose response was similar in non-diabetic and diabetic volunteers and, also, when the pulses or bread were served alone or as part of a mixed meal. In addition, many studies have examined the effects of guar gum and other gums from pulses and reported short- and long-term benefits for diabetic individuals (Anderson *et al.* 2001) In aggregate, all of this research indicates that intake of pulses can offer an important benefit for blood glucose control for diabetic individuals.

Obesity

Pulses are excellent sources of dietary fibre (Anderson, 1990). For almost 30 years epidemiological data, observational studies, human experimental research and clinical trials have supported a role for dietary fibre in the development and management of obesity (Anderson & Bryant, 1986). For example, a recent observational study (Ludwig *et al.* 1999) reported that individuals with higher fibre intakes had significantly lower rates of obesity than individuals with lower fibre intakes. Experimental studies in man suggest that high fibre intakes compared to lower fibre intakes are associated with the following attributes: longer eating times because of the lower energy density of high-fibre foods (Weinsier *et al.* 1982; Heaton, 1993); delayed gastric emptying, leading to earlier sense of fullness (Krotkiewski, 1984; DiLorenzo *et al.* 1988); earlier satiety because of the gastric and intestinal bulking effects of fibre (Haber *et al.* 1977; Porikos & Hagamen, 1986; Blundell & Hill, 1987; Burley *et al.* 1987); decreased absorption of nutrients (Rigaud *et al.* 1987); and effects of short-chain fatty acids on hunger and satiety (Levine *et al.* 1989).

Clinical trials support the role of dietary fibre in the management of obesity but are not conclusive. Blinding of clinical trials using high-fibre foods has not been possible and placebo effects may have contributed to favourable outcomes. Since the early study of Mickelsen *et al.* (1979), demonstrating the weight-reducing benefits of high-fibre bread, many clinical studies have reported weight-loss benefits from increasing fibre intake (Anderson & Sieling, 1980; Duncan *et al.* 1983; Anderson, 1985; Rigaud *et al.* 1990). Other investigators have reported that fibre supplements assisted in weight loss and weight maintenance (Evans & Miller, 1975; Valle-Jones, 1980; Solum *et al.* 1987; Ryttig *et al.* 1989; Rigaud *et al.* 1990). Thus, the available data, while not conclusive, strongly indicate that dietary fibre may offer significant benefits in the clinical management of obesity. These data suggest that increased intake of pulses, rich in dietary fibre, may protect from development of obesity and be useful in weight management.

Conclusions

Pulses are excellent food choices because of their nutritional values and their cardioprotective effects. Emerging evidence indicates that regular intake of pulses, as part of a heart-healthy diet, significantly decreases risk for CVD. Over four decades of research indicates that intake of pulses decreases serum cholesterol values. Our meta-analysis of eleven clinical trials documents the significant effects on serum cholesterol and LDL–cholesterol. Intake of pulses decreases serum cholesterol or LDL–cholesterol by 7 % and serum triacylglycerols by more than 10 %. Pulses do not significantly affect serum HDL–cholesterol values. Although most pulses have lower isoflavone concentrations than soya, they affect serum lipoproteins in a similar fashion qualitatively and quantitatively. The mechanisms for the hypocholesterolaemic effects of pulses are still under investigation. It is likely that serum lipid changes result from a synergism between the following components: soluble and insoluble dietary fibre, vegetable protein, oligosaccharides, isoflavones, phospholipids, phytosterols, saponins and other factors. Bile acid binding and increased excretion of bile acids may play a prominent role in the hypocholesterolaemic effects of pulses. Intake of pulses, with their low glycaemic index and mineral content, has favourable effects on blood pressure, glycaemic regulation and weight management. The cardioprotective effects of pulses are thus multifactorial. The available evidence gives confidence in recommending regular intake of pulses to reduce risk for cardiovascular disease.

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