5 "Eat dry beans, split peas, lentils and soya regularly": a food-based dietary guideline

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Abstract

The objective of this paper is to review recent scientific evidence to support the food-based dietary guideline (FBDG): "Eat dry beans, split peas, lentils and soya regularly". In this review, legumes are synonymous with the term "pulses", while soy beans are classified as "oilseeds". The FBDG was originally introduced to address both under- and overnutrition in South Africa. The nutrient and non-nutrient content, results of recent epidemiological and intervention studies on health effects, recommended intakes and barriers to consumption are briefly reviewed. Legumes are rich and economical sources of good-quality protein, slow-release carbohydrates, dietary fibre (non-starch polysaccharides), various vitamins and minerals and non-nutritive components which may have several beneficial health effects. Pulses have a low energy, fat and sodium content. Therefore, legumes contribute to dietary adequacy, while protecting against noncommunicable diseases through many mechanisms. Evidence is presented that concerns about excessive flatulence from eating beans may be exaggerated, and that there is individual variation in response to different bean types. It is recommended that nutritionists should aggressively encourage consumers to consume more legumes. They should also be advised to evaluate different legume varieties to minimise undesirable symptoms. More research is needed to assess gastrointestinal responses between types of available and consumed legumes in South Africa. The FBDG should be tested in different population groups to determine how to maintain legumes as a traditional food. Increasing familiarity with legumes could help to increase the likelihood that they may be incorporated more regularly into the diet.

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Introduction

Legumes are plants with seed pods that split into two halves. These include alfalfa, clover, lupin, green beans, peas, peanuts, soy beans, dry beans, broad beans, chickpeas and lentils. According to the Food and Agriculture Organization of the United Nations,[1] pulses are a type of legume that are exclusively harvested for dry grain. Therefore, they exclude peanuts and soy beans, which are harvested for oil. Pulses are sometimes also referred to as grain legumes or pulse grains. The species *Phaseolus vulgaris* includes kidney, navy, haricot and pinto beans. While soy beans and peanuts are also leguminous plants, they differ from other legumes by having a much higher fat content, as well as from an agricultural perspective. Traditionally, they are seen as oilseed crops. Green beans and peas are also legumes, but are considered to be vegetable crops in agricultural terms.

Therefore, the legume family includes:

- Vegetable crops
- Oilseeds
- Sow crops (clover and alfalfa) and pulses (dry beans, split peas, chickpeas and lentils).[1]

Because the term "legume" was not well understood when the South African food-based dietary guidelines (FBDGs) were tested before publication in 2001, the formulated FBDG was "Eat dry beans, peas, lentils and soy regularly".[2] In this paper "legumes" refers to pulses and soy beans. The terms "soy" and "soy beans" are usually used in scientific literature, but consumers may be more familiar with "soya".

Background

This FBDG was introduced to improve the overall health of South Africans, as a result of the nutrient and non-nutrient content, to prevent malnutrition (including protein and micronutrient deficiencies), and noncommunicable lifestyle-related diseases (NCDs).[2] Pulses are economical sources of good-quality protein, and are rich in dietary fibre, generally low in fat and virtually free of saturated fatty acids. Soy beans provide significant levels of mono- and polyunsaturated fatty acids, including α-linolenic acid. Substituting dry beans, peas and lentils for food that is high in saturated fat or refined carbohydrates may lower the risk of type 2 diabetes and cardiovascular disease,[3,4] obesity[5] and cancer,[6-8] which are major NCDs in South Africa.[9] Dry beans elicit a low glycaemic response relative to other high carbohydrate-containing foods, because of their high fibre and high resistant starch content. This may be a contributing factor in the prevention or treatment of these health problems.[10] It has been proposed that several non-nutritive phytochemicals, such as phytates, saponins, isoflavones and oligosaccharides, may also have a role to play in cancer prevention.[11]

Darmadi-Blackberry et al[12] reported, in a longitudinal study of older people from different cultures, that every 20 g increase in daily legume intake reduced the risk of death by 8%, concluding that higher legume intake is the most protective dietary predictor of longevity. The results from the Greek European Prospective Investigation into Cancer and Nutrition (EPIC) study, which found that the Mediterranean diet was associated with 14% lower mortality and that high legume consumption contributed to almost 10% of the protective effect, support this relationship.[13] Finally, a comparison of nutrient and food group intake of dry bean and pea consumers in the 1999-2002 National Health and Nutritional Examination Survey (NHANES) showed that daily consumption of half a cup of beans or peas resulted in higher intakes of fibre, protein, folate, zinc, iron and magnesium, with lower intakes of saturated fat and total fat, therefore improving diet quality.[14] All these results support an FBDG for legume intake for South Africans.

The aim of this paper is to motivate for the FBDG by summarising recent research results on the health effects of legumes and comparing figures for intakes by South Africans and other populations, with recommendations from health organisations, as well as speculating on general reasons for non-compliance with recommended legume intakes.

Nutrient profile of legumes

Some of the major nutrients provided by cooked legumes are shown in Table I.[15] The protein content of most beans (uncooked) averages 20-25% according to weight, whereas the protein content of soy beans is approximately 36% according to weight.[15] In general, legumes provide adequate amounts of lysine and isoleucine, but some are deficient in sulphur-containing amino acids (methionine and cystine) and others in tryptophan (cowpeas and lentils).[16] Grains such as maize and wheat contain limited amounts of lysine and a combination of legumes and maize, the staple food of many South Africans,[9] improves the protein quality of their diet.[16] With regard to some soy protein products, the protein digestibility-corrected amino acid score, adopted by the World Health Organization and the US Food and Drug Administration to evaluate protein quality, is close to 1. This is the same score as that of casein and egg protein.[17]

The fat content of dried beans averages only 1% according to weight, with unsaturated fatty acids predominating.[15] Soy beans are richer sources of fat (~18-20% according to weight) and contain saturated, monounsaturated and polyunsaturated fatty acids; 15%, 23% and 58% of total fat, respectively.[15] The polyunsaturated fatty acids in soy beans are linoleic acid (18:2 n-6, 51% of total fat) and α-linolenic acid (18:3 n-3, 7%).[18] Although soy foods are relatively high in fat, they may still be lower in total fat than the foods that they frequently replace, such as meat and cheese. However, soy foods are lower in saturated fat and, as with all plant foods, contain no cholesterol.

Dry beans consist of approximately 70% carbohydrate. Starch (43-45%), non-starch polysaccharides or fibre (16 - 20%), α-galactosides [also known as oligosaccharides (stachyose, verbascose and raffinose) 3-5%] and sucrose (3-5%) are the major types of carbohydrate. Beans are an excellent source of fibre, as can be seen in Table I. Bean and soy fibre is roughly one third soluble and two thirds insoluble. Soy fibre measurably lowers the postprandial increase in serum glucose concentrations, but has only a modest effect on serum cholesterol concentrations.[19] Many soy foods, such as soy beans, soy nuts, soy flour, textured soy protein and tempeh, are rich in fibre. However, isolated soy protein does not include dietary fibre.[19]

Table I: Nutrient composition of sugar beans, chick peas, lentils and soy beans, expressed per 100 g cooked weight[15]

Nutrient	Sugar beans	Chick peas	Lentils	Soy beans
Total fat (g)	0.5	2.6	0.2	9.0
Saturated fat (g)	0.08	0.27	-	1.30
Monounsaturated fat (g)	0.06	0.58	-	1.98
Polyunsaturated fat (g)	0.41	1.16	-	5.06
Protein (g)	7.1	8.9	8.6	16.6
Carbohydrate (g)	19.5	20.8	13.7	4.8
Calcium (mg)	8.2	6.6	7.0	5.1
Magnesium (mg)	32	49	27	102
Potassium (mg)	55	48	27	86
Iron (mg)	368	291	270	515
Zinc (mg)	2.1	2.9	2.3	5.1
Thiamine (mg)	1.06	1.53	-	1.15
Niacin (mg)	0.12	0.12	0.08	0.16
Folate (µg)	0.04	0.06	0.07	0.29

Dry beans and soy beans are low in sodium, but are excellent sources of minerals, including calcium, copper, iron, magnesium, phosphorus, potassium and zinc.[15] The content and bioavailability in dry beans and soy foods varies according to the processing methods and phytate content.[20]

Dry beans and soy beans are good sources of water-soluble vitamins, especially thiamine, riboflavin, niacin and folate, but poor sources of fat-soluble vitamins and vitamin C.[15] In terms of meeting the dietary reference intakes[21] for adults, a one-cup serving of cooked dry beans can provide 44% of the recommended folate, 33% of thiamine, 14-16% of vitamin B_6, 8-10% of niacin and 14-16% of riboflavin.

Non-nutrient profile of legumes

Legumes contain a number of compounds that have potential health benefits, as well as some that can reduce the bioavailability of nutrients. These compounds include saponins, phytic acid, plant sterols, phenolic compounds, enzyme inhibitors and lectins. Isoflavones are nutritionally relevant only in soy beans.[22]

Saponins

Saponins in legumes are poorly absorbed by humans.[23] Saponins are surfactants and were initially thought to be harmful because of their strong haemolytic activity in vitro. However, Hassan et al[24] recently reported that there is no haemolytic activity from soy bean saponin-rich extracts in the concentrations that were investigated. Saponins may have anti-cancer properties, as discussed by Gurfinkel and Rao[25] and Kerwin.[26]

Phytic acid

Phytic acid (myoinositol hexaphosphate) is the main storage form of phosphorous in dry beans. Different forms of phytic acid exist, depending on the pH and metal ions present. Phytate is the calcium salt and phytin is the calcium-magnesium salt.[27] The amount of phytic acid in legumes varies between 0.4% and 2.06%. The consumption of food that is high in phytate influences zinc, calcium and iron bioavailability by forming insoluble mineral phytate complexes in the intestine. These effects are of concern for vegetarians and in developing countries, where cereal and grain products are consumed in large quantities.[28] However, phytate has antioxidant effects and may lower the risk of colon cancer.[22]

Phytosterols

Beta-sitosterol, campesterol and stigmasterol are the most common types of phytosterols in beans. Plant sterols are structurally similar to cholesterol, but the absorption of phytosterols is low relative to cholesterol (20-50%). Only approximately 5% of phytosterols are absorbed, and the remainder is excreted from the colon.[29,30] Bean sterols reduce plasma cholesterol in humans, possibly because of a reduction in cholesterol solubilisation into bile salt micelles, resulting in a reduction of cholesterol absorption.[30] Phytosterols may also have anticarcinogenic effects.[31]

Phenolic compounds

Various phenolic compounds are present in beans, especially ferulic acid, quercitin and kaemphenol. Although polyphenolics are generally poorly absorbed, beneficial effects have been found in humans after consumption of plant phenolics.[22]

Enzyme inhibitors and lectins

Alpha-mylase inhibitors are present in a variety of plants, but are particularly high in common beans. Cooking destroys most, if not all, the α-amylase inhibitor activity.[32] Proper cooking methods (preferably moist heat) also eliminate lectin activity. Lectins are large glycoprotein molecules that bind to glycoconjugates on cell membranes, leading to agglutination of red blood cells in vitro.[22] The lectin, by virtue of its ability to bind to glycoprotein receptors on the epithelial cells lining the intestinal mucosa, inhibits growth by interfering with the absorption of nutrients.[22]

In the past, trypsin and chemotrypsin (protease) inhibitors in legumes were considered to be antinutritional, because of observations that feeding animals raw beans caused growth suppression and stimulated pancreatic hypertrophy.[22] However, commonly employed cooking methods reduce trypsin inhibitor activity in beans by 80-95%. Based on animal studies, only 55-69% of the trypsin inhibitor activity must be destroyed to reduce pancreatic hypertrophy in susceptible animals.[33] Protease inhibitors, especially those that inhibit chymotrypsin (Bowman-Birk inhibitor), have been investigated in several model systems for their ability to suppress carcinogenesis.[34]

Isoflavones

Isoflavones are another group of phytochemicals in beans, but the soy bean is the only nutritionally relevant source of these compounds. The primary isoflavones in soy beans are genistein and diadzein, and their respective β-glycosides, genistin and diadzin. Smaller amounts of glycitein and its glycoside glycitin are present.[35] The isoflavones, which are strikingly similar in chemical structure to mammalian oestrogens, can bind to both α and β isoforms of oestrogen receptors (ERs). However, their binding affinity to ERβ is approximately 20 times higher than that of ERα.[36] ERα and ERβ have opposite effects on regulating gene expression and physiological functions. For example, oestrogenic compounds stimulate the proliferation of human breast cancer cells through binding with ERα, but suppress proliferation via ERβ.[37] Soy isoflavones have potent antioxidant properties[37] and are now being extracted and sold as supplements.

Public health problems addressed by the FBDG

From the discussion of the nutrient content of legumes, it is clear that their contribution of protein and micronutrients will help to address undernutrition. But the total composition of legumes also makes them an ideal food group to include in diets that aim to reduce the risk of chronic NCDs.

Atherosclerotic cardiovascular disease

Epidemiological studies have reported that legume consumption is significantly and inversely associated with cardiovascular disease risk.[3,38,39] In the NHANES 1 epidemiological follow-up study,[40] legume consumption of four times or more per week, compared to less than once a week, was associated with a 22% lower risk.

In the Japan Collaborative Cohort (JACC) study, the highest bean intake (4.5 servings a week) was associated with a 16% reduction in total cardiovascular disease risk and a 10% reduction in total mortality.[41] A meta-analysis of 23 trials, using soy isoflavones, revealed a low-density lipoprotein (LDL) cholesterol-lowering effect of 5%, independent of baseline cholesterol levels.[42] A more recent meta-analysis of 30 studies that contained 42 treatment arms (n = 2 913), with an average soy protein intake of 26.9 g in adults with normal or mild hypercholesterolaemia, resulted in lowering total and LDL cholesterol, equivalent to a 6% LDL reduction.[43]

Soy isoflavone extract supplements[44] and lupin kernel-enriched bread[45] also reduce systolic blood pressure. According to Jenkins et al,[46] the extrinsic potential of soy (e.g. displacing foods higher in saturated fat and cholesterol) and the intrinsic potential effect of soy in reducing LDL cholesterol are 3.6-6% and 4.3%, respectively. Therefore, the combined intrinsic and extrinsic effects of soy protein foods range from 7.9-10.3%. Anderson and Major[47] reported the results of a meta-analysis of 11 clinical intervention trials involving legumes other than soy beans. They found an overall 6.2% lowering of LDL cholesterol and a 22% lowering of triglycerides. Bazzano et al[48] also concluded that non-soy legume consumption has a significant beneficial effect on serum cholesterol levels. Despite the fact that, up to 2008, a food labelling health claim for soy proteins has been approved in nine countries, including South Africa,[49] since 1999, an assessment of 22 randomised trials by the Nutrition Committee of the American Heart Association, showed a slightly decreased LDL cholesterol (3%), but no effect on HDL cholesterol, triglycerides, lipoprotein(a) or blood pressure.[50] Therefore, some inconsistencies in the lipid-lowering functions of soy, especially the magnitude of the effects, still prevail. The contributing factors to these discrepancies are not fully understood, but the source of soy beans and processing procedures of the protein or isoflavones are believed to be important.[49]

In 2010, the Food Regulatory Issues Division of Agriculture and Agri-Food Canada commissioned a systematic literature review to assess the strength of evidence of a relationship between the consumption of pulses and cardiovascular disease.[51] A highly consistent effect on LDL cholesterol and total cholesterol was found, as well as a low consistency of effect on high-density lipoprotein (HDL) cholesterol and triglycerides. A moderate-strength association was reported, with changes in total cholesterol, and a low-strength association with other investigated parameters, including LDL cholesterol, HDL cholesterol, triglycerides, homocysteine and blood pressure.[51]

The proposed mechanisms for LDL cholesterol reduction by beans and soy beans have been reviewed by several authors.[3,38,52]The hypocholesterolaemic effects appear to relate, in estimated order of importance, to soluble dietary fibre, vegetable protein (amino acid composition or protein subunits or composite peptides), oligosaccharides, isoflavones, phospholipids, fatty acids and saponins. Furthermore, soy-based diets may have antioxidant and anti-inflammatory functions which contribute to the prevention of atherosclerosis.[39] The antioxidant properties of the polyphenol flavonoids have to be taken into consideration in cardiovascular health promotion. Small red beans, red kidney beans and pinto beans are in the United States Department of Agriculture (USDA) list of top antioxidant foods.[53]

Martin et al[54] reviewed the mechanisms of action and potential clinical applications of soy isoflavones in hypertension. Soy isoflavones relax vascular smooth muscle via a combination of mechanisms, including the potentiation of endothelial-dependent and endothelial-independent vasodilator systems and the inhibition of constrictor mechanisms.

Type 2 diabetes mellitus and blood glucose control

There is strong evidence to suggest that eating a variety of whole grain foods and legumes is beneficial in the prevention and management of diabetes.[55] However, most epidemiological studies do not separate the effect of wholegrain foods and legumes sufficiently, possibly because of the relatively low intake of leguminous foods in the studied populations. Legumes share several qualities with wholegrains, with the potential benefit of glycaemic control, including slow-release carbohydrate and high-fibre content. For example, the glycaemic index of kidney beans does not exceed 27 (glucose is 100), and those of lentils and chickpeas, 28 and 33, respectively.[56] Legumes alone lower haemoglobin A_{1c} or fructosamine.[57] Finally, the Shanghai Women's Health study revealed significant inverse associations between legume intake and the incidence of type 2 diabetes. The relative risk associated with soy beans alone was 0.53, and with other non-soy legumes, 0.76.[58]

Generally, lifestyle interventions which combine diet and increased physical activity, leading to weight loss, reduce the risk of diabetes in subjects with impaired glucose tolerance. It seems as if weight loss is a major driving force in reducing the incidence of diabetes. However, in the randomised controlled studies of Salas-Salvado et al,[59,60] diabetes incidence reduced by 52% in the absence of significant changes in body weight or physical activity. Based on the evidence from several prospective observational studies and randomised trials, these authors concluded that a diet that might prevent diabetes in healthy subjects, and contribute to glycaemic control in patients with established disease, should contain abundant fibre from wholegrain foods and fruits and vegetables, including pulses and nuts.

Obesity

Compared with glycaemia and dyslipidaemia, the anti-obesity effects of pulse grains are scarce. However, epidemiological studies have consistently found a relationship between pulse consumption and reduced risk of obesity.[61] A recent review[5] presented evidence that indicated reduced hunger and increased satiety two to four hours after pulse consumption. These authors also presented results from observational studies on pulse consumption and weight status, which consistently showed that individuals with lower body mass index consumed a greater amount of pulses as part of their usual diet. Marinangeli and Jones suggest[62] that pulse-derived fibres, trypsin inhibitors and lectins may reduce food intake by inducing satiety via prolonging cholecystokinin secretion, and that arginine and glutamine (major components of pulse proteins) may produce thermogenic effects. It has further been reported that the protein component of yellow peas suppresses short-term food intake and glycaemia.[63] Results of these studies should be interpreted with caution, because pulse consumption may be part of an overall healthy lifestyle.

Cancer

Although legumes are rich in a number of compounds that could potentially reduce the risk of certain cancers, according to the panel of experts of the World Cancer Research Fund and American Institute for Cancer Research, the results of epidemiological studies are too inconsistent to draw any firm conclusions on legume intake and cancer risk in general.[6] However, fibre-containing foods were considered to be probable in reducing the risk of cancer in the colon and rectum, and since legumes are rich in fibre, it can be inferred that eating beans would probably reduce the risk of developing colon and rectal cancer. Data that link the consumption of legumes to a reduction of stomach and prostate cancer were considered to be limited, but suggestive. However, recent meta-analyses of epidemiological investigations suggest that soy consumption is associated with a reduction in prostate,[7] breast[64,65] and colorectal cancer risk in women, but not in men.[66] The expert panel did not include animal studies.[6] The Bean Institute[34] presents results from epidemiological investigations, as well as experimental studies, in animal models, to substantiate its opinion that eating beans may reduce cancer of the colon, prostate and breast, and possibly pancreas and oesophagus.

Actual legume intake compared to recommendations

Few health-related organisations make specific recommendations for legumes. The USDA MyPyramid includes legumes in the vegetable and "meat and beans" groups,[67] while the National Heart, Lung and Blood Institute's (NHLBI) Dietary Approaches to Stop Hypertension (DASH) eating plan,[68] Harvard's Healthy Eating Pyramid,[69] and Canada's Food Guide,[70] include legumes with the "meat and beans" groups. Downs and Willows[71] concluded that the grouping of animal products with legumes, nuts and seeds into a single category in Canada's Food Guide is a shortcoming. The Australian FBDGs classify legumes in the vegetables and fruit group, recommending five vegetable and legume servings per day, as well as two servings of fruit.[72] However, legumes and nuts are also included in the lean meat, poultry, fish and egg group.[72] Recently, the American Heart Association recommended at least four servings of nuts, legumes and seeds per week.[73]

Quantitative recommendations for legumes for 8 400-kJ diets are 50 g according to the NHLBI's DASH eating plan,[68] and 81 g one to three times per day according to the Harvard Healthy Eating Pyramid.[69] The USDA's MyPyramid[67] regards 60 ml of cooked, dry beans as the equivalent of 30 g of meat, poultry or fish, while the Australian FBDGs regard a serving of 120 ml of cooked beans to be the equivalent of one serving from the animal sources.[72]

Data from the most recent Spanish Food Consumption Survey showed that the consumption of legumes and pulses was 11.9 g per person per day.[74] Compared with respondents in Central England, those from a French Mediterranean region consumed beans and pulses significantly less frequently (48.8% once a week in the

French region versus 71.5% in the English region).[75] Compliance with the FBDGs of the Spanish Society of Community Nutrition revealed that 63% of the Catalan population did not meet the recommendation for pulses of 2-4 servings per week.[76] Data from the 1999-2000 NHANES showed that on any given day, only 7.9% of adult Americans consumed dry beans and peas[77] in quantities of 0.1-0.3 servings of legumes per day, which is one third or less than what is recommended.[77]

An investigation into food diversity in South Africa showed that legumes were one of the groups least consumed. The percentage of South Africans consuming legumes daily was reported to be 15.23%.[9] An average daily per capita pulse consumption of 35.66 g was estimated from secondary dietary data analyses.[78] The intake of nuts and oilseeds was reported separately (1.93 g per day). Therefore, the total legume intake, when adding oilseeds, was approximately 37 g per day.

In the Prospective Urban Rural Epidemiology (PURE) study, the daily intake of pulses was found to be 15.54 g for men and 12.36 g for women in the North West province, while consumption of soy bean products was 20.51 g and 21.40 g for men and women respectively (Wentzel-Viljoen, unpublished data). Furthermore, the mean daily intake of mixed dishes with beans, e.g. bean soup, was 22.81 g and 27.88 g for men and women, respectively. When adding the mean soy intake to the mean pulse intake, the average daily per capita consumption of legumes was approximately 34.91 g, excluding the mixed dishes with beans (Wentzel-Viljoen, unpublished data). This figure compares well with the estimated 37 g from secondary data analyses from previous South African studies,[78] suggesting that the legume intake of South Africans has remained constant over the past decade.

More recently, in a cross-sectional study on the diversity of the diet of the adult South African population, Labadarios et al[79] reported that 18% of all adults consumed legumes and nuts, and more in KwaZulu-Natal and the Eastern Cape than in Limpopo, where only 8% consumed legumes. More women than men, more tribal (23%) than urban formal (16%) respondents, more respondents in the older-age category than younger-age category, and more low living standards measure (LSM) (24%) than high LSM (15%) groups consumed legumes,[79] which is not surprising, given the low cost of pulse foods relative to animal protein sources.

The Food Habits in Later Life (FHILL) cohort study[12] identified the following mean daily intakes of legumes (pulses and soy) between 1988 and 1991: Japanese 85 ± 68 g, Swedes 21 ± 18 g, Anglo-Celts in Australia 14 ± 19 g, Greeks in Australia 86 ± 58 g and Greeks in Greece 63 ± 47 g.[12] The legume food group showed a 7-8% reduction in mortality hazard ratio for every 20 g increase in daily intake.[12] Much lower median legume intakes of 9.13 g (5.75-13.32) by Greek men and 6.66 g (3.62-10.52) by Greek women were observed in the Greek EPIC prospective cohort study between 1994 and 1997,[13] which may suggest that legume consumption is decreasing in Greece. Trends are very different from one country to another, as are traditional habits in terms of type of pulses consumed.[80] The USDA recommended that the amount of legume consumption[81] for most adults aged 19 years and older is three cups per week, with the exception of women aged 51 years and older, for whom the recommendation is 2.5 cups per week.[81] However, the weighted average legume intake in the USA, based on available studies up to 2009, was ~ 0.15 cups per day (36 ml).

Implementing the FBDG

Barriers to increased legume intake

Barriers to eating plant foods were investigated in an Australian study.[82] Taste, variety and environmental benefits were considered to be important. Main barriers included lack of knowledge and skills (not knowing how to prepare legumes), length of preparation time (soaking and cooking), flatulence, and lack of availability when eating out at work or in restaurant. Canned legumes were not considered to taste as good as dry legumes that are prepared at home.[82]

Flatulence

Most individuals can incorporate legumes into their diet, particularly if doing so is carried out gradually in order to lessen the discomfort of flatulence caused by the fermentation of the prebiotic oligosaccharides in the colon to short-chain fatty acids and gas.[83] This side-effect usually subsides when the beans become a regular part of the diet. Variety breeding and processing provide some opportunities to reduce α-galactosides, the major factor involved in flatulence, but the results of research have not yet provided sufficient satisfactory data.[83] Soaking cowpeas and yam beans for 12 hours and cooking for 30 minutes degrades malabsorbed oligosaccharides.[84] Furthermore, a recent randomised, double-blind, placebo-controlled, crossover study demonstrated that consumption of 100 g dry-weight Kabuli chickpeas, green Laird lentils and green peas for 28 consecutive days, compared with a potato control, were well tolerated, with negligible perceived changes in flatulence.[85] Windham and Hutchins[86] investigated the perception of increased flatulence in participants who consumed a half a cup of beans daily for eight weeks in randomised, controlled, crossover trials, with canned carrots as the control. Less than 50% reported increased flatulence from eating pinto or baked beans during the first week of each trial, but only 19% had a flatulence increase with black-eyed peas. A small percentage reported increased flatulence across these studies, even on control diets. The authors concluded that people's concerns about excessive flatulence from eating beans may be exaggerated, and that there is individual variation in response to different bean types.[88] Additionally, commercial products such as Beano® (AkPharma, Pleasontville, New Jersey), a digestive aid that contains α-galactosidase, are available so that individuals can eat beans without discomfort. However, the beneficial effects associated with oligosaccharide consumption are then diminished.

Unfamiliarity

Another barrier to legume consumption may be unfamiliarity with regard to the health promotion aspects. Simply increasing familiarity with legumes could help to increase the likelihood that they may be incorporated into a diet more regularly.

Long cooking time

Raw dried beans, peas and soy must be soaked and cooked for hours, resulting in expensive fuel consumption. Solutions to these preparation barriers are to use tinned products or the haybox principle. Lentils can be cooked for a shorter period than the bean varieties.

Soy milk allergy and concerns about isoflavones (oestrogens)

Although all food proteins have the potential to be allergenic for some people, eight foods have been identified as the most frequent human food allergens and account for ~ 90% of food allergies. These foods include soy, according to the Food and Agricultural Organization of the United Nations.[87] However, soy has a long history of successful use in managing cow's milk allergies in infants. Halpern et al[88] compared allergy in cow's milk protein-based formula-fed infants with soy allergy in soy protein-based formula-fed infants, and reported that food allergy was reduced 3.6-fold with soy. A meta-analysis of allergen reactivity patterns in high-risk infants showed soy allergy occurring in 3-4% of subjects versus 25% in those consuming cow's milk.[89] Cordle[90] indicated that soy proteins tend to be less immunologically reactive than many other food proteins. Furthermore, according to the American Academy of Pediatrics,[91] there is no convincing evidence that the use of soy products in infant feeding has any effect on the development of atopic disease. In response to the concern about oestrogens in soy milk and the safety thereof in children, Willet[92] pointed out that regular cow's milk contains many hormones, including oestrogens, and because the long-term effects of these hormones are not yet known, moderation in the diet of children is recommended (one to two glasses of soy milk a day).

Practical applications of dry beans and soy beans

In an Australian study, the benefits perceived by participants were that dry beans and soy beans were tasty and could be stored for long periods of time. They also found canned legumes to be convenient.[82] If the benefits of change outweighed the barriers, it is mostly likely that behavioural change would occur. Taste and visual appeal should be stressed when promoting them, rather than predominantly focusing on health. A strong practical emphasis is required. In-store cooking demonstrations and recipe cards may be useful.[82] A soy recipe book with instructions for various interesting soy dishes for South Africans has been developed by researchers at the Centre of Sustainable Livelihoods at the Vaal University of Technology.[93]

A guide to using dry beans and soy foods in practical ways is provided by Anderson et al.[94] Most consumers will be able to find ways of incorporating legumes into their daily diets. The heath advantages far outweigh the slight inconvenience involved in changing shopping habits and eating patterns.

Sustainability of pulse supply

Unlike in South Africa, dry beans are a staple in many countries around the world. However, the fact that meat and other protein products have become comparatively expensive has resulted in greater market opportunities for pulse production in sub-Saharan Africa. According to Akibode,[95] the global demand for legumes is expected to grow by 10% by 2020 and 23% by 2030, with a higher expected growth rate in sub-Saharan Africa. In South Africa, three types of beans are mainly produced, namely red speckled beans, which are most popular for preparation at home, small white canning beans and large white kidney beans.[96] The domestic consumption of dry beans in South Africa, which is approximately 2.5 kg per head or 105 000-110 000 tons per annum in total, far exceeds the domestic production of between 42 000 and 92 000 tonnes.[96] Beans are imported from China mainly, at an average of 75 000 tonnes per annum, to meet the ever-increasing demand for dry beans. South Africa exports approximately 25 000 tons of dry beans annually to neighbouring African countries. According to the Dry Bean Producers Organisation, there is great potential to expand plantings in South Africa.[96]

Trytsman et al[97] and the Dry Beans Producers Organisation[96] confirm the considerable diversity of legumes that are indigenous to South Africa. The *Phaseoleae* tribe is well presented, with 22 genera and 180 species.[97] The diverse growth forms and distribution patterns are useful in selecting and breeding legumes for specific agricultural applications.[97]

Conclusion and recommendations

This paper presents strong scientific evidence that demonstrates the nutritional value of legumes, and supports the positive effect of eating legumes to prevent and manage NCDs. Legumes are a valuable source of lysine-rich protein, complementing maize as the staple food of most South Africans. Drewnowski[98] recently reported that beans are among the top five classes of food that have the highest micronutrient to price ratio. Legumes have a particularly low glycaemic index. Benefits include that they are affordable and can easily be stored over a long period. Furthermore, legumes may be the solution to current consumer concerns about personal health, food quality and safety, and environmentally friendly crop production.

It is recommended that dietary interventions for disease prevention, as well as educational programmes for the general public, should specifically target legume consumption. Simply increasing familiarity with legumes could help to increase the likelihood that they may be incorporated into a diet more regularly. Lentils can be cooked more rapidly, offer considerable possibilities for cooking a range of dishes, and do not have the military image of canned beans in tomato sauce. Nutrient claims should be used on product labels for pulses and pulse-containing foods to promote them as a source of vitamins, minerals and fibre, as well as advance the knowledge that they are low in fat, and particularly in saturated and trans fat.

Influencing eating behaviour requires more than addressing nutrition knowledge and perceptions about healthy eating. Utilising social marketing and the media to change social norms, as well as upstream strategies by means of public policies and regulatory measures (e.g. the use of legumes in school feeding) are required. Further research is needed to determine existing patterns of legume consumption in South Africans, the sustainability of effects over the long term, the minimum effective intake, beneficial constituents and the effects of different legumes.

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