Legumes in human nutrition

Health aspects – part 2

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Abstract

Legumes (soybeans, faba beans and other types of beans, peas, lentils, sweet lupins and chick peas) are rich in protein, complex carbohydrates and fiber as well as minerals. They are an important component of healthy dietary patterns emphasizing plant foods. Intake in Western populations is rather low. This review presents findings from meta-analyses and some individual studies on their impact on metabolic parameters as well as on disease risks, namely risk of metabolic syndrome and associated disorders, of cardiovascular diseases as well as cancer. There are many studies on the effect of soybeans. Non-soy legumes also decreased in intervention trials LDL cholesterol and blood pressure and improved in part glycemic control. Their intake as well as adherence to a Mediterranean diet were associated with a lower risk of coronary heart disease and cardiovascular diseases. The Mediterranean and other healthy dietary patterns were associated with a lower risk of diabetes mellitus type 2. Whether intake of non-soy legumes affects cancer risk has little been examined up to now.

Keywords: legumes, plant protein, metabolism, health

Citation
Pfeuffer M, Erbersdobler H, Jahreis G: Legumes in human nutrition. Health aspects – part 2. Ernahrungs Umschau 2020; 67(10): 184–9.
This article is available online:
DOI: 10.4455/eu.2020.049

Peer-Reviewed
Manuscript (original contribution) received: January 02, 2020
Revision accepted: March 30, 2020

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The two-part review addresses the question of whether intake of legumes benefits human health. Special interest lies on the role of locally grown legumes. Studies on the role of soybeans/soy products on outcomes are given for comparison.
The first part of the article focused on ingredients of legumes and their impact on metabolic parameters. This second part of the article now represents legumes´ impact on metabolic disorders and risk of diseases.

Metabolic disorders and risk of diseases

Metabolic syndrome (MetS) and associated disorders

MetS is a clustering of at least three of the five following medical conditions: disturbed lipid metabolism (low HDL cholesterol, high fasting triglycerides), hypertension, overweight (most pronounced in the abdomen), and insulin resistance or type 2 diabetes mellitus (T2DM). The incidence of the MetS causes a disproportionately increased cardiovascular disease (CVD) risk [35].

Overweight/obesity

The number of obese people worldwide has almost doubled since 1980. Obesity has become a serious health problem in developed and also in many developing countries. In Germany 59% of men and 37% of women are overweight or even obese [3].
A potential benefit of legumes stems from their satiety effect. According to meta-analyses of intervention trials soy protein supplements [16] or soy protein combined with soy foods [36] did not change body weight (◆ Table 2 in part 1 of the review in Ernährungs Umschau 9/2020). Particularly in severely obese subjects (body mass index, BMI > 30) and with a daily dose > 40 g, body weight was even increased. Ethnicity (Caucasians compared with Asians) did not change the outcome [36].

According to another meta-analysis intake of non-soy legumes decreased body weight. The effect was more pronounced with weight loss diets (i.e. negative energy balance) [37]. A meta-analysis that assessed the role of kidney beans (Phaseolus vulgaris) found no significant weight loss, but a reduction of body fat [38] (◆ Table 2 in part 1 of the review in Ernährungs Umschau 9/2020). In a 12-week individual weight loss intervention study, a lupin flour-supplemented and thus protein- and fiber-enriched diet decreased body weight not significantly more than a high-carbohydrate control diet [19]. In another 3-month individual study, however, legumes (beans, lentils, chick peas) as part of a low glycemic index diet decreased body weight of persons with T2DM significantly more than a high wheat fiber diet [39].

Analysis of three large cohorts in the US, the Nurses' Health Study (NHS) I and II as well as the Health Professionals Follow-Up Study (HPFS) showed that increased intake of total vegetables, of vegetable with low glycemic index (including legumes) as well as soy/tofu was each inversely associated with the 4-year weight change, i.e. resulted in weight loss. The food group 'legumes' alone had no such effect [40]. In another US cohort of women with normal weight at the beginning of the study, higher intake of non-soy legumes was associated with a lower risk to become either overweight or obese during the 16-year observation period [41]. This study is included in a meta-analysis [42] (◆ Table 3).

Hypertension

About a third of the adult population in industrialized Western countries has high blood pressure [43]. According to a meta-analysis of intervention studies intake of soy protein as compared with various control diets decreased systolic and diastolic blood pressure. The effect was more pronounced in hypertensive as compared to normotensive subjects [44]. According to another meta-analysis soy protein decreased in persons with T2DM and MetS the diastolic, but not the systolic blood pressure [16] (◆ Table 2 in part 1 of the review in Ernährungs Umschau 9/2020).

According to a network meta-analysis legumes (in part soy products) did not change systolic and diastolic blood pressure as compared to other food groups [18]. According to another meta-analysis non-soy legumes decreased systolic blood pressure. There was only a nonsignificant trend for diastolic blood pressure [45] (◆ Table 2 in part 1 of the review in Ernährungs Umschau 9/2020). In a 12-week individual weight loss intervention study, the lupin flour-supplemented and thus protein- and fiber-enriched diet decreased systolic and diastolic blood pressure significantly more than a high-carbohydrate control diet [19].

A meta-analysis of cohort studies showed that increased intake of legumes was associated with a lower risk of hypertension. With 75 g legumes/day there was a 6% risk reduction [46] (◆ Table 3). In the three large longitudinal cohorts NHS I, NHS II und HPFS with > 20 years of follow-up, higher intake of the food group 'tofu or soybeans' was associated with lower risk of hypertension, yet higher intakes of the food groups 'peas or lima beans' and 'beans or lentils' were not [47].

Isoflavones contained in soy may contribute to the lowering of blood pressure [44, 47]. But also proteins (or thereof generated peptides) and fiber in soybeans and other legumes may confer such an effect [9, 19, 45], or their high potassium content [45].

Type 2 diabetes mellitus (T2DM)

The prevalence of T2DM is markedly increasing in many regions of the world, in developed as well as in developing countries. Two meta-analyses found that increased intake of soy products was associated with decreased risk of T2DM both in men and women [48] or only women [49] (◆ Table 3).

Another meta-analysis found no association between intake of legumes (soy products included) and T2DM risk [50]. Still another meta-analysis observed no association between intake of non-soy legumes and risk of T2DM. But this meta-analysis includes only two individual studies [51] (◆ Table 3). In a cohort in Spain (PREDIMED, *PREvención con DIeta MEDiterránea*) however, there was an inverse association between total non-soy legume intake ($p < 0.05$) as well as for lentils alone ($p = 0.05$) and T2DM risk [52].

Fatty liver

A nonalcoholic fatty liver, starting off with steatosis (i.e. with triglycerides accumulating within hepatocytes) is frequently the consequence of overweight and is accompanied by further conditions of the MetS [53]. When persons with T2DM consumed a high-protein diet with mainly plant (pea) proteins for 6 weeks, this improved parameters of glycemic control and decreased liver fat. Yet so did also the control diet with mainly animal proteins [54].

Stroke, coronary heart disease (CHD), cardiovascular disease (CVD)

Stroke

According to two meta-analyses intake of soy products was not associated with the risk of stroke [55, 56] (◆ Table 3). Four meta-analyses observed no association between intake of legumes and risk of stroke, regardless of whether soy products were included [57–59] or not [51] (◆ Table 3). There was also no association for non-soy legumes in the PURE cohort (PURE, Prospective Urban Rural Epidemiology), that included more than 135,000 individuals in 18 countries with a median follow-up of 7.4 years [60].

Coronary heart disease

Two meta-analyses found no association between intake of soy products and risk of CHD, as it was the case for stroke [55, 56] (◆ Table 3). But two meta-analyses observed an inverse association between intake of legumes including soy products and risk of

Authors	Food or Dietary patterns		Studies/Comparisons		Relative risk RR (95% CI)	Significance
			Type	n		
Overweight						
Schlesinger et al. 2019 [42]	LG incl. soy	food	C	2	0.88 (0.86–0.93)[a]	*
Hypertension						
Schwingshackl et al. 2017 [46]	LG incl. soy	food	C	6	0.92 (0.86–0.98)[a]	*
Type 2 Diabetes mellitus						
Li et al. 2018 [48]	soy	food	C	8	0.77 (0.66–0.91)[a]	*
Tian et al. 2017 [49]	soy	food	C	8	M + F 0.87 (0.74–1.01)[a]	n. s.
	soy	food	C	5	F 0.74 (0.59–0.93)[a]	*
Schwingshackl et al. 2017 [50]	LG incl. soy	food	C	12	0.96 (0.87–1.05)[a]	n. s.
Afshin et al. 2014 [51]	LG excl. soy	food	C	2	0.78 (0.50–1.24)[b]	n. s.
Jannasch et al. 2017 [74]	Mediterranean diet	food	C	6	0.87 (0.82–0.93)[a]	*
	DASH	food	C	5	0.81 (0.72–0.92)[a]	*
	AHEI	food	C	6	0.79 (0.69–0.90)[a]	*
Stroke						
Yan et al. 2017 [55]	soy	food	C	7	1.00 (0.88–1.14)[a]	n. s.
Lou et al. 2016 [56]	soy	food	C	3	0.92 (0.77–1.10)[a]	n. s.
Shi et al. 2014 [57]	LG incl. soy	food	C	8	0.95 (0.84–1.08)[a]	n. s.
Marventano et al. 2017 [58]	LG incl. soy	food	C	6	1.01 (0.89–1.14)[a]	n. s.
Bechthold et al. 2019 [59]	LG incl. soy	food	C	6	0.98 (0.88–1.10)[a]	n. s.
Afshin et al. 2014 [51]	LG excl. soy	food	C	6	0.98 (0.84–1.14)[b]	n. s.
Grosso et al. 2017 [75]	Mediterranean diet	food	C	5	0.76 (0.60–0.96)[a]	*
Coronary heart disease (CHD)						
Yan et al. 2017 [55]	soy	food	C	8	0.95 (0.82–1.10)[a]	n. s.
Lou et al. 2016 [56]	soy	food	C	5	0.97 (0.74–1.27)[a]	n. s.
Marventano et al. 2017 [58]	LG incl. soy	food	C	9	0.90 (0.84–0.97)[a]	*
Bechthold et al. 2019 [59]	LG incl. soy	food	C	10	0.91 (0.84–0.99)[a]	*
Afshin et al. 2014 [51]	LG excl. soy	food	C	5	0.86 (0.78–0.94)[b]	*
Grosso et al. 2017 [75]	Mediterranean diet	food	C	4	0.72 (0.60–0.86)[a]	*
Cardiovascular disease (CVD)						
Yan et al. 2017 [55]	soy	food	C	10	0.98 (0.89–1.08)[a]	n. s.
Marventano et al. 2017 [58]	LG incl. soy	food	C	14	0.94 (0.89–1.00)[a]	*
Li et al. 2017 [61]	LG incl. soy	food	C	6	death: 0.96 (0.86–1.06)[a]	n. s.
Grosso et al. 2017 [75]	Mediterranean diet	food	C	14	0.73 (0.66–0.80)[a]	*
Cancer						
Colorectal cancer						
Lu et al. 2017 [64]	soy	food	C	5	0.86 (0.72–1.03)[a]	n. s.
Zhu et al. 2015 [63]	soy	food	C	3	0.85 (0.73–0.99)[a]	*
	LG incl. soy	food	C	14	0.91 (0.84–0.98)[a]	*
	LG incl. soy	fiber	C	4	0.85 (0.72–1.00)[a]	0.05
Schwingshackl et al. 2018 [66]	LG incl. soy	food	C	11	0.99 (0.92–1.06)[a]	n. s.
Aune et al. 2011 [62]	LG incl. soy (?)	fiber	C	4	0.89 (0.78–1.02)[a]	n. s.
Vieira et al. 2017 [65]	LG incl. soy (?)	food	C	4	1.00 (0.95–1.06)[c]	n. s.

Prostate cancer						
Applegate et al. 2018 [67]	soy	food	C	7	0.90 (0.82–0.99)[a]	*
Li & Mao 2017 [68]	soy	food	C	5	0.89 (0.78–1.01)[a]	n. s.
	LG incl. soy	food	C	8	0.85 (0.75–0.96)[a]	*
	LG excl. soy	food	C	2	0.93 (0.84–1.03)[a]	n. s.
Breast cancer						
Wu et al. 2016 [70]	soy	food	C	10	0.92 (0.84–1.00)[a]	n/a
Chen et al. 2014[d] [71]	soy	food	C + CC	11	0.64 (0.49–0.80)[a]	*
		isoflavones	C + CC	30	0.74 (0.64–0.85)[a]	*
Stomach cancer						
Lu et al. 2017 [64]	soy	food	C	5	0.85 (0.72–0.99)[a]	*

Tab. 3: **Effect of legumes on risk of metabolic disorders or disease risks – meta-analyses of prospective cohort studies** (in one study mortality; in one study combined with case-control studies)
AHEI = Alternative Healthy Eating Index; C = cohort studies; CC = case-control studies; DASH = Dietary Approaches to Stop Hypertension; excl. = excluding; F = females; incl. = including; LG = legumes; n/a = no information given; n. s. = not significant; M = males; P = protein
[a] highest vs. lowest intake category
[b] per 100 g/week additional intake
[c] per 50 g/day additional intake
[d] Numbers for premenopausal women. Those for postmenopausal women are slightly different.
* level of significance $p < 0.05$ or lower

CHD [58, 59]. This was also the case for non-soy legumes [51] (◆ Table 3). In the PURE cohort there was no association between non-soy legume intake and myocardial infarctions [60].

Cardiovascular disease

Intake of soy products was not associated with the risk of CVD, as it was the case for stroke and CHD [55] (◆ Table 3). But there was an inverse association between intake of legumes including soy products and CVD risk [58]. Another meta-analysis found no association between intake and risk of CVD mortality [61] (◆ Table 3), but an inverse association between intake and risk of all-cause mortality [61]. In the PURE cohort there was only a nonsignificant trend towards less CVD events and cardiovascular deaths with increased non-soy legume intake [60].

A putative beneficial effect of soy intake on risk of CHD and CVD is in the first place attributed to its effect on blood lipids. In 1999 soy protein has been permitted by the FDA to carry a heart health claim based on its cholesterol-lowering ability. The claim is currently being reassessed (cited in [21]). But favorable changes in markers of inflammation, blood pressure, body weight and glycemic control may also contribute to health benefits of soy [2] as well as of non-soy legumes [28].

Cancer

The development of cancer is a complex, multifactorial and long-term process. This makes it particularly difficult to detect causal relationships. It is assumed that overweight and accompanying metabolic disorders are important promoting factors for cancer, as for CVD [3]. The most frequently occurring types of cancer are breast cancer (in women), prostate cancer (in men) and colorectal cancer. The World Cancer Research Foundation (WCRF) and the German Nutrition Society (*Deutsche Gesellschaft für Ernährung*, DGE) systematically update the literature on the association between nutrition and the risk of various types of cancer.

Legumes have a low glycemic index and are rich in fiber. Intake of fiber increases fecal mass, thus diluting the concentration of carcinogens in the intestine. This is a plausible mechanism through which legumes may reduce the risk of colorectal cancer [34, 62]. One meta-analysis found a significantly lower risk of colorectal cancer with increased intake of soy products [63], another one observed only such a nonsignificant trend [64]. In a subgroup analysis the inverse association was limited to Asian populations [63]. No association was observed between intake of legumes, in part including soy products, and cancer risk [65, 66]. But another meta-analysis, which included more individual studies, observed a significantly inverse association [63] (◆ Table 3). Based on the meta-analysis of Vieira et al., which covers a wide range of food groups [65], the World Cancer Research Foundation concluded that intake of legumes does not affect risk of colorectal cancer.

One meta-analysis observed a lower risk of colorectal cancer with increased intake of fiber [62]. For legume fiber there was only such a nonsignificant trend [62] or a marginally significant inverse association [63] (◆ Table 3).

According to one meta-analysis higher total soy food intake was associated with a decreased risk of prostate cancer [67]. Another one, based on fewer individual studies, observed only such an inverse nonsignificant trend [68]. High intake of total legumes, including soy products, was associated with a decreased risk [68]. There was no association between intake of non-soy legumes and risk. This analysis included only two individual studies [68] (◆ Table 3). In a French cohort an inverse association between legume intake and risk of prostate cancer was observed, irrespective of whether soy products were included or not [69].

According to one meta-analysis higher intake of soy products showed a borderline association with breast cancer [70]. Another meta-analysis, which included mainly case-control studies, examined the association between breast cancer risk and intake of soy isoflavones (intake in part calculated from plasma or urine levels) and in a subset analysis also with intake of soy foods in pre- and postmenopausal women [71] (◆ Table 3). Both for total isoflavones and soy foods, there was an inverse association between intake and cancer risk. According to a subset analysis the inverse association was limited to Asian as compared to Western countries [71]. No meta-analysis addressed yet the association between non-soy legume intake and breast cancer incidence.

According to one meta-analysis high intake of soy products was associated with a decreased risk of stomach cancer [64] (◆ Table 3).

Legumes as a component of healthy dietary patterns

In its 2015 scientific report the US Dietary Guidelines Advisory Committee (DGAC) [72] put for the first time a particular focus on the benefits of so-called healthy dietary patterns (healthy diets). Examples are the Healthy Eating Index (HEI) and Alternative Healthy Eating Index (AHEI), the Dietary Approaches to Stop Hypertension (DASH) pattern and the Mediterranean-style pattern. Dietary patterns with health benefits are rich in vegetables, fruit, whole grains, fish, legumes, and nuts, moderately rich in dairy, but provide less red meat and meat products and are low in sugar-sweetened foods and beverages and refined grains [72]. All the various (healthy) vegetarian dietary patterns include legumes in their emphasis on plant foods [72].

A meta-analysis of intervention studies showed that adherence to healthy dietary patterns (DASH, Nordic diet, Mediterranean diet) was associated with decreased blood pressure [73] (◆ Table 2 in part 1 of the review in Ernährungs Umschau 9/2020). A meta-analysis of cohort studies found that healthy dietary patterns (DASH, AHEI, Mediterranean diet) were associated with a lower risk of T2DM [74]. Another one found that higher adherence to a Mediterranean diet was associated with a decreased risk of CVD, and also of CHD, myocardial infarction, and stroke [75] (◆ Table 3). According to pooled analyses of individual components the protective effects of the diet appeared to be most attributable to olive oil, fruits, vegetables, and legumes [75]. One explanation for the protective effect of legumes against CHD and CVD may be that they often replace red meat as a source of protein [58].

The nutritional survey *(Ernährungsbericht)* 2016 of the German Nutrition Society estimates that the annual per capita legume consumption is on average 600 g, i.e. 1.6 g/d [3]. The German National Food Consumption Study II (Nationale Verzehrsstudie II) recorded legume intake only within the food category 'Vegetables'. Men and women alike (15–80 years) consumed on average 124 g/d vegetables (without potatoes) [76]. In France, daily intake of men aged 35–54 years was on average 11.6 g legumes and 137.8 g vegetables (without potatoes) [77]. In Italy, for men aged 18–65 years the daily intakes were 11.7 g and 232.6 g, respectively [78]. Intakes of women were slightly different. Participants of 21 prospective studies from the US, Europe, and Asia had a total fiber intake ranging from 6.3 to 21.4 g/d, legume fiber intake varied from 1.3 to 3.8 g/d [62].

Concluding remarks

The available meta-analyses indicate that higher intake of legumes (with or without soy products) improves several metabolic parameters (amongst others LDL cholesterol) and decreases several disease risks, namely T2DM, CHD and CVD, but not stroke. A higher adherence to a Mediterranean diet was associated with a lower risk of T2DM, CHD, CVD and also stroke. The DASH and AHEI dietary patterns were equally associated with a lower risk of T2DM. The findings support an (increased) intake of legumes as part of a health-promoting diet as advised by many nutrition societies. There are not enough studies available yet to assess the importance of legumes for cancer risk.

Independent of their health benefit legumes are an important food group for a sustainable agricultural production. The nitrogen-fixing nodule bacteria living symbiotic with legume roots fix atmospheric nitrogen and make it available also to other plants. This improves soil quality and reduces the demand for fertilizers. In its 2015 report the Dietary Guidelines Advisory Committee addressed the topic sustainable diets for the first time [72]. In 2019 the Eat-Lancet Commission published its report Planetary Health Diet, with the concept of a healthy, sustainable and at the same time environmentally and climate friendly dietary pattern (healthy reference diet). This emphasizes always plant-based foods, with wide variability. Legumes are a core component [79].

The meta-analyses presented herein were heterogeneous in the way of analysis and presentation and of varying quality. Unfortunately, the meta-analyses and underlying individual studies frequently provided no information on the contribution of soy products to total legume intake. The presently available data are not sufficient yet to judge on the role of non-soy legumes on health.

The literature of part 1 and part 2 of this article is available online
→ www.ernaehrungs-umschau.de

Conflict of Interest
The three authors are members of the Special Committee for Human Nutrition within the Union for the Promotion of Oil and Protein Plants e. V. (UfOP). A first version of this article was published on the homepage of UFOP.

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DOI: 10.4455/eu.2020.049