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PROCESSED LEGUME SEED PRODUCTS AND THEIR SIGNIFICANCE IN THE PREVENTION OF CARDIOVASCULAR DISEASES®

Przetwory z nasion roślin strączkowych i ich znaczenie w profilaktyce chorób układu sercowo-naczyniowego®

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Cardiovascular diseases (CVDs) have been the main cause of death in Europe for years. The development and the course of the CVDs depends on a variety of factors, among other things, nutritional ones. Legume seed products contain high levels of nutrients and phytochemicals linked with the cardiovascular health benefits. The paper provides up-to-date knowledge on the nutritional value and processing and utilization of legume seeds as well as effects exerted by nutrients and bioactive compounds contained in legumes on the cardiometabolic risk factors intermediating in development of cardiovascular diseases. Familiarity with these issues is necessary for a proper planning of nutrition in patients with CVDs risk.

Key words: legume seeds pulses, soybean, cardiovascular risk, cardiometabolic factors.

Choroby sercowo-naczyniowe (CVDs) są od lat główną przyczyną zgonów w Europie. Rozwój i przebieg CVDs zależy od wielu czynników, w tym żywieniowych. Przetwory z nasion roślin strączkowych są bogatym źródłem składników odżywczych i fitozwiązków, które wpływają korzystnie na układ sercowo-naczyniowy. W artykule scharakteryzowano aktualną wiedzę na temat wartości odżywczej, procesów przetwórczych i wykorzystania nasion roślin strączkowych oraz wpływu składników w nich zawartych na kardiometaboliczne czynniki ryzyka pośredniczące w rozwoju chorób sercowo-naczyniowych. Ich znajomość jest niezbędna do prawidłowego planowania żywienia dla osób z ryzykiem CVDs.

Słowa kluczowe: nasiona roślin strączkowych, soja, ryzyko sercowo-naczyniowe, czynniki kardiometaboliczne.

INTRODUCTION

Despite decreasing trends in mortality from cardiovascular diseases (CVDs) [13], CVDs remain the main cause of death in Europe, including Poland. They are responsible for 46% of the total deaths (more than 4 million deaths yearly) in the continent. The number of CVDs death is higher in women than men [62]. In 2016 there were approximately 167 thousand deaths (48,8% of women and 38,2% of men) in Poland resulting from diseases of the circulatory system [15].

High fat diet rich in saturated and trans fatty acids or high carbohydrate or high sodium diets are major contributors to the risk of cardiovascular diseases. On the other hand, adequate vegetable consumption is the cornerstone of dietary approaches for CVDs and the other chronic diseases primary prevention. Current dietary guidelines promote an increase in intake of all vegetables, but legumes (comparing to all vegetables, but also to other food products) are completely unique. Soy legumes, but also non-soy legumes have high nutrition value as a result of high content of protein, unsaturated fatty acids, complex carbohydrates, fiber, vitamins, minerals and bioactive compounds beneficial for cardiovascular health. Legume seed products, especially soy products, can be used as ready to eat or cook products, functional technological

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ingredients, nutrition value enhancers and meat analogues. Replacing energy-dense food with legumes has been shown to have beneficial effects on the prevention of cardiovascular diseases [38, 60].

Given that the soy (soybean) and non-soy (pulses) legumes have a different nutritional profile [8], the aim of the present review is to summarize the existing evidence regarding legume intake and cardiometabolic factors intermediating in development of CVDs, differentiating between soy and non-soy legume seeds. We did not include studies considering fresh legumes and peanuts that have nutritional similarity with nuts [8].

CVDs RISK AND PREVENTION

Cardiovascular diseases cover a broad group of medical problems that affect the heart and blood vessels (the circulatory system), often resulting from atherosclerosis involving large and medium sized arteries. Coronary heart disease (CHD), cerebrovascular disease and peripheral artery disease (PAD), are main groups of CVDs. Clinical manifestations of these diseases include angina, myocardial infarction, transient cerebral ischaemic attacks, strokes and intermittent claudication [35].

Cardiovascular diseases etiopathogenesis is complex and multifactorial. Among factors inducing or enhancing the pathogenic processes in the heart and blood vessels the first place is mentioned to be taken by lifestyle factors such as tobacco use, an unhealthy diet and physical inactivity. These modifiable risk factors result in obesity and progression of atherosclerosis which lead to CVDs [35, 54].

Obesity is independent risk factor for developing CVDs and one of the main causes of the increased risk of other cardiometabolic factors such as dyslipidaemia, insulin resistance, hyperglycaemia, type 2 diabetes (T2D) and hypertension. Under these pathological conditions oxidative stress, inflammatory signals, macrophage accumulation in the wall of vessel, coronary calcification and thrombosis as well as overstimulation of renin-angiotensin and sympathetic nervous systems dysregulate endothelial activation and functions, and influence the pathogenesis of atherosclerosis. Atherosclerosis is a chronic immune-inflammatory disease characterized by atherosclerotic plaques formed in the wall of vessels, consisting of necrotic core, calcified regions, accumulated modified lipids (mainly oxidised low density lipoproteins – oxLDL), and endothelial cells, leukocytes, inflamed intimal smooth muscle cells, and foam cells [5, 10, 11, 26, 29, 35, 49, 51, 57, 69, 71]. The relationships between lifestyle and cardiometabolic risk factors for developing CVDs are presented in Figure 1.

Type 2 diabetes increases CVDs risk and cardiovascular incidences. Pathological vascular processes predispose to cardiovascular diseases worsen when T2D and hypertension coexist. Endothelial dysfunction in obesity, insulin resistance, diabetes and atherosclerosis diminishes production and/or availability of nitric oxide (NO) which is relaxing factor, and disrupt balance between vasoconstriction and vasodilation, growth promoting and inhibitory factors, proatherogenic and antiatherogenic factors, and procoagulant and anticoagulant factors. These functional changes in the vessel wall are accompanied by proliferation, hypertrophy, remodeling and apoptosis of vascular smooth muscle and degradation of endothelial cells [49, 53, 57, 69].

Continuing exposure to cardiometabolic risk factors leads to further progression of atherosclerosis, resulting in vascular stiffening, destabilization of the atherosclerotic plaques, formation of thrombus, narrowing of blood vessels or total occlusion and obstruction of blood flow to vital organs, such as heart and brain. It constitutes a crucial step regarding the risk of acute cardiovascular events [26, 49].

In addition to lifestyle and cardiometabolic risk factors which can be prevented, changed, or controlled, non-modifiable risk factors, as genetic factors, ageing and gender enhance the risk for CVDs. Psychosocial factors, such as chronic emotional stress, symptoms of depression, and low socioeconomic status are also of importance [35, 71].

Important modifiable factor for CVDs is the diet. High fat diet rich in saturated and trans fatty acids or high carbohydrate diet rich in simple sugars or high sodium diet and diets low in mono- and polyunsaturated fatty acids and fiber are the crucial players in the development of the cardiovascular diseases. Lifestyle changes including consuming a diet full of vegetables, fruits, and whole grains, low fat dairy products, poultry, fish, legumes, non-tropical vegetable oils, and nuts and limiting intake of saturated and trans fats, cholesterol, sweets, added sugars, salt and sugar sweetened beverages as well as red and processed meats, may provide the cardiovascular health benefits. Other lifestyle changes including increasing physical activity, avoiding cigarette smoking and alcohol intake, and maintaining a healthy body weight will optimize health benefits. Effective actions will reduce not only mortality, but also morbidity, disability of CVDs and improve quality of life [6, 9, 22, 34, 38, 50, 60].

Diets recommended by international cardiovascular clinical practice guidelines, as Dietary Approaches to Stop Hypertension (DASH), Mediterranean, Portfolio, Nordic and vegetarian dietary patterns have been shown to have a decreasing effects on cardiometabolic risk factors and reduce cardiovascular incidence and mortality [7, 12, 25, 60]. Legumes, whose relevance is characterized below, are considered as a part of these healthy dietary patterns.

LEGUME SEEDS CHARACTERISTIC

Legumes are the pod or fruits of plants that belong to *Leguminosae* (also known as *Favaceae*) family. *Leguminosae* is one of the three largest families of flowering plants and includes the soybeans, chickpeas, lentils, beans, peas, and broad beans among others. Grain (food) legumes can be divided into two groups, the pulses and the oilseeds. The pulses group includes dry seeds of cultivated legumes which are traditional food. The oilseeds group consisting of soybean and peanut is used primarily for their oil content [3, 33, 37].

Legumes are widely grown and used for food purposes because of their unique nutritional value, appropriate functional attributes and low production cost. Chemical composition of legume seeds depends on variety, species and region. Compared to other vegetables, pulses and soybeans are characterized by a higher energy value and protein content (20-45% dry weight). Although soybeans are the richest

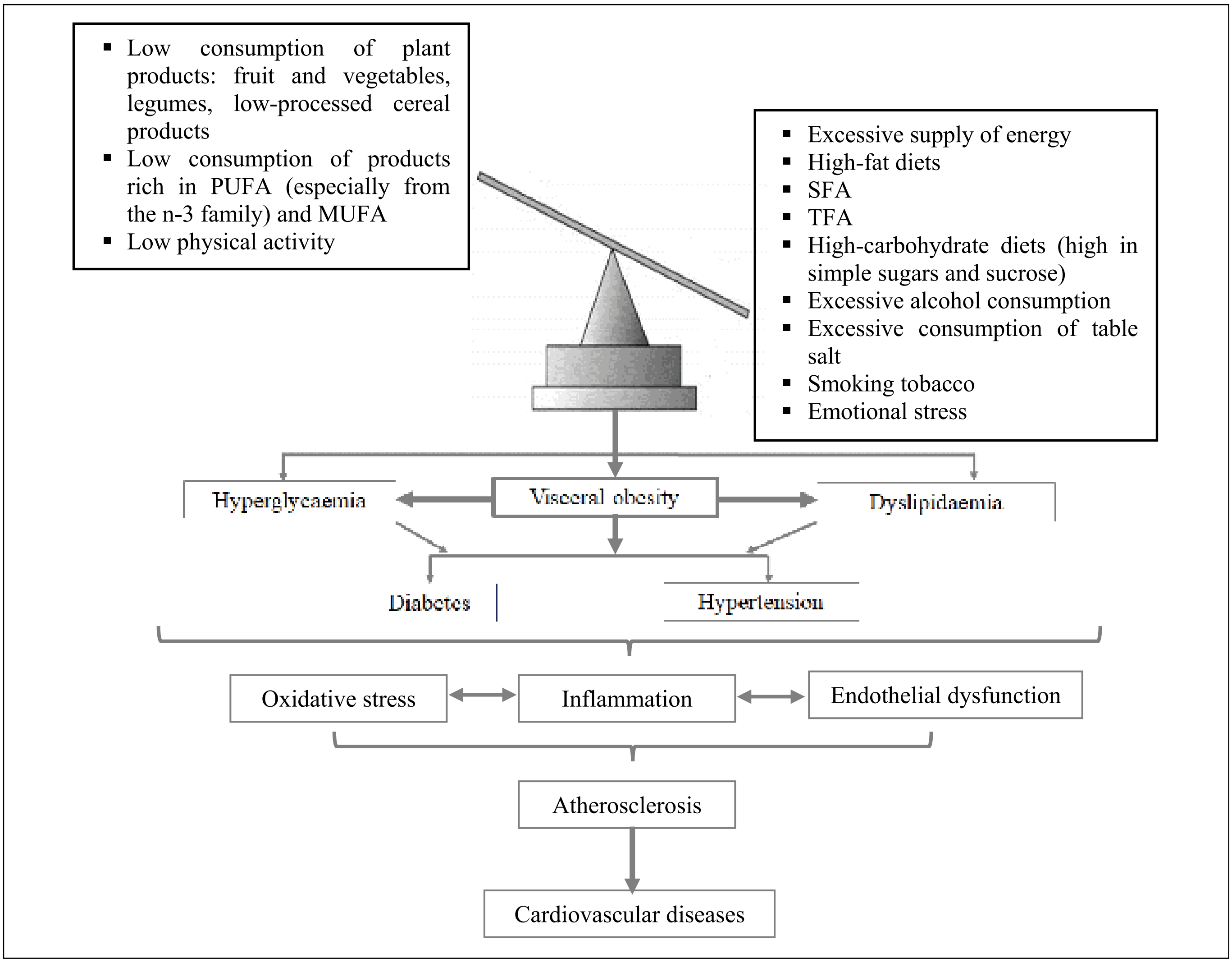

Fig. 1. Relationships between lifestyle and cardiometabolic risk factors for developing cardiovascular diseases (PUFA – polyunsaturated fatty acids; MUFA – monounsaturated fatty acids; SFA – saturated fatty acids; TFA - trans fatty acid isomers).

Rys. 1. Zależności między stylem życia a kardiometabolicznymi czynnikami ryzyka rozwoju chorób sercowo-naczyniowych (PUFA – wielonienasycone kwasy tłuszczowe; MUFA – jednonienasycone kwasy tłuszczowe; SFA – nasycone kwasy tłuszczowe; TFA – izomery trans kwasów tłuszczowych).

Source: Own study

Źródło: Opracowanie własne

source of protein, other legumes are also good source of cheap and widely available proteins with essential amino acids. Legume seeds have an average of twice or triple as much protein as cereals and the nutritive value of the proteins is usually high, though the bioavailability of animal proteins is still proven to be higher. The protein digestibility is affected by other legume compounds like carbohydrates, lipids, and especially anti-nutritional factors. Legume proteins can be divided into four fractions – albumins, globulins, prolamins and glutelins. The majority of pulse and soybean proteins are globulins (approximately 70% of the total legume protein) which can be divided into two groups, namely vialin and legumin. Legumes are gluten free, what makes them suitable for celiac disease patients or individuals sensitive to gliadin or glutenin. Legume (with the exception of soybean) proteins are low in sulphur-containing amino acids (methionine, cysteine and cysteine) and tryptophan, but they have greater amounts of lysine than cereal grains. Improved nutritional quality can therefore be achieved by combining legumes with cereals [37, 45, 52, 59, 61, 66].

Legume seeds are a good source of complex, energy providing carbohydrates (60% dry weight), mainly amylose starch (30–40%), soluble and insoluble fibre (5–37%), and resistant starch. Legumes typically contain more insoluble than soluble fibre. The total fibre content of legumes ranges from 8% to 27,5%, with soluble fibre in range 3,3–13,8% dry weight. Legumes contain also oligosaccharides (consisting mainly of raffinose and stachyose), sucrose and monomers such as glucose, galactose, arabinose, rhamnose, xylose and mannose. The high content of carbohydrates and dietary fibre makes the seeds of legumes have a low glycemic index (GI) [37, 52, 64].

Most legume seeds are very low in fat (<5% energy from fat), with the exception of chickpeas and soybeans (15% and 47%, respectively). Legumes are low in saturated fatty acids and cholesterol-free. An important component of legumes are mono- and polyunsaturated fatty acids (MUFA and PUFA), i.e. oleic acid, omega-6 linoleic acid and omega-3 α-linolenic acid, and phytosterols [37, 45].

Legumes contain water soluble B-group vitamins, namely thiamine, riboflavin, niacin, pyridoxine, folic acid and the vitamin A precursor β-carotene, and minerals, such as iron, calcium, zinc, potassium, phosphorus, copper, selenium, manganese, magnesium and chromium [9, 37, 52]. Beans are good source of folate, and two or more servings of some legumes can provide approximately 400 mg, which represents close to 100% of the daily requirement [52]. Legumes are a poor source of fat soluble vitamins, vitamin C (except broad bean) and are low in sodium [37].

The energy, macronutrient, fibre and micronutrient content of some commonly consumed legumes are presented in table 1.

Legumes contain non-nutrient bioactive compounds with antioxidant properties including polyphenols and their derivatives such as flavanols, flavan-3-ols, anthocyanins/anthocyanidins, condensed tannins/proanthocyanidins and tocopherols as well as saponins and glycosides. Soy isoflavones (genistein and daidzein and their respective β-glycosides, genistin and dadzin) constitute a special group among phytochemicals [1, 37, 39].

Nutritional value of legumes is limited by the presence of proteinaceous and anti-proteinaceous anti-nutritional factors such as some enzyme inhibitors (trypsin and chymotrypsin proteinase inhibitors), phytic acid, flatulence factors (rafinose family oligosaccharides), lectins (hemagglutinins or phytohemagglutinins), tannins, cyanogens, non-protein amino acids and saponins. Many legumes contain a few of these anti-nutritional factors, only a few legumes may contain all of them. Tannins and cyanogens are the two anti-nutritional factors that are present almost in all legumes. Proteinase inhibitors and tannins decrease protein digestibility if they are not properly inactivated during processing. Phytic acid forms a complex

Table 1. Energy and nutritional value of some commonly consumed legumes in Poland [30]

Tabela 1. Energetyczność i wartość odżywcza najczęściej spożywanych w Polsce roślin strączkowych [30]

Legumes / Parameters	Soybean*	White beans*	Pea*	Broad bean	Red lentil*
	in 100g				
Energy (kcal)	382	288	293	66	327
Proteins (g)	34.3	21.4	23.8	7.1	25.4
Carbohydrates (g)	32.7	61.6	60.2	14.0	57.5
Starch (g)	4.8	40.8	44.0	5.4	44.5
Dietary fibre (g)	15.7	15.7	15.0	5.8	8.9
Fats (g)	19.6	1.6	1.4	0.4	3.0
Saturated fatty acids (g)	2.82	0.19	0.22	0.06	0.45
Oleic acid (g)	4.07	0.12	0.22	0.08	0.51
Linoleic acid (g)	9.80	0.33	0.52	0.17	1.14
α-linolenic acid (g)	1.49	0.58	0.10	0.01	0.27
Thiamine (mg)	0.690	0.670	0.770	0.090	1.072
Riboflavin (mg)	0.189	0.230	0.280	0.060	0.446
Niacin (mg)	1.18	2.20	3.10	2.40	3.20
Pyridoxine (mg)	0.81	0.53	0.30	0.06	0.60
Folate (μg)	280	187	151	145	36
Vitamin C (mg)	0	2	2	32	3
β-carotene (μg)	12	0	117	170	60
Iron (mg)	8.9	6.9	4.7	1.9	5.8
Calcium (mg)	240	163	57	60	46
Phosphorus (mg)	743	437	388	57	301
Magnesium (mg)	216	169	124	24	71
Potassium (mg)	2132	1188	937	261	874
Zinc (mg)	3.46	3.77	4.20	1.62	3.34
Copper (mg)	1.5	0.48	0.50	0.10	0.85
Manganese (mg)	2.49	2.00	2.03	0.39	1.35

* - in dry seeds

* - w nasionach suchych

with trace elements and macroelements such as zinc, calcium, magnesium and iron, in the gastrointestinal tract and makes them unavailable for absorption and utilization by the body. It can also inactivate digestive enzymes such as proteases and amylases of the intestinal tract, thus inhibiting proteolysis. Lectins, cyanogens and non-protein amino acids are major anti-nutritional toxic factors limiting the use of legumes. Raffinose, verbascose, stachyose and ajugose are not digested and absorbed in human small intestine due to lack of the enzyme α-galactosidase to cleave the α-galactosyl linkage. These oligosaccharides accumulate in the large intestine where the α-galactosidase containing intestinal bacteria degrade them and subsequent anaerobic fermentation results in production of hydrogen, carbon dioxide and methane. These gases result in abdominal discomfort due to a flatulence and sometimes cause diarrhea. Fortunately, most of the anti-nutritional factors are inactivated or reduced by traditional prolonged cooking and food processing, which increases the bioavailability of nutrients as well as improves flavour and palatability. Moreover, recent research has shown potential health benefits of some of anti-nutritional legume compounds such as polyphenols and saponins [1, 28, 37, 40, 47, 52]. Cotyledons and seed coats of some legumes contain a variety of pigments (for example chlorophyll, carotenoids, lutein and β-carotene) resulting in specific colour of legume seeds [63].

LEGUME SEEDS PROCESSING AND UTILIZATION

Legumes may be consumed by humans in several forms. Most of the crops from both legume groups are harvested as dried grains, but several legumes may be eaten raw as cooked or green vegetables if are picked before the pods are fully ripened and dry out. Dried legume seeds cannot be consume raw and therefore there are processed into semi-finished or finished products through several processing steps (primary and secondary unit operations). Food can be processed at different levels, home-based or industrial, that could be at the cottage or on a large scale [61].

Primary unit operations in the processing of legumes include sundrying, husking (hulling), winnowing, separation and storage. During secondary unit operations before use legumes are sorted and cleaned by dry or wet methods to remove dirts, stones, chaff, broken and spoilt seeds and other foreign materials [61]. Next legume seeds are prepared for consumption by soaking, blanching (soaking in hot water or boiled in water for few minutes), boiling/cooking (traditionally, microwave or under pressure), extrusion, autoclaving, roasting, fermenting, germinating, milling, ultrafiltration, sieving, frying, canning, confectioning, and enzyme processing. Beans can also be used as spices or condiments or processed into vegetable oil that may be extracted by pressing or by solvent extraction. These physical or biochemical processes increase the digestibility of plant proteins and carbohydrates and bioavailability macronutrient and micronutrients in legumes as well as inactivate enzyme inhibitors, and also reduce or eliminate the other anti-nutritional factors such as tannins, phytic acid, hemagglutinins etc. Some of these processes e.g. fermentation and germination, activate endogenous enzymes (α-amylase, phytase, and other glucosidases) which degrade anti-nutritional factors as well as improve the appeal and eating quality of legumes. Chicken peas and broad beans are usually germinated before being eaten, cooked, or used in salad dressings. Canning cooked beans in brine, sugar or tomato purees allows for all year round availability of the product and for food preservation. However, beans processed in this form are expensive [1, 14, 43, 59, 61].

Wet-milling of seeds results in a paste production while dry-milling will produce flour. Wet milled legume may be mixed with other ingredients and steamed in leaves to obtain pudding (moinmoin) or fried in hot oil to produce bean cake (akara). The rehydrated flour may be used to obtain these products. Dry or wet sieving removes unwanted materials from ground legume seeds. Example of wet sieving is in the filtration of ground soybean paste in the production of soymilk. This process removes the okara, an unwanted residue from soybeans. Sieving dry-milled legume flour, in turn, helps to achieve different ranges of particle sizes [61]. Different legume flours may be used as a natural colouring component in the production of durum wheat semolina pasta. Addition of legume flours is also a good way to increase the nutritional value of wheat pasta [63].

A variety of processed soybean products are classified into two groups, non-fermented and fermented (by microorganisms and their enzymes). The former products include soybean milk, tofu (soybean curd), soy cheese, yuba (a sheet-like coagulant formed on the surface of warm soy milk as it cools), soy flour and soybean sprouts. Fermented products, on the other hand, include soy sauce, soy paste, fermented tofu (sufu/furu) and fermented whole bean. These traditional products have a specific aroma, flavor and taste, and have their own local names in each country [19, 20, 36].

In Thailand, most fermented soy products are similar to Chinese soy fermented products mentioned above. Tempeh, originated from Indonesia, is made from whole soybeans which are fermented with spores of *Rhizopus oligoporus*. Tempeh has also been produced from other legumes or mixture with whole grains. The major traditional soybean foods in Japan are soy paste (miso and natto), soy sauce, tofu and its derivatives. Soybean sauces such as shoyu and tamari traditionally used in Asian cooking are processed by fermenting soybeans, usually with the addition of grains [36, 44, 61].

Soy is a plant whose seeds are widely used in the food industry. The basis for the use of soybeans in the food industry is primarily its high protein and fat content. Soya is used to make pastes, to produce substitutes for cereal products (bread, noodles, flour) dairy products (soy milk, cheese), and meat substitutes. Soy milk is the basis for the production of various types of cheese, yoghurts and powdered soy milk, while full-fat flour is used for the production of bakery and confectionery products, sauces, soups, as well as meat extenders and animal protein substitute so-called “Soy meat” and the so-called “Soybean fish”. The following modern technologies are expected to create new products from soybean and create a new market for them: extrusion cooking, high pressure cooking, ohmic heating and others [37, 44, 45, 66]. Possible utilization of non-fermented and fermented soy products is summarized in table 2.

Table 2. Soy-based products utilization [19, 20]
Tabela 2. Wykorzystanie produktów sojowych [19, 20]

Soy product		Utilization
Soy milk		powdered soy milk, soy crude, soy cheese, yoghurts, soy-corn milk
Okara		vegetarian dishes, tofu, yuba
Tofu	silk	a replacement for mayonnaise and cream in dressings and dips as well as puddings and fillings
	soft	replaces ricotta in lasagne, an ingredient in fruit smoothies
	hard	for the production of hamburgers, pates, dishes imitating roast and goulash meat as well as seasoning mixtures
Yuba		meat analogues, for wrapping stuffing, addition to soups and desserts; when fried, it creates a layer that imitates roasted chicken skin
Soy flour and grits		a flour filler or improver in the production of bread and certain meat and delicatessen products; ingredients of vegetarian, gluten-free, textured products and protein hydrolysates
Soy protein concentrate		addition to meat substitutes in the meat and delicatessen industry; used for the production of sausage, luncheon meat, pate and burger; enrichment substance for bread and confectionery products
Soy protein isolate		production of nutrition for infants and children, athletes, people on slimming, health foods, powdered soy drinks, milk replacers, soups, sauces, mayonnaise, bakery and confectionery products; ingredients for edible coatings, mainly in the meat industry; enrichment substance for the production of meatless sausages and meat analogues
Textured soy proteins		production of vegetarian products, dinner concentrates, cereals, vegetable and meat preserves, burgers, meatballs, bread and bakery products, pizza additives; meat extender and substitute in meat and delicatessen products; imitation of ham, bacon, poultry fillet
Tempeh		production of spaghetti sauces, soups, salads, hot spices, casseroles and veggie burgers, meatballs and bacon; addition to other dishes in the form of stewed, deep-fried, marinated and dried
Sufu		use such as ripening cheese
Miso		base for soups, sauces and meat marinades; relish
Natto		addition to rice or vegetables; in dried form as a snack or addition to yoghurts and salads
Soy sauces		flavouring food

The industrial products obtained from legumes, in addition to flour and grits, paste, sauce and vegetable oil, also include texturized vegetable protein, protein concentrates and isolates as well as starch isolates and dietary fiber fractions. The protein extraction methods which are used in the preparation of protein-rich materials are classified into dry and wet processing. Dry method involves the separation of flours and their fractionating into starch and protein rich concentrates at protein level from 40% to 75%. Wet extraction methods including acid/alkaline extraction-isoelectric precipitation, ultrafiltration and salt extraction can be exploited for preparing both protein concentrates an isolates with protein content of 70% and 90% (or higher), respectively. Protein flours, grips, concentrates and isolates from soybeans and pulses can be useful in producing various food products to increase their nutritional value and/or to provide functional attributes such as solubility, gelation, emulsification, oil and water absorption capacity, and foaming. These functional properties of legume proteins impact the texture and organoleptic characteristics of a food [37, 59]. Soy protein concentrates and isolates are a common concentrate and isolate, but they are also made from a variety of legumes such as chickpea, faba been, lentil, mung bean, smooth pea, pea, winged bean, white bean and lupin as well as pinto and navy beans [59, 61]. Pulse protein concentrates and isolates can be incorporated into many food products such as beverages, imitation milk, baby foods, bakery products, meat analogs, cereals, snack food, bars, and nutrition supplements. Legume starch isolates, in turn, are employed as thickeners in soups and gravies in the food industry. Dietary fiber fractions from legume are used in the bakery, meat, extruded products and beverage industries as stabilizers, texturing agents, fortifiers, bulking agents, fat replacers and emulsion stabilizers [37, 59].

In summary legume seed products are attractive not only to vegans or vegetarians, but also to health conscious consumers, athletes, overweight/obese, diabetic and celiac patients. Due to the recommendations to limit the consumption of meat, especially red meat and processed meats, and the high content of vegetable protein, legume seeds are one of the best alternatives to meat in the traditional and plant-based diets.

LEGUME SEED PRODUCTS VS. CVDs

A positive effect of legume consumption on cardiovascular health has been confirmed in many clinical trials, epidemiological and experimental studies. The consumption of legumes, especially pulses was found to significantly reduce total CVDs risk and/or mortality [8, 9, 17, 18, 31, 38, 41, 52, 55, 65], CHD [2, 8, 9, 17, 38, 52, 65] and vascular impairment in PAD [72] as well as myocardial infarction [24, 41], transient cerebral ischaemic attacks [9], stroke [9, 41] and diabetes [8], and all-cause mortality [31].

The mechanism of CVDs protection may depend on the fact that increased consumption of legumes lowers cardiometabolic risk factors: obesity, hyperglycaemia, insulin resistance, dyslipidaemia, hypertension, oxidative stress and inflammation. Thus, legume intake could provide an effective tool in the prevention and management of these CVDs risk factors [4, 16, 46, 67]. A summary of the relationship between pulses and soybeans and CVDs risk factors has been illustrated in table 3.

Table 3. Soy and non-soy legumes and CVDs risk factors

Tabela 3. Sojowe i niesojowe rośliny strączkowe a ryzyko sercowo-naczyniowe

Cardiometabolic factors	Parameters	Legumes	
		pulses	soybeans
Adiposity	Body weight	↓ ↔	↔
	Body mass index (BMI)	↓ ↔	–
	Fat mass	↔ ↓	↔
	Waist circumference	↔	↔
	Waist–hip ratio (WHR)	↓	–
Glucose metabolism	Fasting blood glucose level	$\downarrow^{1,2,3} \leftrightarrow^{2}$	↔
	Fasting blood insulin level	$\downarrow^{1,2} \leftrightarrow^{2}$	$\downarrow^{4} \leftrightarrow^{5}$
	Postprandial blood glucose level	↓	–
	Glycosylated blood proteins	$\downarrow^{1,2,3}$	↔
	Homeostatic Model Assessment – Insulin Resistance (HOMA-IR)	$\downarrow \leftrightarrow^{2,3}$	↔
Lipid profile	Total cholesterol level (TC)	↓	↓
	Low-density lipoprotein cholesterol level (LDL-cholesterol)	↓	↓
	High-density lipoprotein cholesterol level (HDL-cholesterol)	↔	
	non-HDL-cholesterol level	↔ ↓	↓
	Lipoptotein (a) level	↓	–
	Apolipoprotein B level (apo-B)	↔	–
	Triglyceride level (TG)	↓	↓
Blood pressure	Systolic blood pressure (SBP)	↓ ↔	$\leftrightarrow^{4} \downarrow^{5}$
	Diastolic blood pressure (DBP)	↔ ↓	$\leftrightarrow^{4} \downarrow^{5}$
	Mean arterial blood pressure	↓	–
Inflammation	C reactive protein level (CRP)	↓ ↔	↓ ↔
	Interleukin 6 level (IL-6)	↓ ↔	↓ ↔
	Tumour necrosis factor α level (TNF-α)	↓ ↔	↓ ↔
Oxidative stress	Markers of oxidation	↓	↓
	Total antioxidant capacity		–

↓ – decrease, ↑ – increase, ↔ – no effect, – – no data, 1 – alone, 2 – as a part of low-glycemic index diets, 3 – as a part of high fiber diets, 4 - whole soy diets, 5 – purified isoflavones or isolated soy protein

↓ – spadek, ↑ – wzrost, ↔ – brak wpływu, – – brak danych, 1 – samodzielnie, 2 – w ramach diet o niskim indeksie glikemicznym, 3 – w ramach diet bogatych w błonnik pokarmowy, 4 – w ramach pełnowartościowych diet sojowych, 5 – oczyszczone izoflawony lub izolaty białka sojowego

Source: Own study

Źródło: Opracowanie własne

Dietary pulses may be favourable for weight loss and may reduce body fat under both neutral and negative energy balance diets. Diets that included dietary pulses diminished body mass index (BMI) and waist–hip ratio (WHR), but did not significantly reduce waist circumference, while a trend was seen in trials that favoured a reduction in body fat [8, 16, 29, 55, 72]. Soybeans, in turn, did not influence of aforementioned measures of adiposity [8].

Dietary pulses may contribute to the weight loss effect because of being high in fibre and protein and low in the GI. The satiating properties of pulses are one of the mechanisms that could explain their anti-obesigenic effect. The high-fibre content of dietary pulses contribute to the feeling of fullness because it increases the chewing time, thereby decreasing intake rates and stimulating an interaction of neural and hormonal signals that mediate satiety. Moreover, the soluble fibres are able to delay gastric empting and the absorption of macronutrients as they form viscous gels, thereby slowing their passage through the gastrointestinal tract. Last, high-protein food such as pulses stimulates the secretion of the intestinal hormones that regulate appetite and causes the sensation of fullness. These effects of pulse fibre and proteins may help prevent overeating and promote weight control. Another mechanism may have been the reduced amount of energy from fat and starch that can be metabolized, because fibre and cell walls of pulses lower the access of digestive enzymes to the starch granules and decrease physical contact of the nutrients with intestinal villi [29, 32, 48, 52]. Additionally, it has been suggested that indigestible carbohydrates intake and amino acids composition of pulses may play a role in their effects on energy expenditure. Short-chain fatty acids (SCFAs) formed during colonic fermentation of soluble fibre and resistant starch of legumes, increase glycogen storage, decrease glycolysis, thereby stimulate hepatic fat oxidation and energy expenditure. Furthermore SCFAs, particularly propionate, may induce satiety. Glutamine has been shown to increase postprandial energy expenditure, whereas arginine, a major amino acid in pulses, has been shown to have thermogenic properties that enhance carbohydrate and fat oxidation [52].

Legume consumption, while focusing on pulses, lowers glycaemic responses after meal and improves glucose tolerance and medium- and long-term markers of glycaemic control. Pulses were found to decrease fasting and postprandial glucose and insulin levels, glycosylated blood proteins (glycosylated haemoglobin and fructosamine) and peripheral insulin resistance. Normalization of glycaemia, insulinaemia and glycosylated proteins reduces cardiovascular events [8, 16, 52, 58, 64]. Non-soy legumes used alone or in low GI or high-fibre diets improve glycaemic control in individuals with and without diabetes. Glycaemic benefits appeared to be modified by pulse type. The strongest evidence for benefits was for chickpeas, but potential benefit was also seen for beans: black, white, pinto, red and white kidney and fava beans [58]. In contrast, soy food consumption did not influence on most measures of glycaemic control and insulin resistance. Whole soy diets, but not purified isoflavones or isolated soy proteins, reduce fasting blood glucose and insulin levels. A reduction in fasting blood glucose levels was observed after consumption of soy nuts in adults who were at cardiometabolic risk. Diet containing soy nuts did not reduce fasting blood glucose concentrations in postmenopausal women with or without metabolic syndrome. Moreover, fasting blood glucose, insulin or Homeostatic Model Assessment – Insulin Resistance (HOMA, a marker of insulin resistance) did not reduce after the consumption of soy nuggets, desserts, and soy-based drinks [8].

Starch composition and digestibility is the main mechanism that contributes to the regulation of the glycaemic response to pulse and whole soy food intake. Amylose starch digestion and intestinal absorption of its products are significantly lower compered to amylopectin starch. Therefore plasma glucose levels and insulin requirement are reduced after high amylose meal. Moreover, protein-starch interactions and the high fibre content in pulses may further hinder starch digestibility [52]. Additionally, slowly digested starch and high content of fibre make legumes have low GI that reduces blood glucose concentration and insulin release [29, 58, 64]. The discrepancy in results between whole soy food and isolates of soy protein or isoflavones suggests that other (than protein and isoflavones) soybeans components or their interactions might explain the effect of whole soy intake on the improvement of glucose control [58].

Legumes in the diet are related to cardometabolic risk reduction because they improve not only carbohydrate metabolism, but also lipid profile [18, 55, 64]. Non-soy legume consumption, such as beans, peas, chickpeas, lentils and mix pulses (flour and whole food) was found to reduce total, low density lipoprotein cholesterol (LDL-cholesterol), triglycerides and lipoprotein (a) levels. Effects of pulse products were observed in predominately middle aged, normolipidemic or hiperlipidemic adults at moderate risk of CHD. Elevated LDL-cholesterol concentration is a major risk factor of atherosclerosis and cardiovascular incidences and its decreasing is a main goal of dyslipidaemia's therapy. A 5% reduction in LDL-cholesterol concentrations after pulse diet suggest that pulses consumption might reduce the risk of major cardiovascular events by 5-6%. No effect of dietary pulses was reported on apolipoprotein B (apoB), as well as high-density lipoprotein cholesterol (HDL-cholesterol) and non-high-density lipoprotein cholesterol (non-HDL-cholesterol) levels [8, 18, 31, 70]. Moreover, in patients with diabetes, pinto beans and lentils consumption did not have a beneficial effect on lipid profile [8].

It has been shown that soybean-enriched diet, soy protein and isoflavones also improve lipid profile [4, 8, 67, 68]. Soy products (including soy nuggets, burgers, desserts and drinks) significantly reduce LDL-cholesterol, triglycerides, non-HDL-cholesterol and total cholesterol concentrations. Additionally, levels of HDL-cholesterol is increasing. High-density lipoprotein (HDL) has a variety of functions that contribute to anti-atherogenesis [7, 8, 67, 70]. It is worth emphasizing that whole soy products, such as soy milk, soybeans and soy nuts reduced LDL-cholesterol to greater extent than soy extracts or supplement. The hypolipdemic effects of soy products were more pronounced in hypercholesterolemic than in healthy subjects [8].

There are several mechanisms that could explain the hipolipidemic effects of legume-based products. Dietary pulses may contribute to the hypocholesterolemic effects because of being high in soluble fibre. Viscus fibre has the ability to bind to bile acids within the intestine and prevents their reabsorption, thereby the liver increases bile acids production and excretion, resulting in a reduction in the hepatic pool of cholesterol. As a consequence, cholesterol uptake from the blood increases, leading to a reduction of circulating concentrations of cholesterol. Additionally, SCFAs generated during bacterial fermentation of soluble fibre in large intestine might inhibit expression of hepatic enzyme limiting for cholesterol synthesis. Furthermore, other pulse components, such as polyphenols and saponins, might be responsible for the reduction of in serum total cholesterol, triglycerides, LDL-cholesterol, and a significant increase in HDL-cholesterol [8, 34, 38, 52, 55, 64].

The hypolipidemic action of soy-based products might be attributed to soy protein that might decrease the expression of transcriptional factor and genes of lipogenic enzymes, which in turn reduce the biosynthesis of fatty acids, triglycerides and very low-density lipoprotein (VLDL) – the main blood transporter of triglycerides. Moreover, a globulin fraction of soy protein might regulate the synthesis and estrification of cholesterol. On the other hand, isoflavones and amino acids from soy protein might increase hepatic and extrahepatic uptake and degradation of cholesterol through the simulation of the expression of the low-density lipoprotein (LDL) receptor [4, 8, 42, 70]. Additionally, isoflavones as a agonists of estrogens might cause a reduction in blood cholesterol concentrations by binding to estrogen receptors [8]. Also, other constituents of soy, such as soluble fibre, lectin or saponins might act independently or synergistically with soy proteins and exert the lipid-lowering effect [8, 52].

Non-soy legumes have blood pressure-lowering effects [8, 29, 52, 65]. Pulses reduce systolic (SBP) and mean arterial blood, but diastolic blood pressure (DBP) changes are often no greater in comparison with diets containing animal foods. Soy isoflavones and proteins, but not whole soy products, have shown a potential beneficial effect. Soy-based products, such as nuggets, burgers, drink, desserts, and soy nuts or soy flour did not reduce SBP, DBP and 24-h ambulatory blood pressure. In contrast, soy nuts significantly diminished SBP and DBP in hypertensive women and postmenopausal women without metabolic syndrome and DBP in those with metabolic syndrome and SBP in normotensive women. Isolated soy protein supplements and soy milk had also anti-hypertensive effects in hypertensive subjects [4, 8, 23, 42].

Dietary pulses may contribute to the hypotensive effects because of being high in protein and fibre. Increase in protein and/or fibre consumption has been associated with reduced SBP and DBP. Furthermore, these two pulse components may have an additive effect on blood pressure reduction. Additionally, different minerals occurring in non-soy legumes, such as potassium and magnesium have been associated with a blood pressure lowering effect [8, 27, 52]. Anti-hypertensive effects of soy protein, in turn, is mediated by its production of angiotensin converting enzyme inhibitor [4, 42].

Among the potential mechanisms of cardiovascular protection, the antioxidant and anti-inflammatory action of legume compounds may mediate their effects [4, 38]. Legumes are rich in polyphenols, which have been demonstrated to be associated with a significant reduction of oxidative stress markers and stimulation of antioxidant defence systems. Non-soy legume-enriched diets reduced lipid peroxidation, especially concertation of plasma-oxidized LDL and enzyme that generates superoxide anions in arterial cells. On the other hand, they increased nitric oxide and antioxidant enzymes, such as catalase and superoxide dismutase expression and activity [8, 52]. Polyphenols reduce oxidative stress-induce degradation of nitric oxide and vasoconstriction, as well as endothelial dysfunction and increase total antioxidant capacity [1, 41, 52, 55]. Soybeans are also dietary sources of isoflavones, α-linolenic acid and vitamin E, which have CVDs protection probably by their antioxidant effects [4, 38]. Soy consumption reduced advanced oxidation protein products in women, but not in men. The low GI, high fibre content of soy and non-soy legumes and SCFA production and action are another properties that may also improve oxidative stress [8].

Analyses that evaluated the effect of non-soy legume consumption on inflammatory markers are poor and contradictory. In overweight and diabetic adults diets with lentils, chickpeas, peas and beans reduced levels of inflammatory markers, such as interleukin 6 (IL-6) and tumour necrosis factor α (TNF-α). Non-soy legumes lowered also peripheral level of C-reactive protein (CRP) a marker of general inflammation, which is elevated in the presence of CVDs and its cardiometabolic risk factors. Moreover, an evening meal consisting of brown beans decreased IL-6 and interleukin 18 (IL-18) levels. In contrast, in another studies, no effects in CRP, IL-6 and TNF-α were observed after diets enriched pulses [8, 21, 55, 56]. Soy isoflavones, whole soy foods, soy beverages or soy bread did not lower concentrations of CRP. Similarly, soy nuts did not reduce CRP, TNF-α an interleukins, such as IL-6, IL-18 or IL-10. However a significant reduction in circulating CRP was observed in postmenopausal women with and without metabolic syndrome after soy nuts consumption [8]. Dietary fibre (soluble and insoluble) and resistant starch content in pulses can explain the potential effects showed on CRP and other inflammatory markers, because this constituent was inversely associated with different inflammatory markers concentrations. SCFAs, PUFA, L-arginine, magnesium, and phenolic compounds (phenolic acids, flavonoids and anthocyanins) also have well documented anti-inflammatory potentials. Polyphenols have been shown to inhibit cellular enzymes that produce pro-inflammatory metabolites of fatty acids, such as arachidonic acid, prostaglandins and leukotrienes, thus exerting an important anti-inflammatory action, as well as downregulate the expression of pro-inflammatory markers. Additionally, non-soy legume's ability to reduce body weight and hyperglycaemia, and its low GI may also mediate in anti-inflammatory effects by the inhibition of production of advanced glycation end products, thereby decreasing the production of acute-phase reactants [8, 21, 52, 56].

Intakes of legume nutrients and bioactive compounds may also protect against atherosclerosis. Dietary fibre is supposed to ameliorate not only body metabolism and reduce chronic inflammation by affecting body weight, serum lipid profile, blood pressure and insulin sensitivity, but also reduce fibrinolysis and coagulation that may be important in the prevention of atherosclerotic plaque development and progression. Moreover, legume proteins hydrolysed in the digestive tract are a source of bioactive peptides (e.g. lunasin) which have been demonstrated to exert cholesterol-lowering effects, blood pressure-lowering ability as well as antithrombotic and antioxidant activities. Legumes have also folic acid that reduces homocysteine levels and therefore, reduces the risk of atherosclerosis and stroke. It has also been shown a strong association between polyphenols intake and reduction of atherosclerosis. Polyphenols have not only multiple antioxidant and anti-inflammatory effects, but also inhibit platelet activation thereby preventing activation of a prothrombotic state, lower expression of adhesion molecules and inhibit of smooth muscle cells proliferation [34, 38, 42, 52, 66].

Besides the aforementioned potential effects of pulse and soybeans on cardiometabolic risk factors, another potential mechanism of protection is due to the fact that increased intake of legumes reduces the intake of animal sources of protein that are high in saturated fatty acids and total fat which are one of the strongest atherosclerosis and CVDs incidences risk factor [38].

In summary, neither soy legumes nor non-soy legumes affect all cardiometabolic risk factors to the same extent. It may depend on many factors, such as interactions between components of legumes and other food products in the diet or daily amount of soybeans and/or pulses consumed, as well as inter-study heterogeneity, which was high in some analyses. Regardless of this, particularly strong cardiovascular health benefits have been observed with consumption of pulse, such as beans, peas, lentils and chickpeas.

CONCLUSION

Soybean and pulse seeds have an unique nutritional, functional and health attributes. Before use they are subjected to many traditional and modern thermal, mechanical and biochemical processes that allow to achieve the different forms of legume products: ready to eat (e.g. soy milk, tofu, sufu, tempeh, paste, sauce, soy oil) or cook (soy texture proteins) or semi-finished products used by food producers (flours and grits of different fat content, and concentrates and isolates). Processing techniques of soybeans and non-soy legumes reduce or eliminate anti-nutritional factors and enhance digestibility and bioavailability of nutrients as well as improve organoleptic properties of final products.

Systemic revives and meta-analyses of prospective cohort studies and randomized and non-randomized controlled trials have shown that legumes have a beneficial and complex effect on the cardiometabolic factors for the CVDs, including obesity, hypertension, hyperglycaemia and dyslipidaemia. Components contained in legumes and processed legume seed products such as vegetable protein, complex slowly digested carbohydrates, fiber and polyunsaturated fatty acids, as well as B-group vitamins, minerals and numerous bioactive compounds exert a multidirectional effect on satiety, energy expenditure, glucose and lipid homeostasis, and endothelium function, as well as have antithrombotic, antioxidant and anti-inflammatory properties in the endothelial and vascular smooth muscles cells. These variety of mechanisms determine the anti-obesity, antidiabetic, hypoglycemic, hypolipidemic, hypotensive and antiatherosclerotic effects of pulses and soybeans. Therefore, consumption of soy and nonsoy legumes may reduce the risk of morbidity and mortality from cardiovascular diseases.

Consuming legumes as a vegetables and processed legume seed products should be more common in Poland and should be recommended as a means of optimising cardiometabolic factors of CVDs risk in the primary prevention of cardiovascular diseases and their acute or chronic incidents.

PODSUMOWANIE

Nasiona roślin strączkowych charakteryzują się wyjątkowymi właściwości odżywczymi, funkcjonalnymi i zdrowotnymi. Przed spożyciem poddawane są wielu tradycyjnym i nowoczesnym procesom termicznym, mechanicznym i biochemicznym, które pozwalają na uzyskanie produktów o zróżnicowanym stopniu przetworzenia: gotowych do spożycia (np. mleko sojowe, tofu, sufu, tempeh, pasty, sosy, olej sojowy) lub gotowania (teksturaty białkowe) oraz półfabrykatów wykorzystywanych przez przemysł spożywczy (mąki i grysy o różnej zawartości tłuszczu oraz koncentraty i izolaty). Techniki przetwarzania soi i innych roślin strączkowych przyczyniają się do redukcji lub eliminacji składników antyodżywczych oraz zwiększają strawność i biodostępność składników odżywczych, a także poprawiają właściwości organoleptyczne gotowych produktów.

Przeglądy systematyczne i metaanalizy prospektywnych randomizowanych i nierandomizowanych kohortowych badań z grupą kontrolną wykazały, że rośliny strączkowe mają korzystny i złożony wpływ na kardiometaboliczne czynniki ryzyka chorób układu sercowo-naczyniowego, w tym na otyłość, nadciśnienie tętnicze, hiperglikemię i dyslipidemię. Składniki zawarte w roślinach strączkowych i przetworzonych produktach z nasion roślin strączkowych, takie jak białko roślinne, wolno trawione węglowodany złożone, błonnik pokarmowy i wielonienasycone kwasy tłuszczowe, a także witaminy z grupy B, składniki mineralne i liczne związki bioaktywne, wywierają wielokierunkowy wpływ na sytość, wydatek energetyczny, homeostazę glukozy i lipidów oraz funkcje śródbłonka, a także mają właściwości przeciwzakrzepowe, przeciwutleniające i przeciwzapalne w komórkach śródbłonka i mięśni gładkich naczyń. Te różnorodne mechanizmy działania wymienionych składników sprzyjają redukcji masy ciała i decydują o właściwościach przeciwcukrzycowych, hipoglikemizujących, hipolipemizujących, hipotensyjnych i przeciwmiażdżycowych nasion roślin strączkowych. W związku z tym spożywanie soi i roślin strączkowych innych niż soja może zmniejszyć ryzyko zachorowalności i śmiertelności z powodu chorób układu krążenia.

Spożywanie roślin strączkowych jako warzyw i przetworów z nasion roślin strączkowych powinno być w Polsce bardziej powszechne i powinno być zalecane jako sposób optymalizacji kardiometabolicznych czynników ryzyka chorób sercowo-naczyniowych w profilaktyce pierwotnej chorób układu krążenia oraz ich incydentów o ostrym lub przewlekłym przebiegu.

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