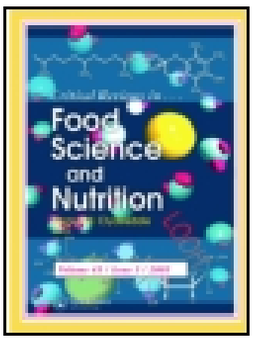

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REVIEW

Seeds from ancient food crops with the potential for antiobesity promotion

Talía Hernández-Pérez, María Elena Valverde, and Octavio Paredes-López

Unidad Irapuato. Departamento de Biotecnología y Bioquímica, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Irapuato, Guanajuato, México

ABSTRACT

Populations like to have a healthy diet without changing their fundamental dietary pattern. The importance of dietetic foods with health potential has increased the interest of consumers on crops with nutraceutical messages. Several plant food products from selected ancient crops like flax, chia, black cumin, sunflower, sesame, and pumpkin seeds contain substances with high health benefits. These crops are usually rich sources in fatty acids, sterols, phenolic compounds and dietary fiber which have mainly shown the ability to increase satiety and obesity control, among chronic degenerative diseases and others. These plant seeds offer outstanding features for the food and nutraceutical industries, due to their functional components. This review focuses on scientific evidence of the different potential benefits of these crops on human antiobesity promotion.

KEYWORDS

Bioactive compounds; nutraceuticals; obesity; overweight; seeds; weight loss

Introduction

Overweight and obesity are a major epidemy of our time throughout the globe; they are defined as having a body mass index (BMI) between 25 and 29.9, and greater than or equal to 30 kg/m^2, respectively. The latter, especially, is associated with negative health consequences. This outbreak is increasing at an alarming rate and is becoming one major problem of public health with incalculable social costs (Hossain, Kawar, and El Nahas 2020). In 2016, over 650 million adults were obese and 41 million children under the age of 5 were overweight or obese; Table 1 shows the percentage of populations in the different world regions with overweight and obesity (World Health Organization Report 2020).

Complex interactions among neuroanatomical, genetic, endocrinological, pathophysiological, nutritional, physical, psychological, and social-environmental factors are the reason of energy balance in humans. Obesity facilitates the development of metabolic disorders such as diabetes and cardiovascular disease, as well as chronic diseases like stroke, osteoarthritis, sleep apnea, some cancers and reduced immunocompetence (González-Castrejón and Rodriguez-Casado 2011).

Obesity is associated to inflammation, one of the most relevant processes involved into its metabolic consequences. It has also been linked to the metabolic syndrome, which is characterized by high levels of triglycerides, decrease of "good" cholesterol (high density lipoproteins, HDL), and increase of "bad" cholesterol (low density lipoproteins, LDL) and in blood pressure (Misra, Singhal, and Khurana 2010).

Developing countries are undergoing rapid nutrition transition concurrent with increases in obesity, metabolic syndrome, and type 2 diabetes mellitus (T2DM) (United States Department of Agriculture 2019). From healthy traditional high-fiber, low-fat and low-calorie diets, shifts are occurring toward increasing consumption of calorie-dense foods containing refined carbohydrates, fats, red meats, and low fiber. The low intake of healthy fats and oils in developing countries may have potentially deleterious metabolic and glycemic consequences (Misra, Singhal, and Khurana 2010).

Reduced calorie diets, increased intake of fiber and healthy fats are some key factors to prevent obesity and metabolic syndrome. In recent years, the potential of natural products to treat obesity has been an effective tool. Some bioactive compounds from oilseeds have been related to weight loss, such as inhibitors of enzymes involved in digestion and absorption of dietary fat and carbohydrates, inhibitors of factors of adipogenesis, as well as appetite suppressants (González-Castrejón and Rodriguez-Casado 2011; Vanamala et al. 2012). The nutritional composition of some staple seeds is shown in Table 2 (Kulaitiene et al. 2007; Muñoz et al. 2013; Sandoval-Oliveros and Paredes-López 2013; United States Department of Agriculture 2019).

In this review, we have analyzed the scientific information related to the anti-obesity capacity of the bioactive compounds from some edible oilseeds to face up the data found in websites promoting weight loss with scarce scientific support.

Benefits of seeds for weight loss

The use of medicinal plants for various ailments dates back to the earliest years of humankind evolution. Some of them have the potential to slow down the digestion of triacylglycerols in the pancreas and small intestine, playing an important role in the reduction of obesity. Seed oils may

CONTACT Talía Hernández-Pérez talia.hernandez@cinvestav.mx Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional, Unidad Irapuato. Departamento de Biotecnología y Bioquímica. Km 9.6 Libramiento Norte Carretera Irapuato-León. Irapuato, Guanajuato36824, México.

exhibit anti-inflammatory and immunomodulatory potential, and partially relieve symptoms of obesity-associated insulin resistance. Overweight and obesity were once considered high-income country problems, but nowadays these conditions are also rising in low- and middle- income countries, particularly in urban settings (Ado et al. 2013).

A well-established risk factor associated with some chronic diseases is an energy-dense dietary pattern rich in fat and refined carbohydrates and low in fiber. Due to its high energy density, fat has been recognized as an important macronutrient which dietary amount and type can be easily modified. It is generally accepted that an overabundance of saturated fatty acids (SFAs) can be harmful for the body, whereas polyunsaturated fatty acids (PUFAs) are considered rather beneficial. This role of PUFA-rich oils in cardiovascular disease and other obesity-related disorders is by improving blood lipid profile, blood pressure, adipocyte hormones, inflammatory response and endothelial function (Astrup et al. 2011).

Many researchers have shown that some selected seeds have the potential to reduce the risk of cardiovascular disease, T2DM, hypertension and improve serum lipid and lipoprotein profiles; these type of seeds are natural sources of α-linolenic acid (ALA, Ω-3), fiber, proteins of high biological value and natural antioxidants (Table 3) (Ajani, Ford, and Mokdad 2004; Buckley and Howe 2009; King et al. 2007; Liao et al. 2010; Marcinek and Krejpcio 2017; Poppitt et al. 2007; Queenan et al. 2007; Rodríguez-Pérez et al., 2019; Takeshita et al. 2007; Tsuda 2008; Yari et al., 2019). Oilseeds are involved in the steroid hormone formation, are also important sources of liposoluble vitamins and present high amounts of carotenoids, phenolic compounds, and tocopherols. They have shown biological functions such as antiinflammatory, anticancer, antimicrobial, antithrombotic, chelating, and immunomodulatory agents, as well as satiety modulators. In addition, non-obese subjects predisposed to T2DM presented reversal effects in obesity-related inflammation and insulin resistance by diets rich in plant seed oils (Henninger et al. 2014).

It has been shown that obesogenic diets (low complex carbohydrates and fiber, and high fat) may affect gut microbiota and potentially be adverse in the distal intestine (Murphy et al. 2010). Currently, there is a tendency toward searching for alternative plant foods with outstanding fatty acid profile, biologically active substances and potential health-promoting properties.

Figure 1 shows in a basic descriptive way the use of selected seeds, and extraction procedures to identify the chemical components responsible for weight control, and the effects on human weight management; induction of satiety is one of the remarkable procedures to control obesity.

Table 1. Estimated prevalence of overweight (BMI 25–29.9) and obesity (BMI ≥ 30) among adults[a] in World Health Organization regions.

	Overweight	Obesity
Region	Percentage (%)	
Africa	31.1	10.6
Americas	62.5	28.6
South-East Asia	21.9	4.7
Europe	58.7	23.3
Eastern Mediterranean	49.0	20.8
Western Pacific	31.7	6.4
Global	38.9	13.1

BMI, body mass index (kg/m^2).
[a]Person aged ≥18 years.
Adapted from World Health Organization Report 2020.

Flaxseed

Flaxseed (*Linum usitatissimum*) belongs to the Linaceae family and is a blue flowering annual herb that produces small flat seeds with crispy texture and nutty taste. Flaxseed is one of the oldest crops and has been cultivated since the beginning of civilization. Today, it is cultivated in more than 50 countries being Canada the world's largest producer and exporter (Singh et al. 2011).

This crop has emerged as an attractive nutritional food and has interested to nutritionists and medical researchers due to its exceptionally high content of ALA, dietary fiber, lignans secoisolariciresinol diglycoside (SDG, lignans precursor), high quality proteins and phytoestrogens. Among the functional foods, flaxseed is a good source of phenolic compounds which have shown anticarcinogenic, antioxidative, antiestrogenic, antiinflammatory, anti-rheumatic, anti-platelet capacity, and hypoglycemic (Singh et al. 2011; Toure and Xueming 2010).

Flaxseed contains about 40–45% oil (from which up to 52% is ALA), 20–25% protein, 20–25% fiber and 1% lignans SDG. Its oil has an exceptional healthy fatty acid profile with high levels of PUFAs, moderate levels of

Table 2. Nutritional composition of some ancient edible seeds (*per* 100 g, dry basis).

Nutrient	Flaxseed	Chia	Black cumin	Sunflower seed	Sesame	Pumpkin seed
Energy (kcal)	450	468	375	584	573	541
Proteins (g)	20	22.7	17.8	20.7	17.3	31.1
Total fat (g)	41	32.5	1.5	51.4	49.6	42
SAFs (g)	*nr*	3.3	0	4.4	6.9	8.6
MUFAs (g)	*nr*	2.3	14.0	18.5	18.7	14.2
PUFAs (g)	23	23.6	3.2	23.1	21.7	20.9
Carbohydrates (g)	29	17.8	44.2	8.6	23.4	17.81
Total dietary fiber (g)	28	33.5	10.5	8.6	11.8	3.9
Insoluble fiber (g)	*nr*	25.4	*Nr*	*nr*	*nr*	*Nr*
Soluble fiber (g)	*nr*	8.2	*Nr*	*Nr*	*nr*	*Nr*

SAFs saturated fatty acids, *MUFAs* monounsaturated fatty acids, *PUFAs* polyunsaturated fatty acids.
nr, not reported.
Adapted from Kulaitiene et al. 2007; Muñoz et al. 2013; Sandoval-Oliveros and Paredes-López 2013; United States Department of Agriculture 2019.

Table 3. Functional compounds from edible seeds and their role in the control of obesity and its metabolic consequences.

Compound	Metabolic effect	Mechanism of action
Dietary fiber	Anti-inflammatory	Anti-inflammatory compounds
	Weight control	Improve anthropometric measurements, lower lipid oxidation, induce satiety
	Insulin sensitivity	Soluble fiber reduces postprandial glucose and insulin and decreases absorption of macronutrients; insoluble fiber increases satiety
	Lipid profile	Increase excretion of bile acids
CLA	Weight control	Reduce lipoprotein lipase activity and increase lipid β-oxidation
MUFAs	Weight control	Lower leptin concentrations
PUFAs	Anti-inflammatory	Dietary modulation of genetic susceptibility, interfere with monocyte chemotaxis and alter eicosanoid synthesis
	Lipid profile	Reduce hepatic synthesis and secretion of very low density lipoproteins
	Weight control	Inhibit lipid synthesis enzymes and increase thermogenesis and prevent lipogenesis
Plant sterols	Weight control	Interfere with intestinal fatty acid absorption
Polyphenols	Anti-inflammatory	Attenuate inflammatory response and suppress oxidative stress
Anthocyanins	Weight control	Lower food intake, decrease lipogenesis, increase lipolysis, stimulate fatty acids β-oxidation and inhibit adipocyte differentiation and growth
	Lipid profile	Reduce blood cholesterol absorption and increase fecal cholesterol excretion
	Weight control	Regulate adipocyte function
High protein foods	Weight control	Lower energy intake by high post-absorptive satiating and thermogenic effect

CLA conjugated linoleic acid, *MUFAs* monounsaturated fatty acids, *PUFAs* polyunsaturated fatty acids.
Adapted from Ajani, Ford, and Mokdad 2004; Buckley and Howe 2009; King et al. 2007; Liao et al. 2010; Marcinek and Krejpcio 2017; Poppitt et al. 2007; Queenan et al. 2007; Rodríguez-Pérez et al. 2019; Takeshita et al. 2007; Tsuda 2008; Yari et al. 2019.

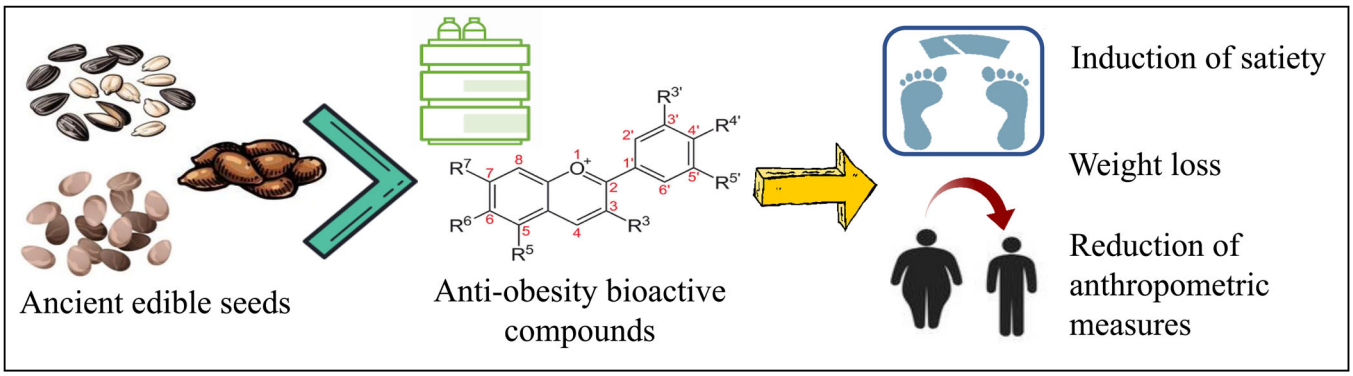

Figure 1. Graphical description of the ancient food crops and their effects.

monounsaturated fatty acids (MUFAs), and low concentrations of SFAs. Elevated intakes of flaxseed ω-3 fatty acids are associated with lower circulating levels of leptin, which is a hormone released by adipose cells and enterocytes in the small intestine that helps to regulate energy balance by inhibiting hunger (Rabetafika et al. 2011). Current dietary recommendations for adults suggest a daily intake of 2.22 g ALA based on a 2,000 kcal diet. Additionally, flaxseed oil helps muscle cells to respond effectively to insulin facilitating energy metabolism; when this oil is consumed in early life helps to inhibit the development of an excess of fat cells. All these findings have led researchers to conclude that flaxseed oil may prevent and reverse obesity (Bloedon and Szapary 2004; Hossain, Kawar, and El Nahas 2020).

A diet enriched with high-oleic canola and flaxseed oils significantly increased *n*-acetylamides (endogenous satiety and energetic molecules) plasma levels with an important reduction in body fat in hypercholesterolemic patients. Flaxseed-enriched diets have shown a reduction of 11 and 18% total cholesterol and LDL levels, respectively (Bloedon and Szapary 2004).

Flaxseed contains, as indicated, high levels of fiber, from which 2/3 are insoluble and 1/3 soluble. The insoluble fraction slows down the release of sugar in the blood stream and reduces glucose levels. The soluble portion (mucilage) increases viscosity of intestinal content, delaying gastric emptying and nutrient absorption, which prevent cardiovascular diseases by reducing lipid absorption (Thakur et al. 2009).

The flaxseed lignans SDG significantly reduce visceral and liver fat accumulation, hyperlipidemia, hypercholesterolemia and hyperinsulinemia in mice (Fukumitsu et al. 2008). Park and Velasquez (2012) found that an SDG-enriched flaxseed powder reduces body weight and fat accumulation, improves lipid profile and blood pressure in rats.

In the last decades, research in the nutritional and health benefits of flaxseed has included this ancient seed in a regular dietary patterns as preventive measure against obesity and chronic diseases (Tsuda 2008; Yari et al. 2019). Most of this information is related to its effect in weight loss and satiety, as well as diuretic and depurative properties; flaxseed is indicated as slim agent due to the capacity to "burn off" the ingested calories. Also, it is mentioned that the antioxidants present in flaxseed improve metabolism, the dietary fiber promotes satiety and fullness, and the ω-3 fats reduce the urge for sweets; these characteristics are shown as alternative to lose weight rapidly. Besides, this seed is indicated to reduce the urge for snacks, which is an effective tool to lose weight or to support the reduction of extra pounds (How to use flaxseed oil for weight, loss, December 10, 2019, http://superfoodprofiles.com; Slimming benefits of flax

seeds: how to lose weight faster using ground flaxseed, December 22, 2019, http:l//www.brainyweightloss.com).

Chia

Chia (*Salvia hispanica*) belongs to the Lamiaceae family and is an annual herb growing up to 1 m tall and has opposite arranged leaves with small white or purple flowers. The seed color varies from black, gray, and black spotted to white, with oval shape (1–2 mm size). It is native to Mesoamerica and its use as human food dates back to 3, 500 BC. Aztecs and Mayas used this seed to prepare medicines and dishes. Chia was one of the main crops of pre-Columbian societies; the Aztecs handled it as tributes and also was used as offering to their gods; however, Spanish conquerors suppressed it for religious reasons (Ayerza and Coates 2005; Muñoz et al. 2013).

Seeds have approximately 15–25% protein, 26–41% carbohydrates and 30–33% fat; its oil comprises 55% Ω-3, 18% Ω-6, 6% Ω-9, all of them essential fatty acids, and 10% saturated fat. It has the highest known percentage of ALA of any plant source. ALA is the dietary precursor of the long-chain Ω-3 PUFAs (eicosapentaenoic and docosahexaenoic acids), which are associated to weight loss, well-balanced body composition, reduction of risk factors in overweight adults, inflammation, oxidative stress, and blood pressure (Capitani et al. 2012; Reyes-Caudillo, Tecante, and Valdivia-López 2008).

S. hispanica seeds comprise 36–40 g/100 g dietary fiber, including soluble and insoluble, which is equivalent to 100% of the daily recommendations for adults. The seed releases mucilage (soluble fiber) when soaked in water and can absorb up to 12 times its weight, which aids digestion, increases post-meal satiety and decreases subsequent hunger (Martínez-Cruz and Paredes-López 2014; Orona-Tamayo, Valverde, and Paredes-Lopez 2019). Also, it is a rich source of B vitamins and minerals, as well as antioxidants, such as phenolic compounds, *i.e.*, chlorogenic and caffeic acids, quercetin and kaempferol (Chicco et al. 2009). It is worth to mention that chia is a gluten-free seed, thus it is a suitable option for celiac patients (Vuksan et al. 2017).

Several investigations have been conducted regarding the intake of seeds on health. Diabetic overweight or obese patients followed a 6-month calorie-restricted diet and received either *S. hispanica* (Sh) or an oat bran-based control (30 and 36 g/1,000 kcal/day, respectively). Sh patients lost more weight than control, accompanied by greater reductions in waist circumference. C-reactive protein, an inflammation marker, was reduced in Sh group and in plasma adiponectin increased 6.5%; adiponectin is involved in insulin sensitivity, lipid oxidation, development of atherosclerosis and coronary heart disease. Obese mice fed with a high-fat diet received chia oil from 90 to 135 days, and reduced fat mass accumulation and increased lean mass as evidenced by nuclear magnetic resonance. They also improved glucose levels and insulin tolerance, decreased serum leptin and triacylglycerols, and increased LDL cholesterol (Fonte-Faria et al. 2019).

Due to the outstanding nutraceutical potential of chia, it has been related to promote the feeling of satiety for a long period, thus reducing the urge of binge or eat food rich in sugar, processed carbohydrates or saturated fat. Consumption of chia for 12 weeks has been associated to significant reductions in body weight, waist circumference, and blood lipid profiles (Chia seeds weight loss, January 22, 2020, http://jma4law.com; Can chia seeds help me lose weight? January 7, 2020, http://longevity.about.com).

Black cumin

Nigella sativa (black cumin) is native to the Middle East and is one of the most common traditional herbs used here for weight loss. It is an annual flowering herb of the Ranunculaceae family and widely used in India, some countries of Europe and Egypt. The plant grows 20–30 cm tall and is commonly used as spice and in traditional medicine to treat inflammatory diseases and obesity (Botnick et al. 2012; United States National Institutes of Health 2019).

Black cumin contains different bioactive compounds, mainly sterol and essential fatty acids, 36–42% fixed oils, 23% proteins, 1% volatile oils, alkaloids, tannins, saponins, phytosterols, and reducing sugars. The major fatty acids are linoleic, oleic, palmitic, margaric, stearic, eicosenoic, linolenic and myristic. Its essential oils contain thymohydroquinone, a compound with antioxidative properties (Kokoska 2011).

N. sativa was mentioned in the "Medicine of the Prophet" as natural remedy to cure all pathological conditions (Dajani, Shahwan, and Dajani 2016). It is also known as the blessed seed by the Arabs, black cumin in the Holy Bible, and black caraway and Kalonji in South Asia; it has been used for centuries as food and as complementary drug. Its active ingredients are used since ancient times as Unani, Ayurveda, and Chinese medication for diseases like asthma, rheumatoid arthritis, and immune disorders. Additionally, it has been employed to treat hypertension, hypercholesterolemia, bronchitis, cough, dizziness, fever, headache, and influenza. Studies indicate that black cumin also has cardioprotective, anticancer and antidiabetic properties (Dajani, Shahwan, and Dajani 2016; Payab et al. 2020).

Black cumin has been a complementary treatment for obesity and its metabolic alterations (Vanamala et al. 2012). Datau et al. (2010) reported that obese men consuming 1.5 g of black cumin daily for three months significantly reduced body weight, waist circumference, and systolic blood pressure. Besides, cumin powder in a weight reduction diet showed improvement in anthropometric and biochemical parameters in overweight/obese women (Heshmati and Namazi 2015).

The antihyperglycemic activity of the seed extract has demonstrated its ability to increase insulin secretion, induce proliferation of pancreatic β-cells and stimulate glucose uptake in skeletal muscle cells and adipocytes. Seed extracts inhibited intestinal glucose absorption with an IC_{50} value close to 10 pg/ml. *N. sativa* has the ability to modulate hyperglycemia and lipid profile dysfunction due to its antioxidant capacity and influence on insulin secretion, glucose absorption, gluconeogenesis and gene expression (Heshmati and Namazi 2015).

Alanazi et al. (2016) identified 277 proteins in *N. sativa* proteome and the majority were involved in carbohydrate metabolism, amino acids and shikimate pathway, lipid metabolism, cell organization, transport, and defense processes. The study of its proteome is important because of the high application as nutraceutical ingredient.

Cleopatra and Queen Nefertiti used black cumin as beauty treatment; it was referred as "remedy for every illness". Hippocrates used the seeds to cure digestive and metabolic imbalances. There are numerous studies demonstrating that cumin has the capacity to cure, improve, or inhibit cancer, autoimmune disorders, tumor growth, human immunodeficiency virus (HIV), high blood pressure, and high cholesterol. Also, it has anti-obesity properties and the ability to prevent and treat metabolic syndrome, a common side effect of prolonged obesity (Black cumin seed shown to increase benefits of exercise and combat obesity, February 25, 2020, http://blogs.naturalnews.com; Can you lose weight with Nigella sativa? February 19, 2020, http://www.nigella–sativa.com).

Sunflower seed

Sunflower (*Helianthus annuus* L.) belongs to the *Asteraceae* family and is an annual crop formed only by a single large inflorescence in the top and erect rough-hairy stem. Sunflower was first domesticated in Central and North America and then introduced into Europe in the XVI century. Nowadays, it is the fourth most important oilseed and the main centers of production are the USA, Ukraine and Argentina (Salas et al. 2014). The seed is rich in linoleic acid, which accounts from 48 to 74% of the total fatty acids. Besides, it contains low levels of SFAs (palmitic and stearic) and, unlike other seed oils such as soybean and rapeseed, negligible amounts of ALA (Rolletschek et al. 2007).

Ziv et al. (2009) reported that high oleic sunflower oil fatty acid esters of plant sterols mixed with diacylglycerol fed to diabetes-prone gerbils counteracted the increase in body weight and epididymal fat deposits and resulted in lower circulating insulin levels. A diacylglycerol-rich oil from sunflower seeds reduced postprandial hypertriglyceridemia as compared to dietary triacylglycerol oil, which could be a promising way to control obesity (Dhara and Singhal 2014). Stachoń, Furstenberg, and Gromadzka-Ostrowska (2006) demonstrated that rats consuming high amounts of linoleic acid in high fat diets supplemented with sunflower oil tended to have higher plasma leptin levels than with rapeseed and palm oil; they also found low levels of the hypothalamus neuropeptide Y. In addition, a 12-week administration of sunflower seed extracts (500 mg/day) to male and female obese patients led to significant reductions in body weight, BMI, and waist circumference, especially in females. Changes were associated to fat mass loss and decreases in blood cholesterol were also observed (Leverrier et al. 2019).

Along different websites, *H. annuus* seeds are described as triple threats; besides being tasty and good for health, they contain nutrients that help to lose weight fastly, but safely. These seeds are ideal crunchy snacks that reduce appetite and are the best whole-food source of vitamin E; besides, they are a rich source of proteins and low in carbohydrates. Furthermore, they provide benefits for a healthy cardiovascular status. It is important to note that no single food can successfully lead to weight loss; to get the best results it is necessary to follow balanced dietary plans including wide varieties of healthy and low-calorie foods (Can sunflower seeds make you lose weight? February 25, 2020, http://www.livestrong.com; Sunflower seeds – healthy snack packed with vitamin E, February 28, 2020, http://www.shapefit.com)

Sesame seed

Sesame (*Sesamum indicum* L., Pedaliaceae family) is one of the oldest edible oil crops and its seeds are used as food source. It is an annual plant growing 50–100 cm tall with yellow, white, blue, or purple flowers, and small seeds (4 mm long, 2 mm wide); and main sesame world producers are Tanzania and India (FAOSTAT 2019).

S. indicum seeds are a traditional health food in Asian countries for thousands of years and have been used to improve nutritional status and prevent various diseases. These seeds are not only rich in oil (about 50%) and protein (about 20%), but also in lignans (up to 1.5%). Its oil is characterized by its resistance to oxidative rancidity despite its high content of unsaturated fatty acids (about 85%); this oxidative stability is attributed to the presence of γ-tocopherol and lignans, mainly sesamin, sesamolin, and sesamol. Linoleic and oleic acids are the most abundant unsaturated fatty acids, representing 40% of the total oil. In fact, around 70% of the world's production of sesame is used for oil extraction (Konsoula and Liakopoulou-Kyriakides 2010; Moazzami, Haese, and Kamal-Eldin 2007).

Some studies suggest that sesame lignans may comprise beneficial effects for cardiovascular diseases due to its unique lignans. Sesamin, its major lignan, is a precursor to phytoestrogens, enterolactone and enterodiol. These compounds protect the liver against ethanol-induced injury and possess *in vivo* and *in vitro* anticancer and neuroprotective capacity; sesamin also suppresses hepatic fatty acid synthase expression in rats. An increased intake of sesame seeds or purified sesamin showed hypocholesterolemic and antihypertensive effects (Hsu and Parthasarathy 2017; Liu, Saarinen, and Thompson 2006).

Brown adipose tissue is the site of non-shivering thermogenesis in mammals, wherein energy is dissipated as heat. Sesaminol diglucoside obtained from sesame extracts increased the expression of uncoupling protein 1 in brown adipocytes from mice. It also decreased white fat pads and serum glucose levels, thereby protecting mice against high fat induced weight gain (Jahagirdar et al. 2018). In addition, sesame components exhibited a very high binding activity to adenosine A1 receptor, which is associated with lipolytic activity (Yuliana et al. 2011).

Chen et al. (2005) observed that hypercholesterolemic patients consuming 40 g of roasted sesame for four weeks

showed reductions of 6.4 and 9.5% in serum total and LDL cholesterol, respectively; sesame also exerted antioxidant capacity.

According to ayurveda experts, sesamol provides antioxidant properties and could be used for the management of obesity. Also, sesame oil (sesamolinol) promoted the reduction of over 30 kg in more than 3000 patients in India. These same experts revealed that 10 kg-weight loss has been registered in nearly 10,000 patients along the country (Can sesame seeds help you lose weight? January 8, 2020, http://www.livestrong.com; Sesame oil helps in weightloss, December 29, 2019, http://timesofindia.indiatimes.com).

Pumpkin seed

Cucurbita plant belongs to the Cucurbitacea family and is native to Mesoamerica and to the Andes. This crop is primarily grown as vegetable or ornamental plant. It produces orange, green, gray, yellow or red fruits (pumpkin). Its high nutritional value is essential for human health. Pumpkins (*Cucurbita* sp.) have been used for long time in Chinese medicine to treat intestinal parasites, biliary vesicle and prostate problems. Their seeds have shown hypoglycemic, antioxidant, anticancer and anti-inflammatory effects (Adams et al. 2011).

Oil is the main component of pumpkin seeds (42%), being MUFAs (oleic) and PUFAs the most abundant, with some SFAs (palmitic and stearic). They are also a valuable source of protein (25–37%) with low amounts of sugar and starches. Thus, the oil comprises palmitic, stearic, and mainly oleic and linoleic acids. Tocopherols and phytosterols occur in the largest quantities. Seeds also contain squale (89 mg/100 g), biosynthetic precursor to steroids in plant and animal cells (Applequist et al. 2006; Kulaitiene et al. 2007).

Adams et al. (2011) demonstrated that trigonelline, nicotinic acid, and d-chiro-inositol from pumpkin seeds possess hypoglycemic properties and could assist in maintaining glycemic control and satiety. Besides, diets with flax and pumpkin seeds administered to hypercholesterolemic rats showed significant anti-atherogenic, hypolipidemic and antioxidant potential.

The prevention and treatment of obesity is the best strategy to reduce cardiovascular risk, diabetes and depression. Obese male Wistar rats receiving pumpkin extracts (100, 200, or 400 mg/kg) once daily for six weeks, dramatically decreased triglycerides, LDL cholesterol and liver enzymes while HDL was markedly increased. Hence, the capacity of pumpkin to ameliorate oxidative stress and dyslipidemia leads to reductions of heart conditions in obese patients (Quanhong et al. 2005). A study by Kalaivani et al. (2018) using *Cucurbita maxima* seeds oil (100 mg/kg body weight, supplemented over 30 days on high-fat diet-induced obese rats, significantly reduced body weight gain, glucose and insulin levels, and improved lipid profile.

Data from internet show that *Cuburbita* seeds help to burn fat, thus it is recommended as snack to promote health, endurance and better body weights. Also, the consumption of this seed is encouraged due to its ability to boost the metabolism, improve heart health, help sleep, protect bones, eliminate kidney stones, as well as to enhance the immune system, and detoxify the body (5 reasons to add pumpkin seeds to your diet, January 15, 2020, http://inspiyr.com; Health benefits of pumpkin seeds, January 25, 2020, https://www.organicfacts.net).

Conclusions

Nowadays, obesity is a major epidemy worldwide and the growing interest on its prevention and treatment through the use of functional foods and nutraceuticals has increased the research on the effects of ancient edible seeds such as those considered for this work.

These crops used in different ways since old times have been extensively studied in the last few decades as source of bioactive compounds and as natural agents to reduce the side effects of obesity and overweight, *i.e.*, metabolic syndrome; crops that with frequent uses in human nutrition may improve the quality of life.

Besides, seed oil components as additional products have become economically attractive for farmers and food producers, in order to exploit better the functional properties of these interesting old and at the same time novel crops. The economic and health costs of obesity and its comorbidities such as fatty liver, insulin resistance/diabetes, or cardiovascular events are considerably high; therefore, every strategy designed to reduce obesity may imply important social security benefits and savings.

Disclosure statement

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