Polyphenol-Rich Lentils and Their Health Promoting Effects

Subjects: Food Science & Technology

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Lentil (Lens culinaris; Family: Fabaceae) is a potential functional dietary ingredient which has polyphenol-rich content. Several studies have demonstrated that the consumption of lentil is immensely connected to the reduction in the incidence of diseases such as diabetes, obesity, cancers and cardiovascular diseases due to its bioactive compounds. There has been increasing scientific interest in the study area of lentils as the functional food due to its high nutritive value, polyphenols, and other bioactive compounds. These polyphenols and the bioactive compounds found in lentil play an important role in the prevention of those degenerative diseases in humans. Besides that, it has health-promoting effects.

polyphenols lentils antioxidants degenerative diseases health-promoting effects

1. Introduction

Lentil (*Lens culinaris*; Family: Fabaceae) is an annual indigenous plant from Western Asia and other parts of the world, including North America. Furthermore, this species is now diversified from Hindukush to Afghanistan and Ethiopia to Mediterranean countries [1]. It is well known for its lens-shaped edible seed, which has the most significant dietary compositions, containing macro- and micro-nutrients [2]. Lentils exist as a spectrum of colors, which includes yellow, orange, red, green, brown or black, depending on the cultivar, the composition of the seed coats and cotyledons [3]. The color of dehulled seeds is mainly associated with the cotyledon color, which could be yellow, red or green. While the color of the intact seed is based on the seed coat, it could be tan, brown, green, gray or black. The seed coats of lentil have a higher amount of flavan-3-ols, proanthocyanidins and some flavonols. This suggests that lentil featuring green and gray seed coats might be more promising for a health-promoting diet. According to the Food and Agriculture Organization statistics report in 2014, the global production of the lentils was primarily cultivated and harvested by Canada and India, which were estimated to be 1.99 million and 1.1 million metric tons, followed by Turkey (0.34 million), Nepal (0.22 million) and China (0.125 million) [4]. The evidence demonstrated that the consumption of lentils is highly associated with reductions in the incidence of degenerative diseases including diabetes, cardiovascular disease (CVD) and cancers. There has been an increase in scientific interest of the study of lentils as a functional food due to their high nutritional compositions, nutritive value and the presence of bioactive secondary metabolites. These bioactive compounds in lentils play a vital role in the prevention of degenerative diseases in humans and a significant role in improving health.

2. Nutritional Compositions of Edible Lentils

Nutritional compositions of raw, sprouted and cooked lentils are summarized in **Table 1**. Lentils are known to be an abundant source of protein storage, providing essential and non-essential amino acids to the human body. The predominant proteins in lentils are globulin (47% of the total seed proteins) and an adequate quantity of albumin [5]. Lentils play an important role in crop rotation and the ability to fix atmospheric nitrogen. High quantities of these proteins and essential amino acids in lentils offer an important dietary source for low and middle-income countries [6]. Among 23 pulses, lentils yield the second highest starch percentage of 47.1% and a greater percentage of insoluble dietary fibers [7][8]. Lentils are known to be a good source of prebiotics [9] and have nutritionally important quantities of prebiotic carbohydrates (12.3–14.1 g/100 g of dry lentils) that help to keep up the gut microbial environment and prevent gut-associated diseases [10][11]. Furthermore, lentils are relatively low in fat and sodium, but high in potassium content (1:30 ratio of sodium and potassium) [12]. Given that, it is the best dietary food for patients with obesity and CVD. Lentil seeds are an excellent vegetable source of iron. Studies have shown that the consumption of cooked lentil in the diet prevents iron deficiency anemia [13], iron being a very important mineral, which is required daily, especially for adolescents and pregnant women. Several minerals (zinc, copper, manganese, molybdenum, selenium and boron) and vitamins (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, folate, α, β and γ tocopherols and phylloquinone) have been well documented in lentils [7][14][15]. Furthermore, lentils have an average quantity of vitamin K of 5 µg/100 g, as reported by the United States Department of Agriculture (USDA) [7]. However, the daily requirement of this vitamin in adults is about 80 µg. The low content of vitamin K renders lentils as safe for patients with CVD upon anticoagulant treatment. Overall, lentils are considered as one of the best dietary sources that has health-promoting effects on various illnesses.

Table 1. Nutritional compositions of lentils in 100 g of the edible portion [7].

Nutrients	Unit	Raw	Sprouted	Cooked
Water	g	8.26–9.65	51.85–67.34	69.64–137.89
Energy	kcal	343–356	82–106	116–226
Protein	g	24.44–25.71	6.9–8.96	9.02–17.86
Total lipid (fat)	g	0.92–1.06	0.42–0.55	0.38–0.75
Carbohydrate	g	60–64.44	17.05–22.14	20.13–38.69
Total dietary fiber	g	10.7–31.4	-	7.9–15.6

Nutrients	Unit	Raw	Sprouted	Cooked
Total sugars	g	2.03–2.86	-	1.80–3.56
Minerals				
Calcium	mg	35–57	19–25	19–38
Iron	mg	6.51–7.71	2.47–3.21	3.33–6.59
Magnesium	mg	47–69	28–37	36–71
Phosphorus	mg	281–335	133–173	180–356
Potassium	mg	677–943	248–322	369–731
Sodium	mg	3–6	8–11	123–471
Zinc	mg	3.27–5.89	1.16–1.51	1.27–2.51
Vitamins				
Vitamin C	mg	3.4–4.5	12.7–16.5	1.5–3.0
Thiamin	mg	0.756–0.873	0.176–0.228	0.169–0.335
Riboflavin	mg	0.189–0.211	0.099–0.128	0.073–0.0145
Niacin	mg	2.605–3.459	0.869–1.128	1.060–2.099
Vitamin B6	mg	0.540–0.698	0.146–0.190	0.178–0.352

Nutrients	Unit	Raw	Sprouted	Cooked
Folate	µg	479–555	77–100	181–358
Vitamin B12	µg	0.00	0.00	0.00
Vitamin A, RAE	µg	2.0–2.5	1.8–2.0	0
Vitamin A, IU	IU	32–39	35–45	8–16
Vitamin E	mg	0.49–0.55	0	0.11–0.22
Vitamin K	µg	4.2–5.0	0	1.7–3.4
Lipids				
Total saturated fatty acids	g	0.154–0.198	0.044–0.057	0.053–0.105
Total monounsaturated fatty acids	g	0.0179–0.193	0.08–0.104	0.064–0.127
Total polyunsaturated fatty acids	g	0.469–0.526	0.169–0.219	0.175–0.346

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Bioactive Functional Groups	Individual Components	Quantity in 100 g of Lentils	Biological Functions	Reference
Phytosterols	β-sitosterol	15.0–24.0 mg	Regulate the membrane fluid	[14][16]
	campesterol	15.0 mg		
	stigmasterol	20.0 mg		
Active Proteins				

Bioactive Functional Groups	Individual Components	Quantity in 100 g of Lentils	Biological Functions	Reference
Trypsin/protease inhibitors	Bowman–Birk trypsin inhibitors	3–8 trypsin inhibitor unit (TIU)/mg	Anti-nutritional components; decrease the digestibility of dietary proteins; inhibit the cell proliferation in cancer	[17][18]
Lectins	Lectins or hemagglutinins	12.0 mg	Ability to agglutinate red blood cells RBC and strong stimulators of murine B lymphocyte proliferation	[19][20]
Defensins	Defensins	8.0 mg	Participate in the development of innate immunity	[21]
Dietary Fibers	Fibers	Insoluble fibers (93–99.7 mg/g) and soluble fibers (<7 mg/g)	Potential effect of hypocholesterolemic, anti-cancer, anti-tumor, antibacterial and hypoglycemic effects	[7][22]
	Resistant starches	25.4 g	Significant contributor to gastrointestinal health and gut microbiota	[23]
Polyphenols Flavonoids	Flavonols (e.g., quercetin and kaempferol)	0.03 to 10.85 and 0.24 to 13.20 mg	Antioxidant potential	[3][24]
	Flavones, flavanones	Total phenolic content: 26 mg gallic acid equivalents (GAE/100 g	Antioxidant activity and potential effect on cardiovascular disease	[24][25]

Bioactive Functional Groups	Individual Components	Quantity in 100 g of Lentils	Biological Functions	Reference
		fresh wt; total flavonoid content: 21 mg catechin equivalents/100 g, and the condensed tannin content of 870 mg catechin equivalents/100 g	(CVD), diabetes, osteoporosis and neurodegenerative diseases	
	Proanthocyanidins or condensed tannins (e.g., prodelphinidins and procyanidins)			
	Flavan-3-ols or flavanols (e.g., catechin and gallocatechin)	759 mg (GAE)/100 g; glycosides of flavanones: 33.1–186.0 µg; glycosides of flavonols: 9.6–241 µg; dimers procyanidins: 619–1122 µg; trimer procyanidins: 441–498 µg; tetramer procyanidins: 18.5–59.5 µg; galloylated procyanidins 69.3–123 µg	Antioxidant activity	[3][24]
	Anthocyanidins (e.g., delphinidin and cyanidin)			
Polyphenols Non-flavonoids	Hydroxybenzoic acids	Hydroxybenzoic acids: 4.5–28.4 µg	Antioxidant activity and potential effect on diabetes, osteoporosis CVD and neurodegenerative diseases	[24][25]
	Hydroxycinnamic acids (e.g., *p*-coumaric acid, ferulic acid and sinapic acid)	Prodelphinidins 369–725 µg; condensed tannins: 870 mg catechins equivalent	Antioxidant activity	[3][24]

Bioactive Functional Groups	Individual Components	Quantity in 100 g of Lentils	Biological Functions	Reference
	Stilbenoids, trans-resveratrol-3-*O*-glucoside	Glycosides of trans-resveratrol: 5.5–9.3 µg;	Antioxidant activity and potential effect on diabetes and CVD	[24][25]
Phytoestrogens: isoflavones	Formononetin, daidzein, genistein, glycitein, matairesinol, biochanin A, coumestrol, lariciresinol, pinoresinol, secoisolariciresinol, coumestrol [30][31]	Total isoflavones (9.5 µg), total lignans (26.6 µg) and total phytoestrogens (36.5 µg) [3]	Antioxidant potential	[26]
Phytate	Phytic acid	620 mg	Inhibit the proliferation of colorectal cancer	[27]
Triterpenoids	Squalene	0.7 mg [31][32]	Chemopreventive potential against colorectal cancer [30][31][32][33][34][35][36][37]	[28]
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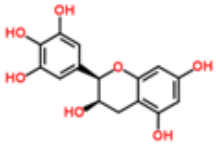
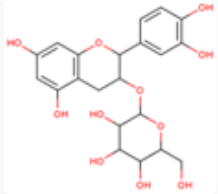
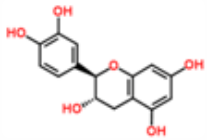
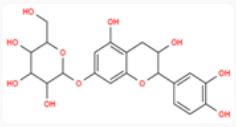
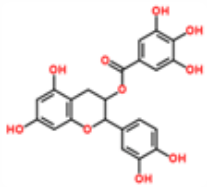
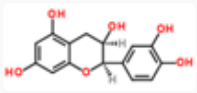
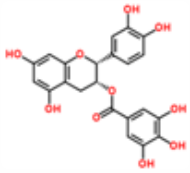
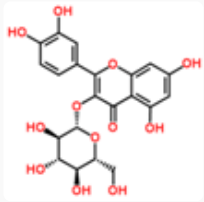
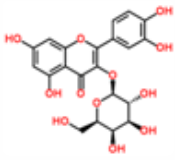
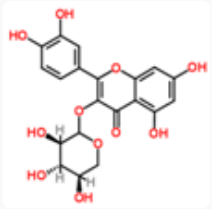
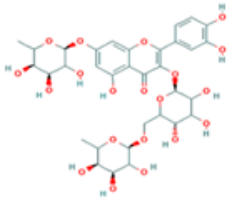
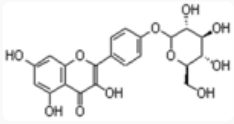
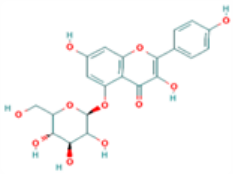
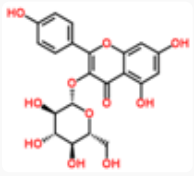
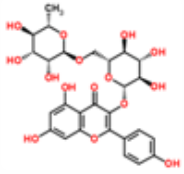
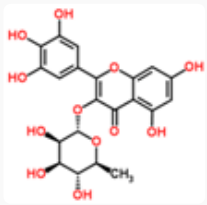
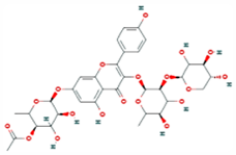
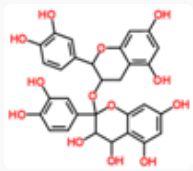
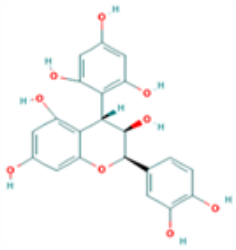
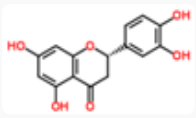
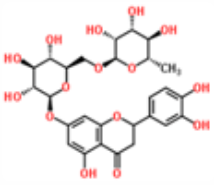
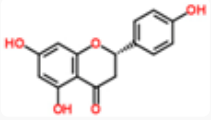
Polyphenol	Classes	Sub-Classes	Compound Name	Structure
Flavonoids	Flavonoids	Flavanols	(−)-Epigallocatechin	
			(+)-Catechin-3-*O*-glucose	

Polyphenol	Classes	Sub-Classes	Compound Name	Structure
			Catechin	
			Catechin-7-*O*-glucoside	
			Catechin gallate	
			Epicatechin	
			Epicatechin gallate	
		Flavonols	Quercetin-3-*O*-glucoside	
			Quercetin-3-*O*-galactoside	

Polyphenol	Classes	Sub-Classes	Compound Name	Structure
			Quercetin-3-*O*-xyloside	
			Kaempferol-3-*O*-rutinoside 7-*O*-rhamnoside	
			Kaempferol-4′-*O*-glucoside	
			Kaempferol-5-*O*-glucoside	
			Kaempferol-3-*O*-glucoside	
			Kaempferol-3-*O*-rutinoside	

5. Health Promoting Effects of Lentils

Polyphenol	Classes	Sub-Classes	Compound Name	Structure
			Myricetin-3-*O*-rhamnoside	
			4′′′′-Acetylsagittatin A	
		Proanthocyanidins	Procyanidin	
			Prodelphinidin	
		Flavanones	Eriodictyol [47][48][49][50]	
			Eriodictyol-7-*O*-rutinoside [7]	
			Naringenin [48][49]	

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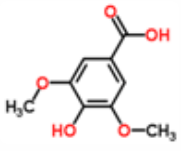
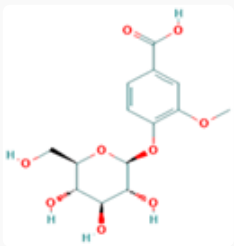
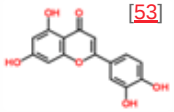
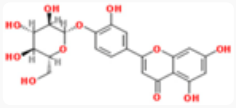
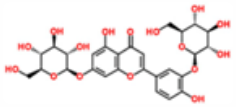
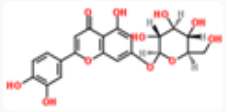
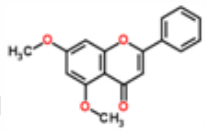
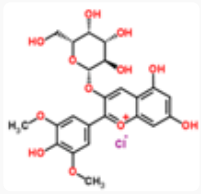
Large prospective epidemiological studies have reported that the intake of phenolic-rich lentils is inversely connected with the incidence of obesity and diabetes [51]. An earlier human study shows that the intake of lentil seed along with pasta and sauce reduces food intake, body weight and waist circumference [52]. Furthermore, lentil

Polyphenol	Classes	Sub-Classes [52]	Compound Name	Structure
Non-flavonoids	Phenolic acids	Hydroxybenzoic acids [21][65]	Syringic acid	
			Vanillic acid 4-|A-D-glucoside	
Flavonoids	Flavones	Flavone [56][57]	Luteolin	 [53]
			Luteolin-4′-*O*-glucoside [37]	 [54][55]
			Luteolin-3′,7-diglucoside	 [43]
			Luteolin-7-*O*-glucoside [58]	 [59][60]
			5,7-dimethoxyflavone	 [61][62]
		Anthocyanins	Malvidin-3-*O*-galactoside	

5.5. Antimicrobial Activ

Lentils containing flavonoids ar diagnostic kits [63]. A bioactive peptide call s a broad spectrum of biological activities, n bacteria and fungi [21][64]. It is a group o ved in the

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reast and nd breast [67]. Lentil seeds have a high polyphenolic content that potentially could prevent carcinogens through chemo-preventive activities, including the uptake of carcinogens, activation or formation, detoxification, binding to DNA and fidelity of DNA repair [69][70]. Moreover, lectins in lentils have anticancer properties, which have been observed in various in

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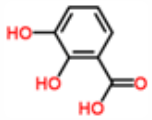
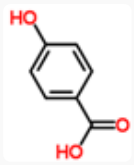
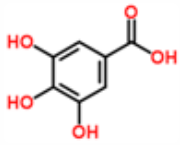
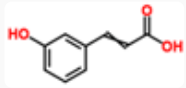
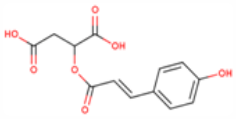
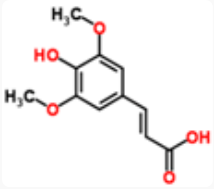
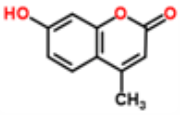
administration of lentils actively and pathological manifestations seed and its diet prescription as

[66][67][68]

Polyphenol	Classes	[20] Sub-Classes	Compound Name	Structure
			[20] 2,3-Dihydroxy benzoic acid	
			p-hydroxy benzoic acid	
			Gallic acid	
		Hydroxycinnamic acid	3-hydroxy cinnamic acid	
			p-Coumaroyl malic acid	
			Sinapic acid	
	Other polyphenols	Hydroxycoumarin	4-Hydroxy-6-methyl coumarin	

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