EFFECT OF GERMINATION ON NUTRITION QUALITY AND PHYTOCHEMICAL PROFILES OF COMMON SPROUTS

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ABSTRACT

Regular consumption of fruits and vegetables reduces the risk of chronic diseases while most of the population don’t meet the recommended intake of fruits and vegetables in United States and worldwide. Sprouted vegetables may provide an alternative way to solve this problem by providing increased nutrition value. The germination process of fruits and vegetables generally optimizes the nutrition value and phytochemicals content and at the same time reduces antinutrients. Indeed, intake of sprouted vegetables seeds reduces the risk of some type of cancers. The paper intends to encourage a higher intake of sprouted vegetables to remedy the lack of intake of fruits and vegetables to reduce the risk of chronic diseases.

BIOGRAPHICAL SKETCH

Siyuan Sheng, Graduate from Purdue University with the degree of Bachelor of Science in food science in December 2016. He started his study in functional food and nutrition at Cornell University under Dr. Rui Hai Liu's supervisory from January 2017.

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LIST OF ABBREVIATIONS

CARDIOVASCULAR DISEASE (CVD); CONFIDENCE LEVEL (CL); DRY WEIGHT (DW); TOTAL PHENOLICS CONTENT (TPC); Γ-AMINOBUTYRIC ACID (GABA); LOW-DENSITY LIPOPROTEIN CHOLESTEROL (LDL-C); HIGH-DENSITY LIPOPROTEIN CHOLESTEROL (HDL-C); PEROXYL RADICAL SCAVENGING CAPACITY (PSC)

CHAPTER 1

Introduction

Regular consumption of fruits and vegetables is considered as one of the most effect way to lower the risk of non-communicable diseases such as cardiovascular disease, diabetes, cancer, Alzheimer disease, and some aging related functional declines (Chen & Liu, 2018; F. J. He, Nowson, Lucas, & MacGregor, 2007; Liu, 2004, 2013; Mellon, Bennett, Holst, & Williamson, 2002; Yahia, 2017). The 2015-2020 edition of USDA dietary guidelines suggested a healthy US-style dietary pattern with vegetable consumption of 2.5 cups (850 grams) per day and legumes consumption of 1.5 cups (510 grams) per week (USDA, 2015). World Health Organization recommended a minimum daily intake of 400 grams of fruits and vegetables to prevent cardiovascular diseases and cancers, equivalent to five serving a day. In the United States, Behavioral Risk Factor Surveillance System (BRFSS) indicated that 76% population does not meet fruit intake recommendations and 87% population does not meet vegetable intake recommendations in 2013. Also, Half of Americans consume less than 1 cup (340 grams) of fruits and 1.5 cups (510 grams) of vegetables (Moore & Thompson, 2015). A WHO report suggested that the low intake of fruits and vegetables attributes to 6.7 million deaths daily globally (Lim et al., 2012). Thus, an increase of intake of fruits and vegetables up to 9 servings is in urgent need to most population to prevent chronic diseases with wide verities of fruits and vegetables, and germinated vegetables may provide a resolution to this issue due its high content of plant nutrients and phytochemicals.

Germination is defined as a process initiate when the seed starts uptake water from the environment and end with the elongation of embryonic axis (Bradbeer, 1988). When seed germinated, nutrition profile changes in a large scope when macronutrients such as lipids, long chain carbohydrates and protein are broken down to smaller nutrients such as amino acids and soluble sugars. Vegetable sprouts provided a significant higher amount of nutrients and phytochemicals than their seeds and mature vegetables, and at mean time, the germination process lead to the degradation of some compounds with anti-nutrients (Arendt & Zannini, 2013; Hoogenkamp, Kumagai, & Wanasundara, 2017). Common vegetable sprouts (Table 1) include legume sprouts (mung bean, soybean, alfalfa, cowpea, pigeon pea, and kidney bean), cereal sprouts (buckwheat, brown rice, flaxseed, corn and quinoa) and Brassica sprouts (broccoli, kale, radish, cabbage and mustard) and radish sprouts. Based on literature research from PubMed and Web of science, The current reviews haven't cover the most recent two years' data, nutrient quality change for vegetable sprouts are not well discussed and there is a lack of discussion on the decreasing of antinutrients during the germination process (Gan et al., 2017; Hubner & Arendt, 2013; Márton, Mándoki, Zs, & Csapó, 2010; Omary, Fong, Rothschild, & Finney, 2012; Singh, Rehal, Kaur, & Jyot, 2015). Therefore, the objectives of this review are examining the nutrition quality improvement of common sprouted grain, legumes and vegetable seed during the generation process with former and most current research; discussing the germination conditions on the bioactive compounds accumulation and antinutrients diminishing of sprouting; providing perspective for future research on sprouted foods and giving dietary suggestions for the consumption of common sprouts.

Sprouted vegetables are mainly divided into three groups, legumes (mung bean, soybean, alfalfa etc.), grain (rice, Flaxseed and corn etc.) and vegetables (Radish and brassicas etc.) (Table 1). Germination generally provides an alternative method to consume these vegetables with increased overall nutritional quality.

Table 1. Common Sprouts consumed.

Species	Common name	Scientific name	Food Consumed
legume	Mung bean	*Vigna radiata*	flour,bean, sprouts
	Soybean	*Glycine max*	soy milk, bean, tofu, natto, sprouts
	Alfalfa	*Medicago sativa L.*	sprouts
	Cowpea	*Vigna unguiculata*	flour, fermented cowpea, bean, sprouts
	Pigeon pea	*Cajanus cajan* L.	flour, bean, sprouts
	Kidney bean	*Phaseolus vulgaris* L.	flour, bread, bean, sprouts
	lentil	*Lens culinaris* L.	flour, bread, chapati, cookie, bread, bean, sprouts
Grain	Brown rice	*Oryza Sativa* L.	rice, flour, sprouts
	Flaxseed	*Linum usitatissimum*	flaxseed oil, baked goods, sprouts
	Corn	*Zea mays* L.	Corn cake, tortilla, popcorn
	Waxy wheat	*Triticum aestivum* L.	flour, thickener and gelling agent, baked goods, sprouts
pseudo-cereal	Quinoa	*Chenopodium quinoa* Willd.	quinoa meal,sprouts
	Buckwheat	*Fagopyrum esculentum* Möench	buckwheat meal, pudding, sprouts
cruciferous vegetables	Radish	*Raphanus sativus* L.	vegetable, sprouts
	broccoli	*Brassica oleracea var. italica*	vegetable, sprouts
	cabbage	*Brassica oleracea var. capitata*	vegetable, sprouts

CHAPTER 2

LEGUMES SPROUTS

Legume is one of the most important economic crops in the world with 3000 years history of domestication (Graham & Vance, 2003). Roughly 750 genres and 20000 species of legumes have been discovered and identified so far, many of them (mung bean, soybean, alfalfa, cowpea, pigeon pea and kidney bean) can be consumed as sprouted form (Duke, 1981). Recent researches suggested that sprouted legumes tend to possess much higher content of nutrients and phytochemicals with total antioxidant activities and decrease of antinutrients such as tannin and phytic acids (Kumari, Krishnan, & Sachdev, 2015; Z. Ma, Boye, & Hu, 2018; Megat Rusydi & Azlan, 2012; Pal et al., 2016; Pal et al., 2017; Sokrab, Mohamed Ahmed, & Babiker, 2012).

2.1 Mung bean sprouts

Mung bean (Vigna radiata) and mung bean sprouts are among the most common consumed food in East Asia diet. During the germination process, about 88 percent of total phenolic compounds in mung bean sprouts are germinated (Cevallos-Casals & Cisneros-Zevallos, 2010). Guo et al reported that the germination of mung bean substantially increased nutrition quality by increasing the content of vitamin C and flavonoids. In a germination process of 10 days, the vitamin C content in mung bean sprouts increased 23.4 times from 11.69 ± 0.38 mg/ 100 g dry weight (DW) to 285 ± 25.7 mg/ 100 g DW and reach a peak at day 8. The total antioxidant activity was measured by peroxyl radical scavenging capacity (PSC) test, PSC test accurately measures both hydrophilic and lipophilic antioxidants (Adom & Liu, 2005). Total antioxidant activity incerased sharply from 451.9 ± 66.7 μmol of vitamin C equiv / 100g DW to

2168 ± 228 µmol of vitamin C equiv / 100g DW on day 4. Then the value was slightly increased from day 5 to day 7 and then reach a peak at day 8 with a final value of 2657 ± 156 µmol of vitamin C equiv /100 g DW. Major phytochemicals such as flavonoids which mainly presented as Quercetin-3-O-glucoside increased 7 times higher than its initial value (Guo, Li, Tang, & Liu, 2012). Free and bound form phenolic acids content, which existed mainly as p-coumaric and ferulic acid, increased from 0.72 and 25.35 mg/100 g DW to 9.95 and 183 mg/100 g DW respectively (Pająk, Socha, Gałkowska, Rożnowski, & Fortuna, 2014).

Germinated mung bean are devided into six part, seed coat, euphylla, cotyledon, epicotyl, hypocotyl and root. After six days' germination, Euphylla part contains the highest amount of vitamin C (72.31 ± 0.62 mg/100 g FW), seed coat contains the highest pehnolics content (mg GAE per 100 g FW), seed coat, Flavonoids distribute equally amoung seed coat, euphylla, cotyledon and epicotyl (mg CE per 100g FW). Measured by PSC assay, euphylla exhibits the highest antioxidant activitry (645.4 ± 28.5 µmol ASA equiv./100 g FW,) among all part of a mung bean sprouts (J. Wang, Ye, Li, Abbasi, & Guo, 2017).

Phytic acids, one of the major anti-nutrients presented in mung beans reduces by about 60 percent in the 48 hours of germination due to the increasement of polyamines (Tajoddin, Shinde, & Junna, 2011; T. Zhou, Wang, Yang, & Gu, 2017). Phytic acids can be further reduced by sprayning inorganic salt. In a 4-day germination process of mung bean, Yan et al reported that the spraying of NaCl-CaCl2 on germinating mung bean effectively reduced the total phytic acids content by 77% by enhancing phytase activity and increasing biomass without affecting the overall nutrition quality of mung bean sprouts (Yan, Wang, Zhou, Gu, & Yang, 2017).

2.2 Soybean sprouts

Soybean (Glycine max) is a native East Asia species of legume. Soybean is good source of vitamins, proteins, minerals and phytochemicals (Sinclair, 2017).The annual production of soybean in US keep rising from 1,328 million bushels in 2012 to 1985 million bushels in 2016 (USDA ERS, 2017). Soybean is consumed as a variety of forms in eastern diet such as soymilk and tofu, and is used as a major ingredient in miso, soy sauce, and fermented tofu. Soybean sprouts, as a popular form to consume soybean in East Asian diet, boosted the nutrition quality of its seeds to a great extent by increasing the content of vitamin A, C, E and B group and phytochemicals and decreasing the antinutrient content (Ebert, Chang, Yan, & Yang, 2017; Gu et al., 2017; Luo et al., 2018).

Wang et al. reported dynamics changed of the major water-soluble vitamin - ascorbic acid, fat-soluble vitamins - tocopherols and total antioxidant change during soybean germination in 5 days. The total ascorbic acid content increased sharply form 11.63 ± 1.71 mg/100g DW on day 1 to 65.91 ± 7.01 mg/100g DW on day 3 and slowly reached a peak on day 5 with the final value of 74.42 ± 1.64 mg / 100g DW. The total tocopherols increased from 22.94 ± 0.81 mg / 100g DW on day 1 to 35.85 ± 2.81 mg / 100g DW on day 5. The α-tochopheol content incresed prominently from 2.29 ± 0.09 mg/100DW in day 1 to 7.64 ± 0.13 mg/100g DW in day 5. The total antioxidant assay was done by peroxyl radical scavenging capacity (PSC) assay (Adom & Liu, 2005). The total antioxidant of soybean was measured by PSC methods which increased 2.1 times from 145.73 ± 19.32 µmol L-ascorbic acid (ASA) equiv./100 g DW to 311.01± 49.01 µmol ASA equiv./100 g DW on day 5 (L. Wang et al., 2015).

Plaza et al reported the vitamins and phytoestrogens change of soybean germination. Vitamins A, B¬1, B2 and B6 increased 81%, 327%, 1047%, and 144% respectively. The greatest change was observed on vitamin B2, which content increased from 1.29 ± 0.14 mg / kg DW to 14.80 ± 0.40 mg / kg DW. Besides the vitamins, phytoestrogens content increases substantially as well, daidzein content increased from 29.65±5.05 mg / kg DW to 109.09±17.36 mg / kg DW, and genistein content increased from 25.50±0.88 mg / kg DW to 70.34±5.87 mg / kg DW (Plaza, de Ancos, & Cano, 2003).

Total protein and oil compositions maintained at the same level with a slight variation during a germination process of 6 days. Lecithin content increases about 22% from 12.4 mg/g to 15.1 mg/g compared to its seeds (Mostafa, Rahma, & Rady, 1987).

Kim et al. reported the bioactive compounds change in a 5-day germination on 8 cultivars of soybean under dark and colored-light (yellow and green) germinating conditions. The average isoflavones of all eight cultivars increased 52 times than its seed in dark and 131 times than that under colored-light. Malonylglucoside is the major flavone in soybean which increased from 9.4 µg/g DW to 313.9 µg/g DW in dark and 1034.3 µg/g DW under colored light. The average phenolic compounds increased from 23.1 µg/g DW to 29.8 µg/g DW in dark and 48.3 µg/g DW under colored light. The research not only reveals that the significant phytochemicals increase during the gemmination but also implicates that light could be a triger factor to the formation of phytochemicals (E. H. Kim et al., 2006).

2.3 Alfalfa sprouts

Alfalfa (Medicago sativa L.) as known as lucerne sprouts is one of common sprouted vegetables added in salad. Though Alfalfa is not used to be consumed as grain form, germination increased its nutrition quality significantly.

Plaza et al tested the vitamins and minerals' value changes before and after germination (Plaza et al., 2003).All tested minerals (Ca, Cu, Fe, K, Mg, Mn, Na and Zn) and vitamins (A, E, B1, B2, B6 and C) content in geminated Alfalfa increased. Among these nutrients, vitamin A content increased 1256 times from 0.42 ± 0.69 retinol equivalent (RE) / 100 g DW to 531 ± RE / 100 g DW. Mineral iron content increased 3 times to 153.73 ± 9.63 mg/ Kg DW making alfalfa seed a good source of iron (Plaza et al., 2003). Alfalfa sprouts contains the highest protein content (45% DW), among all common consumed sprouted vegetables (S. Narina, A. Hamama, & L. Bhardwaj, 2012). Also, germination under daylight germinated more nutrients (ascorbic acids, riboflavin and iron) than that in dark (Hamilton & Vanderstoep, 1979).

A recent research shows that soundwave can increase the ascorbic acid content during germination by affecting genes related to ascorbic acid synthesis. Ascorbic acid content increases by 24-50% compared to the untreated sample under both short-term and long-term soundwave treatment at the frequency of 800-1000 Hz (J. Y. Kim, Lee, Kim, Park, & Jeong, 2017). Irradiation process was reported also has the same effect of increasing ascorbic acid content as well as total antioxidant activity on wet weight bases in alfalfa germination process. Vitamin C and total antioxidant capacity in alfalfa sprouts irradiated with 3kGy gamma radiation is 66% and 31.8% higher than the untreated sample. (Fan, Rajkowski, & Thayer, 2003; Fan, Thayer, & Sokorai, 2004).

2.4 Cowpea sprouts

Cowpea (Vigna unguiculata) is an indigenous legume of Nigeria with beige color. Cowpea is known for its high protein (28 ± 4.5g /100g DW) and fiber (3.1± 0.6 g / 100g DW) content (Longe, 1980).

Devi et al reported the nutrition composition change on three varieties of cowpea after sprouting at 25 °C for 24 hours. Antinutrients such as phytic acid decreased 80-90% to an average of 46.67 ± 3.08 mg / 100g DW and. trypsin inhibitor (TIA) decreased 40% to an average of 3.32 ± 0.07 TIU/ mg protein. Protein and fiber increased roughly 10% and 20 % respectively. Vitamin C content increased from a negligible value to 3.1 ± 0.46 mg / 100g DW (Devi, Kushwaha, & Kumar, 2015). Germination not only increases the nutrition quality but also increases digestibility, Uppal and Bains reported that 24 hours germination for cowpea increases its in vitro digestibility for protein by 17% and starch by 12.6% compared to the raw untreated seed (Uppal & Bains, 2012) .

2.5 Pigeon pea sprouts

Pigeon peas (Cajanus cajan L.) is a yellow to brownish high protein tropical legume pervasively cultivated in India. Essential Amino acids content in pigeon peas is close to that in soybean. Moreover, Aspartic acid (105.6 mg/ g crude protein) and glutamic acid (247.1) are abundant in pigeon peas while not found in soybean (Oshodi, Olaofe, & Hall, 1993). Pigeon pea sprouts are reported owe higher nutrition value, total phenolics content (TPC) and radical scavenging capacity (Uchegbu & Ishiwu, 2016).

Torres et al. reported a nutrition composition change after a germination of 4 days at 20 °C. The major change was observed on the vitamin C and E group increase while the rest major nutrients content stayed steady. Vitamin C increased from negligible to 13.9 ± 1.65 mg / 100g DW and Vitamin E increased 108% attributed to the increase of α- (135%), δ -(625%) and γ -(75%) tocopherols (Torres, Frias, Granito, & Vidal-Valverde, 2007).

Uchegbu and Ishiwu reported a germination of 3 days at 28 °C increased TPC 30% to 95.01 ± 0.02 mg GAE equivalent / 100 g DW along with the antioxidant scavenging capacity (ASC) by 63% which in align with a former research (ASC increase 28%) conducted by Torres et al. (Torres et al., 2007; Uchegbu & Ishiwu, 2016). Germination of pigeon peas also cleavage phosphorus form phytic acids and reduced the phytic acids content by 35% in 24 hours and 39 % in 48 hours (Duhan, Khetarpaul, & Bishnoi, 2002).

2.6 Kidney bean sprouts

Kidney bean (Phaseolus vulgaris L.), a native American legume, usually has a red color and its shape visually resemble to kidney where its common name comes from. Sprouting is reported to reduce the antinutrients in kidney bean (Limon, Penas, Martinez-Villaluenga, & Frias, 2014; Modgil, Mankotia, Verma, & Sandal, 2016; Shimelis & Rakshit, 2007; Yasmin, Zeb, Khalil, Paracha, & Khattak, 2008).

In a germination of 12 hours at 25 ± 2 °C, Modgil et al. reported a reduction of 17.73% of phytic acid content was observed along with the decreased of phytate phosphorus and slight increase of non-phytate phosphorus. In the following animal study, the germination process also increased apparent protein digestibility (14.9%), biological value (3.7%) and true protein digestibility (6.7%) (Modgil et al., 2016).

A longer time of germination showed an effect on lowering antinutrients. After 96 hours germination, Shimelis and Rakshit reported a 92% reduction of phytic acid, 76% reduction of tannins while the protein digestibility keep at the same level (Shimelis & Rakshit, 2007). It is also reported by Yasmin et al that only germination can reduce the phytic acid in kidney bean, cooking do not have an effect on phytic acids but lowering the total polyphenol content by 78.7% (Yasmin et al., 2008). Germination of kidney bean can be largely accelerated by adding elicitor such as ascorbic acid or chitosan without affecting the sprouts' nutrition quality (Limon et al., 2014).

2.7 Lentil bean sprouts

lentil (Lens culinaris L.) is one of the oldest legumes cultivated by human starting from 13000 years B.C (Sandhu & Singh, 2007). Nowadays, lentil and its sprouts are prevalently cultivated Canada, India and Australia etc. More and more recently researches have shown that germination of lentil elevated nutrition quality and antioxidant capacity and exhibiting more health benefits with some nutrient reduction (Gharachorloo, Tarzil, Baharinia, & Hemaci, 2012; M. Swieca & Baraniak, 2014). Phytochemicals increment during germination may bring some unfavorable sensory attributes thus the germination time should not exceed 5 days (Troszynska et al., 2011). Elicitation at 4 °C for 3 days optimize the nutrition quality and bioavailability of phytochemicals in lentil sprouts (M. Swieca & Baraniak, 2014) and illumination treatment significantly improve the phytochemicals profile and antioxidant capacity (M. Swieca, Gawlik-Dziki, Kowalczyk, & Zlotek, 2012).

Gharachorloo et al. reported a significant elevation of total phenolics content and total antioxidant capacity in the germination of lentil in 5 days. Total phenolics content was extracted by three different solvents, hexane, methanol and acetone and evaluated by colorimetric method. The average total phenolics content extracted increased by 44.5% from its original value and the total antioxidant capacity correspondingly increased by an average of 172%. There is a large variance between different extraction solvent (Gharachorloo et al., 2012).

Yeo and Shahidi evaluated the bond and soluble phenolics and antioxidant change during the germination of lentil in 4 days. Total phenolics increased 31% from 8.13 ± 0.05 GAE mg/g to 10.69 ± 0.14 GAE mg/g and total flavonoids content was steady while the ratio of bound over soluble increase from 1.19 to 1.96. Corresponded with the increasement of phytochemical content, Antioxidant activity, measure by DPPH and ABTS methods, increased by 18.9% and 10.1% (Yeo & Shahidi, 2015). The results were in accorrdance with a latter research conducted by Bubelova et al. who also pointed out that germinated lentil beans possess higher digestibility than the unprossed and cooked one (Bubelová, Sumczynski, & Salek, 2018).

Lentil sprouts exhibits health benefits of lowering serum lipid level and as supplemental treatment to cardiovascular diseases and type 2 diabetes (Aslani, Mirmiran, Alipur, Bahadoran, & Abbassalizade Farhangi, 2015; Ganesan & Xu, 2017). Aslani et al reported the effect of lentil sprouts on a group of thirty-nine patients with obesity or type 2 diabetes in an 8-week intervention study. An average decrease (12.81%) of LDL-C and Increase (18.33%) of HDL-C with significant difference from original value on patients who finished the study were observed.

CHAPTER 3

GRAIN SPROUTS

Grain included in the family of grass supplies half of the energy need for the entire human beings. Except for some cases such as white rice, cereals are usually consumed as whole grain form exhibiting health benefits of lowering the risk of chronic diseases (Liu, 2007; Okarter & Liu, 2010; Xi & Liu, 2016). Ranking by the production volume, the world's most important cereals are maize, paddy rice and wheat (Wrigley, 2017). Buckwheat and quinoa are classified as pseudo-cereal. All the grains above can be consumed as sprouted form with increased nutrition quality.

3.1 Brown rice sprouts

Germinated brown rice (Oryza Sativa L.) has a higher TPC, antioxidant capacity amino acid profile and lower phytic acids content than unterminated brown rice. Some post germination process such as sun drying promotes the accumulation of bioactive components (γ -oryzanol and TPC) and antioxidant activity (Cáceres, Peñas, Martinez-Villaluenga, Amigo, & Frias, 2017). Germination increased brown rice flour amino profile and physical properties such as oil and water absorbing capacity, foaming capacity and corresponding emulsification capacity. The germination of brown rice increased the total essential amino acids by 10.1-fold with the only reduction of glutamic acids (Sibian, Saxena, & Riar, 2017).

Cornejo et el. tested bioactive compounds (GABA, γ -oryzanol and TPC) and antioxidant activity in germinated brown rice in 48 hours germination time. In general, germination constantly increased protein, fat, and decrease phytic acid and carbohydrates content. For bioactive compounds, germination significantly increased GABA and TPC by approximately

460% and 80% respectively in a constant rate. Total antioxidant activity decreased 30% initially then increased 15% higher than the original value in 48 hours in a steady rate (Cornejo, Caceres, Martinez-Villaluenga, Rosell, & Frias, 2015).

Tian et al reported another comparison of phenolic acids in brown rice flour and germinated brown rice flour. The germination process was taken at 32 °C for 21 hours. Total phenolic acid content in germinated brown rice flour is 26.23 mg /100 g of flour higher than that of unterminated brown rice (20.64 mg / 100 g of flour). 94 percent of phenolic acids in germinated brown rice flour was in insoluble form and ferulic acid (80.87%) takes account the majority followed by p-coumaric acid (12.3%) and others (Tian, Nakamura, & Kayahara, 2004). Germinated brown rice is nutritiously more abundant than its seed and white rice, thus exhibiting some health benefits such as lowering the risk of cardiovascular diseases. Imam et al. reported an animal study on rats fed with white rice, brown rice and germinated brown rice respectively for five weeks. Body weight of mice group fed with germinated brown rice consistently reduced slightly with improved body lipid profile while the body weight of all the rest of group increased consistently. Also, germinated brown rice feeding reduces oxidative stress and plasma oxidized low-density lipoprotein level. Germinated brown rice group displays the best overall biomarker indexes suggesting the preventative effect of GBR on the developing of cardiovascular diseases (Imam et al., 2014).

3.2 Flaxseed spouts (flaxseed is classified as oily grain)

Flax (Linum usitatissimum) seed has long been known as a functional food source mainly due to its abundant alpha-linolenic acid (52% of total fatty acids), lignin and soluble fiber content (Oomah, 2001). However, the adding of flaxseed meal in food such as bakeries reduces the consumer rating for most sensory attributes (Ramcharitar, Badrie, Mattfeldt-Beman, Matsuo, & Ridley, 2005). A recent research on dynamic change of flaxseed sprouts' nutrients, phytochemicals and antioxidant activities during germination process suggested an alternative way to consume flaxseed in spouts form (H. Wang et al., 2015). Consuming flaxseed in sprouts form is not only as a palatable way but also brings more health benefits to consumer because sprouting increased the bioavailability of nutrients and at the same time reduce antinutrient such as cyanide (Bagchi, Swaroop, Stohs, & Swaroop, 2017).

Wang et al reported the germination of flaxseed dramatically increased the total phenolics compounds as well as the total antioxidant activities. Major phytochemicals content and antioxidant activities are examined and recorded every other day in a scope of 10 days. The antioxidant activity assay was done by cellular antioxidant activity (CAA) assay, and the antioxidant activity was measured and recorded as quercetin per 100 grams in dry weight (µmol QE/100 g DW) (Wolfe et al., 2008; Wolfe & Liu, 2007). The total phenolics content was measured by using a modified Folin-Ciocalteu method (Liu & Sun, 2003) and flavonoid content was measured by using borohydride/chloranil colorimetric method (X. J. He, Liu, & Liu, 2008). The total flavonoid contents in the sprouts increased 53 times and total phenolics increased 5.7 times than that in their seeds, both reached a peak at day 10 of germination. The lignin contents in flaxseed are presented mainly as secoisolariciresinol (SECO), secoisolariciresinal diglucoside (SDG) and coniferyl alcohol (CA). SECO content increased from 29.26 ± 0.06 µg/g DW to 553.29 ± 0.88 µg/g DW and peak at day 10, SDG content increased from 130.8 ± 3.35 µg/g DW to 386.41± 30.78 µg/g DW and peak at day 8, and CA content increasd from 79.13 ± 6.09 µg/g DW to 307.61 ± 1.88 µg/g DW and peak at day 8. The total antioxidant activity of flaxseed sprouts correlated with the amount of total phenolics and total flavonoids, increases 585% from its seed. Overall, 8 days sprouting time of flaxseed generates optimal health benefits in terms of phytochemicals contents and total antioxidant activities (Kajla, Sharma, & Sood, 2017; H. Wang et al., 2015; H. Wang et al., 2016).

Herchi et al reported flaxseed oil composition kept steady before and after the germination while the crude oil content decreased from 35% to 28%. Fat soluble nutrients such as carotenoids and chlotophyll content constantly increased from 2.23 ± 0.05 mg/kg oil to 6.27 ± 0.07 mg/kg oil and 4.45 ± 0.12 mg/kg oil to 7.37 ± 0.28 mg/kg oil respectively. Ascorbic acids content increased form 1.35 ± 0.12 mg/100 g to 2.74 ± 0.26 mg/ 100 g. The total antioxidant activity of flaxseed oil keep constant during the 4 days' germination (Herchi et al., 2015). The research results was in accordance with a fomer research that germination decreases oil content and some minerals but increaes total protein content and other nutrients (S. Narina et al., 2012).

Flaxseed sprouts are reported to have beneficial effect on cancers (Lee & Cho, 2012). Lee and Cho conduct a in vitro research on human breast cancer cell line for 72 hours. The results suggested that flaxseed sprouts have an effect on inhibiting cancer cell growth by increasing apoptosis but have no significant influence on health human cell growth (Lee & Cho, 2012).

3.3 Corn sprouts

Corn (Zea mays L.) is a native American crop and one of a major food source in the United States. Various cultivars of corn including sweet, yellow, white, purple, red and high amylose corn are rich in nutrients and phytochemicals.

Antioxidant activity of sweet corn formerly reported can be increased by thermal processing and the mechanism is thermal processing releases bound form ferulic acids (Dewanto, Wu, & Liu, 2002). Germination also increases antioxidant activity by increasing form phytochemicals. Xiang et al reported the antioxidant activity change of sweet corn during the germination process under dark and light condition.

Free form flavonoids along with total phenolic content doubled during germination in both dark and light condition. Germination under light condition triggered relatively more phytochemicals and antioxidant capacity than that in dark condition. Oxygen radical absorbance capacity (ORAC) assay was used to determine the antioxidant activity and the value was expressed as µmol Trolox equivalent (TE) /100 g DW (Prior, Sintara, & Chang, 2016). Antioxidant in Free form extract increased four times than the radicle stage to 27305 ± 3220 µmol TE/100 g DW under light and five times than radicle stage to 17579 ± 628 µmol TE/100 g DW in dark (Xiang et al., 2017a). The research results were in align with a former research on light and dark germinated corn (Randhir & Shetty, 2005).

To optimize the nutrition value after germination, light condition and germination stage need to be taken into consideration. Xiang et al. conducted a research on the light condition on the phytochemicals accumulation and antioxidant change during the germination process under light and dark condition in sweet corn (Xiang et al., 2017b). Total flavonoids in euphylla stage of germination were two times higher than in radicle stage, the early stage of germination. Correspondingly, total antioxidant activity from free form extract in euphylla stage (27,305 ± 3220), which measure by ORAC method, was 2 to 2.5 times higher than that in radicle stage (6893 ± 624 µmol TE/100 g DW). Compare with the sweet corn sprouts germinated in dark condition, sprouts germinated in light condition increases total antioxidant activity by 38.97%, and total flavonoids content by 15.87% (Xiang et al., 2017b). Thus, germinated sweet corn under light condition at euphylla stage (usually for three days) exhibited highest nutrition value, and the germination temperature was recommended at 26 C (L. M. Paucar-Menacho, Martinez-Villaluenga, Duenas, Frias, & Penas, 2017; Xiang et al., 2017a).

Germination not necessary to lead to the increase of total phenolics content and antioxygen capacity while the phytochemicals profile changed dramatically. Paucar-Menacho et al. conducted a research to identify an ideal temperature and germination time to maximize the content of bioactive compounds and antioxidant activity of purple corn by response surface methodology. The results indicated that germination strategy at 26 °C for 63 hours will maximize the health benefits of purple corn sprouts. The γ-aminobutyric acid (GABA) increased 137% to 53.17 mg / 100g DW while TPC decreased 10%-37% and total antioxidant activity reduced by 15% (Luz María Paucar-Menacho, Martínez-Villaluenga, Dueñas, Frias, & Peñas, 2017).

3.4 Waxy wheat sprouts

Waxy wheat (Triticum aestivum L) is kind of new developed low amylose wheat which can be used in breadmaking to produce a unique viscous and soft texture with reduced retrogradation effect (F. Ma, Ji, & Baik, 2017). Germinated wheat and waxy wheat has a higher nutrition value such as free amino acids, dietary fiber, vitamins and phenolic compounds and can be applied in the baking industry with influence on the sensory attributes (Gawlik-Dziki, Dziki, Pietrzak, &

Nowak, 2017). Proteases from germinating wheat can be used as a treatment to celiac diseases (Stenman et al., 2009).

Hung et al reported that the radical-scavenging phenolics content increased roughly 50% while that of bound phenolics content keep consistent during 48 hours' germination. All amino acids found in waxy seed increased significant in 48 hours. Essential fatty acids including isoleucine, leucine, phenylalanine, and valine increased from 64, 58, 53 and 119 mg / kg flour DW to 334, 392, 249, 1990 mg / kg flour DW. Free fatty acids and protein content keep consistent in 48 hours (Hung, Maeda, Yamamoto, & Morita, 2012).

3.5 Quinoa sprouts (pseudo-cereal)

Quinoa (Chenopodium quinoa Willd.), a pseudo-cereal, has a cultivation history of thousands of years in Andean region. It is receiving increasing attention due to its rich nutrition composition of essential amino acids. (Arendt & Zannini, 2013). A unique characteristic of pseudo-cereals is that they do not contain gluten thus become an ideal substituent for cereal to people with celiac disease (Theethira & Dennis, 2015; Zevallos et al., 2014). 200mM treatment of hydrogen peroxide increases total phenolics compounds as well as total antioxidant capacity by 28% and 71% (Michal Swieca, 2016).

Pasko et al reported phenolic acids, flavonoids and antioxidant capacity change of quinoa and its sprouts in both light and dark. Flavonoids in quinoa increased 5 % in light but decreased significantly in dark than its seed, ferulic acids accounts for most of the increased phenolic acid content. Flavonoids content increased 35.8% to 304.1 mg / 100 g DW in light while decreased 23.8% in dark. The antioxidant activity is measured by ferric reducing ability of plasma (FRAP) assay and expressed in mmol Fe2+ / kg DW (Benzie & Strain, 1996). Antioxidant activity in quinoa increased 745% in 4 days and 1457% in 6 days with the value of 77.4 ± 0.2 mmol Fe2+ / kg DW under light. The antioxidant capacity measured in dark was 20-30% lower than that in dark (Pasko, Sajewicz, Gorinstein, & Zachwieja, 2008). The results was in accodance with a latter research conducted by Carcoichi et al. who also suggested that germination increased ascorbic acid content by 14.38 fold and tocopherols content by 1.64 fold (Carciochi, Galván-D'Alessandro, Vandendriessche, & Chollet, 2016).

3.6 Buckwheat (pseudo-cereal)

Similar as Quinoa, Buckwheat (Fagopyrum esculentum Möench) is classified as-pseudo cereal. Although it contains wheat in its name, buckwheat belongs to the family Polygonaceae (Aryal, Thapa, Tiwari, & Chaudhary, 2016). Buckwheat sprouts' nutrient reach an overall maximum level at day 8 of germination (Lin, Peng, Yang, & Peng, 2008). Low concentration of sodium bicarbonate treatment during germination (0.05%) can increase the accumulation of total phenolic compounds and D-chiro-inositol by around 10%, 60% than untreated control (Qin et al., 2017).

Zhang et al reproted the changes of nutrients, antinutrients, phytochemicals and antioxidant activities on initial stage of germination (72 hours). Initial stage of germintaion of buckwheat leads to an significant increase of reducing suger and a slight increase of crude protein with a slight decrease of crude fat. For phytochemicals, TPC increases 178% to 8.42 ± 0.44 mg GAE / g DW, TFC increasd 180% to 11.69 ± 0.87 mg RE / g DW.Phenolic acids increases 10 fold to 409.02 ± 17.97 µg/g DW. Chlorogenic acid and Trans-3-hydroxycinnamic acid were the most aboundant phenolic acids in buckwheat sprouts. Antinutrients such as phytic acid decreased 16.8% to 12.64 ± 1.06 and TIA decreased 21.6% to 2097.3 ± 21.0 U/g. Total antioxidant activity was meausured by 4 methods, DPPH, TEAC, FRAP and ORAC. The average increase was between 250% to 300% (Zhang et al., 2015).

In a long run, Ren and Sun reported the nutrition quality change of the germination of buckwheat in 9 days. TPC and TFC value increased significantly and peak at day 7. The total antioxidant activty value increase significantly and peak at day 7 matching with the increase of TPC and TFC. The results were in algin with an earlier conducted by kim et al. that a 6-8 days' germination makes buckwheat sprouts reach its optimal nutrition quality (S. L. Kim, Kim, & Park, 2004; Y. M. Zhou et al., 2015).

Lin et al report an animal study on rodent treated with diets containing different concentration of buckwheat sprouts and buckweat seed for 28 days. The results shown that all diet containing buckwheat have effect on reducing LDL-C and bodyweight at same time increasing HDL-C. The potential reason could be the significant increase of rutin which inhibit the fatty acid synthesis and fiber content which accerlerate bile acids excretion in buckwheat sprouts (Lin et al., 2008). The results were inaccordance with a latter research results that buckwheat sprouts significantly increased mice LDL/HDL level but do not have apparent effect on type 2 diabetes (Watanabe & Ayugase, 2010).

CHAPTER 4

OTHER SPROUTS

Besides cereals and legumes, Brassica (broccoli, kale, cabbage, turnip, mustard and radish) vegetables and some flower seeds (sesame) and some tree seeds (Moringa oleifera etc.) can be consumed in sprouts form and exhibiting health benefits on preventing non-communicable diseases (Fahey, Zhang, & Talalay, 1997; Ha et al., 2017; Ijarotimi, Adeoti, & Ariyo, 2013).

4.1 Brassica sprouts

Yong cruciferous vegetables including brassica sprouts (broccoli, cabbage etc.) are an exceptionally rich source of inducers of phase 2 enzyme. Brassica sprouts contains a substantial amount of glucosinolate such as sulforaphane and isothiocyanate than its mature plant (Fahey et al., 1997; Mellon et al., 2002).

Broccoli belongs to cruciferous family and its sprouts are rich in phase 2 enzyme inducers and have shown a positive effect on protecting chemical carcinogens from an extensive amount of research. Fahey et al reported that 3-day-old broccoli contains 10-100 higher levels of glucoraphanin which is the glucosinolate of sulforaphane than its mature plant. Sulforaphane is the major substances as the phase 2 enzyme inducer. Remarkably, Methylsulfinylalkyl, a major glucosinolates content in the sprouts is 20 times higher than that in their mature plants. Broccoli Sprout has lower indoles, a chemical play both inhibitor and enhancer to carcinogen, than their mature plants. About 67% of glucosinolates in mature broccoli plants were indoles in contrast to only 3% of total glucosinolates in its sprouts were indoles. The subsequent antitumor study on rodent shown that hot water extracts from broccoli sprouts is significantly more effective on suppressing the development of tumor than mature broccoli extracts. The finding leads to a suggestion of 15 grams daily intake of broccoli sprouts to prevent cancer (Fahey et al., 1997).

Bioactive compounds in broccoli sprouts has effect on various cancers. Li et al reported a combination of human cell study in vitro and rodent study in vivo suggested that sulforaphane extracted form broccoli and its sprouts inhibits proliferation and induces apoptosis of breast cancer and eliminates cancer steam cell in vivo (Li et al., 2010). Abbaoui et al. reported that isothiocyanate extracted from broccoli effectively inhibit the bladder cancer development in human cancer cell from the results of animal study in vivo and human cell line study in vitro (Abbaoui et al., 2012). Keum et al. reported that prostate cancer can be prevented and inhibited by extracts from broccoli sprouts based on an in vivo animal study on rodent (Keum et al., 2009). In a randomized clinical trial on human, Kensler et al. reported that sulforaphane extracted from broccoli sprouts exhibiting a significant effect of detoxification on both foodborne and airborne toxicants when compared with the placebo group (Kensler et al., 2005).

Sulforaphane in fresh broccoli spouts have a better bioavailability than the mature plant and glucoraphanin supplements. Atwell et al. reported that bioavailability of sulforaphane largely depends on the consumption form, less sulforaphane are absorbed in sulforaphane supplements than that in broccoli sprouts potentially due to the absence of myrosinase in sulforaphane supplements (Atwell et al., 2015). High pressure processing at 400-600Mpa at room temperature reached a significant higher conversion rate (85%) of glucosinolate to isothiocyanates than conventionally boiling which leads to the thermal inactivation of myrosinase (Westphal et al., 2017).

4.2 Radish sprouts

Radishes (Raphanus sativus L.) are fast maturing plants belong to crucifer family with 2000 years history of cultivation worldwide (Andersen, University of, & Cooperative Extension, 2011).

Hanlon and Barnes reported the comparison of phytochemical composition of eight varieties of radish sprouts and their mature plants in 7 days. A significant higher concentration of glucosinolate (3.8-fold) and isothiocyanates (6.9- fold) are found in radish sprouts than their corresponding mature plants. Glucosinolate in Miyashige radish sprouts increased 5.3-fold while that of Nero Tondo radish sprouts was kept at the same level. Isothiocyanate content in all variety of radishes increased significantly. Total phenolic compounds in all eight variety of radishes sprouts increased significantly and the average increase was 7-fold. In contrast to the glucosinolate and phenolics content increase, Anthocyanins are only detectable as a low concentration (0.29 ± 0.22 mg/g DW) in red Meat radish sprouts while the total concentration in their mature plant is 4-fold higher (Hanlon & Barnes, 2011).

Byun et al. reported an in vitro cell study on the effect of radish sprouts extract on human colon cancer cell. The results shown that the active compounds in radish sprouts, sulforaphene inhibit the malignant cancer cell but has negligible effect on health cell. Sulforaphene also involved in G2/M cell cycle arrest, poly (ADP-ribose) polymerase cleavage and then cancer cell apoptosis (Byun et al., 2016).

CHAPTER 5

CONCLUSION

Germination process generally increases nutrition quality and content of phytochemicals of plant seeds and grains and provides an alternative way to consume seeds and grains. Vitamin C, B and E groups tends to increase significantly in grains and legumes and amino acids profile tends to become more nutritiously abundant in legumes. Total antioxidant activities increase along with the accumulation of total phenolics are found in the majority germination process. Germination conditions such as light, temperature, elicitation with certain elicitors and germination time play a vital role to boost the nutrition quality for most germination process of sprouted vegetables. Illumination have positive effect on accumulation of some specific nutrients, phytochemicals and antioxidant activity. The application of some selected elicitors promoted the synthesis of phytochemicals in some sprouts. Cold temperature tends to help accumulate some nutrients and the highest nutrition quality appears at a certain period of germination. Some other techniques such as the application of ultrasound and irradiation appear to increase the bioactive compounds as indicated in some research results. There is an insufficient research on the kinetics of key nutrition content, anti-nutrients content, phytochemicals and total antioxidant activities change for many common consumed sprouted vegetables.

Some sprouts such as broccoli sprouts and lentil sprouts exhibit enhanced nutrition values and corresponding health benefits on fighting against chronic diseases than their mature plant. Both in vivo and in vitro studies, and prospective and retrospective studies on selected population on health benefits of many sprouts are also in need. A large amount researches have been done on the health benefits of lentil and broccoli sprouts but seems insufficient on other sprouted vegetables. There is also a lack of research on the synergistic health promoting effect of sprouts with other fruits and vegetables. The future research on germination of sprouted vegetables and corresponding health benefits is warranted.

APPENDIX

Table 2. nutriention quality improvement

Legumes	Mung bean	nutrients	seed	Germination	fold increase	Reference
		Vitamin C	11.69 ± 0.38 mg/ 100 g DW	285 ± 25.7 mg/100 g DW	24.37	(Guo, Li, Tang, & Liu, 2012)
		total pehnolic acid	26.07 mg/100g DW	192.95mg/100g DW	7.40	(Pająk, Socha, Gałkowska, Rożnowski, & Fortuna, 2014)
		Total phenolic content	0.49 ± 0.02 mg/100 g DW	10.98 ± 1.24 mg/100 g DW	22.40	(Guo, Li, Tang, & Liu, 2012)
		Total flavonoids	195.3 ± 21.8 mg catechin equiv/100 g DW	1319 ± 143 mg catechin equiv/100 g DW	6.75	(Guo, Li, Tang, & Liu, 2012)
		Total Antioxidant Activity	451.9 ± 66.7 µmol of vitamin C equiv/100 g DW	2168 ± 228 µmol of vitamin C equiv/100 g DW	4.79	(Guo, Li, Tang, & Liu, 2012)
	Soybean	Vitamin A	18.79 ± 4.15 RE/ 100 g DW	34.02 ± 3.92 RE/ 100 g DW	1.81	(Plaza, de Ancos, & Cano, 2003)
		Vitamin B1	0.47±0.02 mg/kg DW	2.01±0.17 mg/kg DW	4.27	(Plaza, de Ancos, & Cano, 2003)
		Vitamin B2	1.29±0.14 mg/kg DW	14.80±0.40 mg/kg DW	11.47	(Plaza, de Ancos, & Cano, 2003)
		Vitamin B6	7.79±0.66 mg/kg DW	19.08±0.82 mg/kg DW	2.45	(Plaza, de Ancos, & Cano, 2003)
		Phytoestrogens	55.15 ± 5.93 mg/kg DW	179.43 ± 23.22 mg/kg DW	3.25	(Plaza, de Ancos, & Cano, 2003)
		Vitamin C	11.63 ± 1.71 mg/100 g DW	74.42 ± 1.64 mg/100 g DW	6.4	(L. Wang et al., 2015)
		α-tocopherol	2.29 ± 0.09 mg/100 g DW	7.64 ± 0.13 mg/100 g DW	3.33	(L. Wang et al., 2015)
		Total Tocopherols Content	22.94 ± 0.81 mg/100 g DW	35.85 ± 2.81 mg/100 g DW	1.56	(L. Wang et al., 2015)
		Total Antioxidant Activity	45.73 ± 19.32 µmol vitamin C equiv./100 g DW	311.01 ± 49.01 µmol vitamin C equiv./100 g DW	2.14	(L. Wang et al., 2015)
		GABA	0.04± 0.01 mg/g DW	0.26 ± 0.016 mg/g DW	6.5	(Luo et al., 2018)
	Alfalfa	Vitamin A	0.42±0.69 RE / 100 g DW	531.89±54.43 RE / 100 g DW	1266.4	(Plaza, de Ancos, & Cano, 2003)
		Vitamin B1	0.56±0.02 mg/kg DW	5.92±0.40 mg/kg DW	10.57	(Plaza, de Ancos, & Cano, 2003)
		Vitamin B2	1.69±0.06 mg/kg DW	6.98±0.32 mg/kg DW	4.13	(Plaza, de Ancos, & Cano, 2003)
		Vitamin B6	5.07±1.03 mg/kg DW	31.94±6.35 mg/kg DW	6.29	(Plaza, de Ancos, & Cano, 2003)
		Vitamin C	81,14±0.80 mg/kg DW	826,80 mg/kg DW	10.18	(Plaza, de Ancos, & Cano, 2003)
		α-tocopherol	10.42±1.00 mg/kg DW	37.94±0.04 mg/kg DW	3.64	(Plaza, de Ancos, & Cano, 2003)
cereals	Flaxseed spouts	Vitamin C	9.25 ± 0.87 mg/100 g	222.93 ±13.31 mg/100 g	24.1	(Wang et al., 2015)
		Chlorophyll	4.45±0.12 mg/100g oil	7.37±0.28 mg/100g oil	1.66	(Herchi et al., 2015)
		Carotenoids	2.23±0.05 mg/100g oil	6.27±0.07 mg/100g oil	2.81	(Herchi et al., 2015)
		secoisolariciresinol (SECO)	130.8 ± 3.35 ug/g DW	386.41 ± 30.78 ug/g DW	2.96	(Wang et al., 2016)
		secoisolariciresinol diglucoside (SDG)	79.13 ± 6.09 ug/g DW	307.61 ± 1.88 ug/g DW	3.89	(Wang et al., 2016)
		Total Flavonoids content	20.61 ± 4.55 mg CE/100 g DW	553.29 ± 0.88 mg CE/100 g DW	26.84	(Wang et al., 2016)
		Total phenolic content	136.45 ± 3.83 mg GAE/100 g DW	773.70 ± 38.25 mg GAE/100 g DW	5.68	(Wang et al., 2016)
		Total Antioxidant Activity	28.17 ± 0.55 µmol TE/g DW	192.51 ± 7.38 µmol TE/g DW	6.83	(Wang et al., 2016)
Vegetables	Broccoli	total glucosinolate	45.1 µmol/g DW	64.4 µmol/g DW	1.43	(Fahey et al., 1997)
Seed	White Seasame	Catechin	ND	13.5 mg/g DW	N/A	(Ha et al., 2017)
		Phenolic acids	7.78 mg/g DW	23.65 mg/g DW	3.04	(Ha et al., 2017)
	Black Seasame	Catechin	ND	19.09 mg/g DW	N/A	(Ha et al., 2017)
		Phenolic acids	3.79 mg/g DW	26.01 mg/g DW	6.86	(Ha et al., 2017)
	Sunflower	Total Phenolic Acids	770.25 mg/100g DW	1083.46 mg/100g DW	0.4066	(Pająk, Socha, Gałkowska, Rożnowski, & Fortuna, 2014)

TE stands forTrolox equivalent, CE stands for catechin equivalent, GAE stands for gallic acid equivalent, RE stands for retinol equivalent, ND Not Detected, N/A not available

Table 3. Antinutrients decreasing after germination

Legumes	Mung bean	Anti-nutrients	seed	Germination	percentage decrease	Reference
		phytic acid	8.20±0.11mg/g DW	2.92±0.20 mg/g DW	64%	(Tajoddin, Shinde, & Junna, 2011)
	Cowpea	phytic acid	308.83±5.21 mg/ 100 g DW	19.07±3.06 g/ 100 g DW	94%	(Devi, Kushwaha, & Kumar, 2015)
		trypsin inhibitor activity	5.65±0.02 TIU/100 g DW	4.05±0.17 TIU/100 g DW	31%	(Devi, Kushwaha, & Kumar, 2015)
	Pigeon pea	phytic acid	886 ± 8 mg/100 g DW	680 ± 6 mg/100 g DW	23%	(Duhan, Khetarpaul, & Bishnoi, 2002)
	Kidney bean	Tannins	5.37 ± 0.01 mg/g DW	1.28 ± 0.01 mg/g DW	76%	(Shimelis & Rakshit, 2007)
		phytic acid	23.51 ± 0.01 mg/g DW	1.88 ± 0.01 mg/g DW	92%	(Shimelis & Rakshit, 2007)
	Black Soybean	Tannins	3.12 ± 0.04 mg/g DW	1.01 ± 0.02 mg/g DW	68%	(Kumari, Krishnan, & Sachdev, 2015)
		Phytate	28.90 ± 0.06 mg/g DW	10.03 ± 0.04 mg/g DW	65%	(Kumari, Krishnan, & Sachdev, 2015)
		Raffinose	10.20 ± 0.02 mg/g DW	4.06 ± 0.03 mg/g DW	60%	(Kumari, Krishnan, & Sachdev, 2015)
		Trypsin inhibitor activity	75.32 ± 0.8 TIU/mg DW	22.81 ± 0.1 TIU/mg DW	70%	(Kumari, Krishnan, & Sachdev, 2015)
	Yellow Soybean	Tannins	2.18 ± 0.03 mg/g DW	1.08 ± 0.04 mg/g DW	50%	(Kumari, Krishnan, & Sachdev, 2015)
		Phytate	22.50 ± 0.04 mg/g DW	11.40 ± 0.08 mg/g DW	49%	(Kumari, Krishnan, & Sachdev, 2015)
		Raffinose	8.60 ± 0.04 mg/g DW	4.72 ± 0.04 mg/g DW	45%	(Kumari, Krishnan, & Sachdev, 2015)
		Trypsin inhibitor activity	65.40 ± 0.7 TIU/mg DW	28.35 ± 0.8 TIU/mg DW	57%	(Kumari, Krishnan, & Sachdev, 2015)
	Horsegram	Tannins	828.33 mg/100 g DW	611.4 mg/100 g DW	26%	(Pal et al., 2016)
		Oxalic acid	523.14 mg/100 g DW	426.25 mg/100 g DW	19%	(Pal et al., 2016)
		Phytic acid	9.67 mg/100 g DW	6.55 mg/100 g DW	32%	(Pal et al., 2016)
		Trypsin Inhibitor	11.57TIU/mg DW	8.47 TIU/mg DW	27%	(Pal et al., 2016)
	Peanut	Tannins	32.69±2.392 mg/100 g DW	11.71±1.447 mg/100 g DW	64%	(Megat Rusydi & Azlan, 2012)
		Phytic acid	21.124±2.373 mg/100 g DW	13.074±1.1 mg/100 g DW	38%	(Megat Rusydi & Azlan, 2012)
	Lentil	Tannins	6.91 g /kg DW	2.64 g/kg DW	62%	(Pal et al., 2017)
		Phytic acid	0.3 mg/100 g DW	0.15 mg/100 g DW	50%	(Pal et al., 2017)
		Trypsin inhibitor activity	2.96 mg/g DW	0.98 mg/g DW	67%	(Pal et al., 2017)
	Yellow field pea (Pisum sativum L.)	Tannins	2.4 ± 0.1 g /kg DW	1.9 ± 0.0 g /kg DW	21%	(Z. Ma, Boye, & Hu, 2018)
		Trypsin inhibitor activity	2.7 ± 0.2 g/kg DW	1.7 ± 0.1 g/kg DW	37%	(Z. Ma, Boye, & Hu, 2018)
Cereal	Brown Rice	phytic acid	1.15±0.02 g/100 g DW	0.23±0.05 g/100g DW	80%	(Caceres, Martinez-Villaluenga, Amigo, & Frias, 2014)
	Corn	phytic acid	87.16- 1047.00 mg/100 g DW	14.10 - 189.20 mg/100 g DW	82-84%	(Sokrab, Mohamed Ahmed, & Babiker, 2012)
	Flaxseed	Cyanogenic glycosides	506.6 mg/kg DW	97.63 mg/kg DW	81%	(Kajla, Sharma, & Sood, 2017)
		Phytic acid	23.6 g/kg DW	11.6 g/kg DW	51%	(Kajla, Sharma, & Sood, 2017)
pseudo-cereal	Buck wheat	Phytic acid	15.20 ± 2.03 mg/g DW	12.64 ± 1.06 mg/g DW	17%	Zhang et al., 2015
		trypsin inhibitor activity	2676.2 ± 61.4 TIU/g DW	2097.3 ± 21.0 TIU/g DW	22%	Zhang et al., 2015
tree seed	drumstick tree (*Moringa oleifera*) seed	Tannins	241.67 ± 1.67 mg /100 g DW	181.67 ± 1.67 mg/100 g DW	25%	(Ijarotimi, Adeoti, & Ariyo, 2013)
		Phytate	78.33 ± 1.67 mg/100 g DW	40.00± 0.00 mg/100 g DW	49%	(Ijarotimi, Adeoti, & Ariyo, 2013)

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