

Nutritional and Mineral Composition of Flax Sprouts

Satya S. Narina¹, Anwar A. Hamama¹ & Harbans L. Bhardwaj¹

¹ Agricultural Research Station, Virginia State University, Petersburg, USA

Correspondence: Satya S. Narina, Agricultural Research Station, Virginia State University, Petersburg, USA. Tel: 1-804-524-1533. E-mail: snarina@vsu.edu

Received: June 29, 2012 Accepted: July 19, 2012 Online Published: October 12, 2012

doi:10.5539/jas.v4n11p60

URL: <http://dx.doi.org/10.5539/jas.v4n11p60>

Abstract

Flax (*Linum usitatissimum*) is a well-known economically viable crop with excellent nutritional qualities. The nutritional potential of flax seed sprouts has not been studied to date. Therefore, the current study was conducted to analyze nutritional qualities of sprouts of three flax cultivars (Rahab-94, Pembina and Linott) and to compare it with those of flax seeds. The results indicated lack of significance difference among the three cultivars for several traits. The sprouts were significantly different for protein with highest protein composition (25.2%) in Rahab-94. Sprouts were rich in glucose (5.1%) and fructose (2.6%) compared to sucrose (0.4%). Significant differences were observed for nitrogen (4.1%), calcium (0.27%), phosphorous (0.72%), zinc (51%), copper (23%) among sprouts of three cultivars. There were no significant differences for potassium (K), magnesium (Mg), boron (B), manganese (Mn), iron (Fe) and aluminum (Al) contents among the sprouts of three cultivars. Sprouts had higher protein content (22.3%) and lower crude fiber content (17%) as compared to that of seeds (21.7%, and 19.4%, respectively). Sprouts contained higher total sugars as compared to seeds (8.08% and 2.6%, respectively). The macronutrient and micronutrient compositions were comparatively high in seed and sprout respectively. The micronutrient values were relatively high in sprouts for boron (16.3%), iron (63.4%), manganese (52.9%) and zinc (44.4%). Flax sprouts were a good source of protein, crude fiber, simple sugars and essential micronutrients compared to flax seed and other crop sprouts.

Keywords: flax, crude fiber, protein, mineral, glucose, sugar

1. Introduction

Flax (*Linum usitatissimum*) belongs to family Linaceae. It is a versatile crop for seed as well as fiber. The reports on nutrient qualities in sprouts of canola (Bhardwaj & Hamama, 2009), lupin (Bhardwaj & Hamama, 2012) and seeds of white lupin (Hamama & Bhardwaj, 2004), barley (Peer & Leeson, 1985) and flax (Bhardwaj et al., 2012; Saeidi & Rowland, 1999) revealed the potential of crop seeds and sprouts as human diet and in nutrition. Leguminous sprout consumption reduced the risk of cancer due to presence of higher concentrations of health-protecting phytochemicals found in the sprouts (Fernandez- Orozco et al., 2006).

Use of natural sources to enrich the nutritional quality for human health is increasing momentum. One of the feasible solutions is to harvest valuable compounds from nutritional sprouts. Sprouts are nutritionally rich in enzymes that help to keep good health. Most commonly used sprouts to date are from pulses and cereals which proved sprouts as nutrient rich natural sources for human health compared to seeds (Finney, 1982; Bhardwaj & Hamama, 2011).

Michalova et al. (2001) observed an increase in the level of vitamin C, riboflavin and thiamine during the germination of buckwheat seeds with high levels of iron and zinc. Michalova et al. (2001) revealed that buckwheat sprouts were with more rutin (113mg/100g) and with higher contents of riboflavin and vitamin C. They also observed buckwheat sprouts with higher contents of lysine, mineral elements (Ca, K and Mg), sugars (fructose and glucose). The results of hydroponically sprouted barley indicated greatest nutritional values of one-day old sprout compared to four-days old (Peer & Leeson, 1985). Amino acids (aspartic acid and alanine) and fat were found to increase with increased sprouting time (Peer & Leeson, 1985). Finney (1982) revealed an increase from 43 mg original vitamin C content 59, 65 and 79 mg per 100 g (dry basis) respectively with addition of Fe(NO₃)₃, Cu(NO₃)₂, and MnCl₂ during 48 h germination of mungbean in light. Finney (1982) observed greatest vitamin C increase (392%) with increased levels of glucose in cowpea and mungbean.

Flax seeds are rich in monounsaturated fatty acids like oleic acid. Flax seed oil has 55% of alpha linolenic acid which improves human cardiovascular health and flax seed lignan has roles in atherosclerosis (Prasad, 2009) and

type 2 Diabetes (Bhardwaj et al., 2012). Previous studies have indicated that consumption of wholeseed flax by human volunteers for 12 weeks significantly increased carbon dioxide (24.23 vs. 23.03 mmol/L), lowered total serum protein (7.17 vs. 7.02 d/dl) and total globulin (2.99 vs. 2.78g/dl) in the blood. Flax consumption did not affect overall cholesterol and triglyceride concentrations in human blood. However, results point to the possibility that consumption of wholeseed ground flax may be helpful in reducing total cholesterol and triglycerides in females as compared to males (Bhardwaj et al., 2012).

The consumer's feedback about difficulty in consumption of ground whole seed flax and the results achieved on its impact on human health (Bhardwaj et al., 2012), lead to our present investigation related to characterization of flax sprouts for their composition. Our objectives were to analyze the nutritional composition of sprouts and seeds of three flax cultivars and compare the results with literature values of sprouts of other crops.

2. Materials

Mature seed of three flax cultivars (Rahab-94, Pembina and Linott) used in the study were selected from the flax germplasm collection of the New Crops Program of Virginia State University. The chemicals and reagents used for biochemical analysis were HPLC grade and were obtained from Sigma-Aldrich Corporation (St. Louis, MO, USA).

Flax seeds are difficult to sprout due to lot of mucilage upon soaking seeds in water. Seeds of several flax cultivars were used for their sprouting ability as described previously by Hamama and Bhardwaj (2004) and Bhardwaj and Hamama (2007). The seeds of yellow seeded cultivars didn't sprout uniformly and were eliminated from current study. The experiment was conducted twice with three brown seed coated flax cultivars (Rahab-94, Pembina and Linott) in three replications. The procedure for obtaining uniformly germinated flax sprouts is described briefly below.

2.1 Growing Flax Sprouts

- 1) Flax seeds (6 g) were thoroughly rinsed thrice (8 am, 12 noon and 4 pm) with a continuous flow of water using a sieve for one minute on the first day and soaked overnight in Petri dishes in the dark.
- 2) On the second day, the seeds were washed thoroughly twice (8 am and 4 pm) to get rid of the mucilaginous gel-like material of the seeds and were uniformly spread on moistened filter paper (Whatman #1, 150 mm) in Petri dishes (130 × 15 mm; Thermo Fisher Scientific Inc.) and were kept in dark at room temperature.
- 3) On the third day, rinsing was continued twice a day (8 am and 4 pm). The Petri dishes with germinating seeds were kept at room temperature with artificial room lighting (10 h) to enhance the sprout growth from third day onwards.
- 4) On the fourth day, the fresh sprouts were measured for their fresh weights (g). They were also freeze dried and the dry weight (g) and the moisture contents of sprouts were measured (%).

2.2 Data Collection and Statistical Analysis

The ground powder from freeze dried sprouts and seeds of three cultivars were used to determine protein, crude fiber, sugar concentrations (gram/100g dry weight basis) using previously published protocol (Bhardwaj and Hamama, 2007). The contents of macro and micronutrients in freeze dried ground flax sprouts and seeds were analyzed by a commercial laboratory (A&L Eastern Agricultural Laboratory, Richmond, VA) as per AOAC (1975) methods. The sprout nutrient data were compared with those of pure ground seed as well as with literature values of sprouts from other crops. All data were analyzed by analysis of variance procedures (PROC GLM) in version 9.2 of SAS (SAS, 2008).

3. Results and Discussion

3.1 Growing Flax Sprouts

Better-quality of the sprout was determined by its uniformity in sprouting, non-sticky tender appearance and fresh sprout smell. The best sprouts were obtained with ease from brown seed cultivars compared to golden yellow seed cultivars within four days. Non-uniform sprouting with extreme sticky exudation from seed coat along with foul smell was observed in golden yellow seeded cultivars. Germination requires oxygen due to metabolic break down of stored chemical compounds (Saeidi & Rowland, 2000; Peer & Leeson, 1985). Thus the failure to sprout could be attributed to lack of oxygen in the growing atmosphere due to heavy, sticky, mucilaginous material extruded from the seed coat of yellow seed cultivars encircling the germinating seed. The phenolic acids (tannins) present in the brown seed coat can influence the seed vigor and uniform germination when compared to golden yellow cultivars (Saeidi & Rowland, 2000).

3.2 Nutritional Quality

The average sprout yield from six grams seed ranged from 26.1 to 29.4 g. Fresh sprout yield, moisture content, protein, crude fiber and sugars in sprouts of three flax cultivars were presented in Table 1. There was significant variation among the sprouts of three flax cultivars for nutritional values: protein and glucose while the remaining components analyzed were observed to be relatively similar and non significant (Table 1). The highest levels of protein (25.2 g) were observed in Rahab 94. Genetic vigor of the seed could be the reason for increased levels of protein (Saeidi & Rowland, 1999) in sprouts of Rahab 94. The sprouts contained more glucose (5.21%) and fructose (2.6%) compared to sucrose (0.42%). There was no significant difference among the three cultivars for three kinds of sugars including total sugars (Table 1). This indicates that germination is breaking down the complex sugars to simple sugars like fructose and glucose in presence of water (Michalova et al., 2001). Increased availability of sugars directly correlated with increased concentration of Vitamin C (Finney, 1982).

Table 1. Fresh yield, moisture content, protein, crude fiber and sugars in sprouts of three flax cultivars

Cultivar	Fresh yield g*	Length of the sprout cm	Moist. Content ^y (%)	Protein ^x	Crude fiber	Fructose ^x	Glucose ^x	Sucrose ^x	Total sugars ^x
Rahab94	29.31a	5.69a	22.7a(77.5)	25.24a	16.96a	2.63a	5.02a	0.43a	8.1a
Linott	26.1a	6.4a	19.4a(74.1)	21.1b	15.8a	2.6a	5.1a	0.46a	8.2a
Pembina	29.4a	6.0a	22.9a(78)	20.7b	18.3a	2.4a	5.21b	0.36a	8.0a
Mean	28.3	6.0	21.7(76.58)	22.3	17.0	2.6	5.1	0.42	8.1
R ²	9.8	68.7	9.6	37.3	28.2	12.4	4.3	5.8	5.5
CV (%)	23.5	10.8	33.2	14.1	14.3	12.0	16.3	55.4	12.2

*From 6 gram seed (means of three replications and two experiments).

^x Contents are mean values expressed as g/100g dry basis. Means with same letter (a or b) are significantly not different.

^y moisture content values expressed in g followed by percent values in parenthesis.

Significant variation was observed for nutritional values of seeds when compared to those of sprouts (Table 3) except for protein. The protein levels of seeds (21.68%) and sprouts (22.34%) were relatively similar. It was also observed from Table 3 that the crude fiber content for sprouts (17%) was comparatively low to those of seeds (19.4%) while total sugars were relatively high in sprouts (8.1%) compared to seeds (2.6%). The presence of significant quantities of sugars could be attributed to the metabolic conversion of stored chemical compounds / starch to various sugars to supply energy for the germinating sprout (Saeidi & Rowland, 2000; Peer & Leeson, 1985; Bhardwaj & Hamama, 2012).

Among all the crops, alfalfa sprouts were the superior to most crops with highest protein (45%) followed by radish sprouts (Table 4). Crude fiber was rich in sprouts of alfalfa (25.2%) followed by flax (Table 4). The flax sprout protein levels were superior (22.34%) to those of Brussels sprouts and equally competed with those of canola sprouts (25.08%). The moisture content of flax sprouts was lowest (76.5%) compared to that of other crop sprouts. Total sugars were rich in sprouts of flax (8.08%) followed by mungbean (4.13%). The starch from the seed is converted to more tasty simple sugars in sprouts eliminating the non-nutritional elements while providing the essential minerals and nutrients (Finney, 1982). Therefore flax sprouts are a good source for readily digestible palatable food to provide instant energy in the form of simple sugars like fructose and glucose.

3.3 Mineral Composition

The mineral composition of sprouts of three flax cultivars (Table 2) was compared to ground seed powder (Table 3) and sprouts of other crops (Table 4). Significant differences for nitrogen (4.1%), calcium (0.27%) and phosphorous (0.72%), zinc (51%), copper (23%) were found among sprouts of three flax cultivars (Table 2). There were no significant differences for potassium (K), magnesium (Mg), boron (B), manganese (Mn), iron (Fe) and aluminum (Al) among the cultivars. Flax sprouts contained higher contents of Fe (63.4%), Mn (52.9%), and Zn (44.4%). The increase in contents of Fe and Zn was positively correlated with an increase in vitamin C,

riboflavin and thiamine in seed sprouts (Michalova et al., 2001). These results were confirming that the flax sprouts could be rich sources of vitamin C, riboflavin and thiamine due to increased availability of Fe and Zn.

Table 2. Mineral composition of flax sprouts of three cultivars Rahab-94, Linott and Pembina

Nutrient	Rahab 94	Linott	Pembina	Mean	R ² (%)	CV (%)
N	4.1a	3.6b	4.0a	3.9	35.9	9.4
S	0.23a	0.20b	0.21b	0.22	52.4	7.3
P	0.72a	0.7a	0.69a	0.7	10.3	10.3
K	0.85a	0.74a	0.76a	0.78	18.8	16
Mg	0.42a	0.40a	0.41a	0.41	16.3	8.3
Ca	0.27a	0.25a	0.24b	0.25	12.1	20.8
Na	0.08b	0.06a	0.07ab	0.07	39.6	15.3
B	17.5a	15.8a	15.5a	16.3	31.4	9.94
Zn	51a	39.8a	42.3b	44.4	51.6	13.1
Mn	55.3a	50.5a	53a	52.9	16.3	21.4
Fe	64.2a	62.8a	63.3a	63.4	19.7	15.9
Cu	23 a	18.8b	18.2b	20	42.1	15.2
Al	7 b	12.8a	9.8a	9.9	19	75.2

The individual values of mineral content for three cultivars were means of three replications and two experiments; Means with same letter (a or b) are significantly not different.

Table 3. Nutritional values of ground flax seed and sprouts

Nutrient Item	Flax sprouts ^x	Flax seed ^y
Protein (%)	22.34	21.68
Crude fiber (%)	17.03	19.44
Total Sugars (%)	8.08	2.57
Macronutrients		
Nitrogen (%)	3.88	20
Phosphorous (%)	0.70	0.21
Potassium (%)	0.78	0.65
Calcium (%)	0.25	0.40
Magnesium (%)	0.41	0.90
Sulfur (%)	0.22	3.42
Sodium (%)	0.07	0.26
Micronutrients		
Aluminum (%)	9.89	15
Boron (%)	16.28	0.08
Copper (%)	20	55
Iron (%)	63.44	43.67
Manganese (%)	52.94	37.33
Zink (%)	44.39	17.67

Contents are the mean % values of three cultivars (g/100g dry basis) for ^x sprouts and ^y seed.

Table 4. Nutritional value of flax sprouts in comparison to those of canola, alfalfa, mungbean, radish and Brussels sprouts

Nutrient*	Flax	Canola	Alfalfa	Mungbean	Radish	Brussels Sprout
Moisture (%)	76.58	80.3	91.1	90.4	90.1	86.0
Protein (%)	22.34	25.08	45.0	31.7	38.4	3.4
Crude fiber (%)	17.03	-	25.2	18.7	-	3.8
Total Sugars (%)	8.08	-	0.18	4.13	-	2.20
Macronutrients						
Phosphorous (%)	0.70	.61	.07	.05	.11	.07
Potassium (%)	0.78	.43	.08	.15	.09	.39
Calcium (%)	0.25	.43	.03	.01	.05	.04
Magnesium (%)	0.41	.31	.03	.02	.04	.02
Sulfur (%)	0.22	.57	-	-	-	-
Sodium (%)	0.07	.01	.01	.01	.01	.02
Micronutrients						
Aluminum (%)	9.89	9.81	-	-	-	-
Boron (%)	16.28	12.35	-	-	-	-
Copper (%)	20	5.69	1.57	1.64	1.20	.70
Iron (%)	63.44	88.46	9.60	9.10	8.60	14.00
Manganese (%)	52.94	45.44	1.88	1.88	2.60	3.37
Zink (%)	44.39	48.98	9.20	4.10	5.60	4.20

*The nutrients are mean % values measured as g/100g on dry weight basis. The nutrient values for canola, alfalfa, mungbean, radish and brussels sprouts were extracted from National Nutrient Database for Standard Reference Release 24 Software v. Release 1.0 3/30/12 accessed on April 22, 2012.

Significant difference was observed for mineral nutrient composition between seeds and sprouts (Table 3). The macronutrient compositions were comparatively high in seed for all the nutrients studied and were low in sprouts except for phosphorous (0.7%) and potassium (0.8%). The micronutrient values were relatively high for B (16.3%), Fe (63.4%), Mn (52.9%) and Zn (44.4%) and low for Al (9.9%) and Cu (20%) in sprouts when compared to those of ground flax seed. The increase or decrease in the quantity of mineral nutrients influence the specific amino acid composition of sprout as the original complex seed protein change to simpler amino acids along with the production of non protein amino acids (Rudra, 1938; Finney, 1982). Forty-two hours germination of black gram gave maximal production of lysine, an essential amino acid that absorbs Fe and Zn (Finney, 1982). This indicates that flax sprouts could be healthier due to availability of essential micronutrients (Fe and Zn) and can be used as potential alternative in place of ground flax seed for human consumption. These results are in line with the findings of Michalova et al. (2001) in buckwheat sprouts; Bhardwaj and Hamama (2007, 2009) in canola; and Saeidi and Rowland (1999) in flax revealing the nutritional potential of flax sprouts.

Composition of flax sprouts was comparable to sprouts of canola, mungbean, alfalfa, radish and brussels sprouts (Table 4). Flax sprouts were observed, in general, to be a good source of essential micronutrients among all the crop sprouts except for Fe when flax sprouts contained lower values (63.4%) as compared to canola sprouts (88.5%).

Based on the nutritional quality and relative comparisons made during the current study, we conclude that Rahab 94 was the most desirable cultivar for sprouting.

4. Conclusions

The current study revealed distinct nutrient profiles for sprouts compared to ground seed indicating potential use of flax sprouts as an alternative to ground seed powder. The current characterization, based on three cultivars, provides an understanding of nutrient values of flax sprouts. We propose further studies related to changes in

flax seed composition associated with sprouting related to compositions of amino acids, fatty acids, antioxidants, and phenolic compounds to fully characterize nutritional quality of flax sprouts for human health. An additional area of investigation might be related to production of sprouts from golden yellow seeds.

Acknowledgement

This project was supported by the Specialty Agricultural Research Grant from Virginia Department of Agriculture and Consumer Services. Contribution of Virginia State University, Agricultural Research Station, Journal Article Series No.293. Use of any trade names or vendors does not imply approval to the exclusion of other products or vendors that may also be suitable.

References

- AOAC. (1995). *Official Methods of Analysis*. Association of Official Analytical Chemists (16th Ed). Arlington, VA.
- Bhardwaj, H. L., & Hamama, A. A. (2007). Yield and nutritional quality of canola sprouts. *HortScience*, *42*(7), 1656-1658.
- Bhardwaj, H. L., & Hamama, A. A. (2009). Effect of cultivar and growing location on the mineral composition of canola sprouts. *HortScience*, *44*(2), 508-511.
- Bhardwaj, H. L., Hamama, A. A., Narina, S. S., & Parry, J. (2012). Consumption of ground wholeseed flax and human blood traits. *Journal of Agricultural Science*, *4*(8), 106-111.
- Bhardwaj, H. L., & Hamama, A. A. (2012). Yield and nutritional quality traits of White Lupin sprouts. *Journal of Agricultural Science*, *4*(1), 58-61.
- Fernandez-Orozco, R., Piskula, M. K., Zielinski, H., Kozłowska, H., Frias, J., & Vidal-Valverde, C. (2006). Germination as a process to improve the antioxidant capacity of *Lupinus angustifolius* L. var. Zapaton. *European Food Research and Technology*, *223*, 495-502. <http://dx.doi.org/10.1007/s00217-005-0229-1>
- Finney, P. L. (1982). Effect of germination on cereal and legume nutrient changes and food or feed value: A comprehensive review. Recent Advances in Phytochemistry Volume 17 Mobilization of Reserves in Germination. Plenum press, New York and London (pp. 228-307).
- Hamama, A. A., & Bhardwaj, H. L. (2004). Phytosterols, triterpene alcohols and phospholipids in seed oil from white lupin. *J Am Oil Chem Soc.*, *81*, 1039-1044. <http://dx.doi.org/10.1007/s11746-004-1019-z>
- Hamama, A. A., & Bhardwaj, H. L. (2011). Characterization of total and individual sterols in canola sprouts. *J Am Oil Chem Soc.*, *88*, 361-366. <http://dx.doi.org/10.1007/s11746-010-1676-9>
- Harrison, H. C. (2007). Growing Edible Sprouts at Home. Retrieved November 23, from <http://learningstore.uwex.edu/pdf/A3385.PDF>
- Michalova, A., Gabrovska, D., Fiedlerova, V., Holasova, M., Maskova, E., & Smrcinova, H. (2001). Nutritional changes during the germination of diploid and tetraploid buckwheat seeds. The proceeding of the 8th ISB, 564-570. Retrieved from <http://lnmcp.mf.uni-lj.si/Fago/SYMPO/2001sympoEach/2001s-564.pdf>
- Prasad, K. (2009). Flax Seed and Cardiovascular Health. *J Cardiovasc Pharmacol.*, *54*(5), 369-377. <http://dx.doi.org/10.1097/FJC.0b013e3181af04e5>
- Peer, D. J., & Leeson, S. (1985). Nutrient content of hydroponically sprouted barley. *Anim. Feed Sci. Technol.*, *13*, 191-202. [http://dx.doi.org/10.1016/0377-8401\(85\)90022-7](http://dx.doi.org/10.1016/0377-8401(85)90022-7)
- Rudra, M. N. (1938) Studies in vitamin C. Part V. Vitamin C content of some germinated cereals and pulses. *J. Indian. Chem. Soc.*, *15*, 191-93.
- Saeidi, G., & Rowland, G. G. (1999). The effect of temperature, seed color and linolenic acid concentration on seed germination and seed vigor in flax. *Can Journal of Plant Sci.*, *79*, 315-319. <http://dx.doi.org/10.4141/P98-100>
- Saeidi, G., & Rowland, G. G. (2000). The effect of autoclaving with nursery soil on emergence in flax. *Can. J. Plant Sci.*, *80*, 725-727. <http://dx.doi.org/10.4141/P99-179>
- SAS. (2008). *SAS system for windows*. SAS Institute, Inc, Cary, NC.