GoBarley

Barley: An Incredible Source of Antioxidants and Phytochemicals

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Growing Forward 2
A federal-provincial-territorial initiative

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The National Academies of Science, Engineering, Medicine (NASEM) recommends that diets contain antioxidants.[1] While new foods are appearing in the grocery aisles touting their antioxidant content, barley is an ancient whole grain that is packed with nutrients, including antioxidants.

Why are antioxidants important? Everyday life is tough on our cells. They are under constant attack from molecules known as reactive oxygen species (ROS). ROS occur as a result of normal processes necessary to sustain life—including breathing, which generates approximately 90 per cent of cellular ROS.[2] When there is an imbalance between the levels of ROS and antioxidants, oxidative stress can cause damage to cells. In fact, research shows that oxidative stress plays a role in the development of chronic diseases, including: cancer, cardiovascular disease and even neurological impairment.[2]

The IOM defines an antioxidant as a substance in food that significantly decreases the adverse effects of ROS on normal physiological functions in humans.[1] Antioxidants are natural or synthetic compounds that can "neutralize" ROS before they are able to damage cellular components. The body has complex defense mechanisms that are supported by the consumption of antioxidant-rich foods, including those with vitamins A, C and E, minerals and a variety of other compounds. As humans age, the body's antioxidant levels decline, which can result in oxidative damage. Dietary antioxidants are necessary to maintain the body's defense systems.[2]

Phytochemicals are naturally occurring substances in plants, many of which possess antioxidant activity.[3] A healthy diet is recognized as one that not only meets all essential nutrient requirements, but also includes foods that are rich in bioactive components. Studies have shown that supplements of individual vitamins and minerals do not appear to offer the same beneficial effects as diets rich in fruits, vegetables and whole grains. The health benefits of whole foods are likely due to the interactions of many phytochemicals working together.[4]

Barley: Rich in Antioxidants

Barley is an excellent source of biologically active nutrients, including dietary fibre, sterols, tocopherols, tocotrienols, alkylresorcinols, phenolic acids, vitamins and minerals. The phytochemical content of barley as compared to wheat and oats are shown in table 1.

Table 1. Comparison of phytochemical content of barley, wheat and oats[3]

Phytochemical	Barley	Wheat	Oats
Polyphenols (mg/100g)	50–196	50–196	9–34
Phenolic acids (µg/g)	100–550	200–900	350–874
Ferulic acid (mg/100g)	110–120	16–213	2.1–2.4
Flavanoids (mg/100g)	12–18	30–43	5.6–8.2
Alkylresorcinols (µg/g)	0–150	200–750	Not present
Betaine (mg/100g)	40–76	22–291	11.3–100
Phytosterols (mg/100g)	90–115	57–98	Unknown

In cereal grains, antioxidants are found mostly in the outer layers of the kernel to protect the endosperm nutrients from oxidation. The removal of the hull, aleurone and germ during pearling reduces antioxidant capacity.[5] However, the thermal and milling processes used to make grains more palatable may in fact increase the bioavailability of phytochemicals in spite of a potential reduction in their total content.[3] Pot barley undergoes a shorter pearling process than pearl barley, so most of the barley bran remains intact, conserving the antioxidant content. Hulless barley does not require pearling prior to consumption and may offer benefits due a higher antioxidant capacity.[5]

Plant Sterols, Alkylresorcinols and Phenolic Acids

Phytosterols or plant sterols are compounds that help to lower serum cholesterol levels in humans. Ingestion of 1–3 g/day of plant sterols is associated with a 10 per cent decrease in "bad" serum LDL-cholesterol without altering levels of "good" HDL-cholesterol.[6] Barley is a natural source of phytosterols with 70–80 mg per 100 g, approximately twice the amount found in oats.[6]

Alkylresorcinols are found in high amounts in rye, wheat and barley, and do not occur in oats.[6] The health benefits of these unique phytochemicals include the ability to reduce the absorption of cholesterol and to regulate triglyceride metabolism.[6] Alkylresorcinols have antioxidant as well as antibacterial and antifungal properties.[6] The alkylresorcinol content of barley ranges from 41–210 mg/g.[6]

Phenolics are also antioxidants found in grains. They consist of a wide variety of subgroups, including phenolic acids, flavonoids, stilbenes, coumarins and tannins.[7] Barley contains two major groups of phenolic acids, hydroxybenzoic acids and hydroxycinnamic acids. Hydroxycinnamic acids consist of ferulic, sinapic, p-coumaric, and caffeic acids.[8] Ferulic acid is located

mostly in the cell walls of the outer layers of the barley grain, primarily in the bran fraction.[9] Ferulic acid possesses high antioxidant activity, and has anti-inflammatory and tumour inhibition properties.[9] Diets rich in phenolic compounds are associated with reduced risk of cardiovascular disease and some cancers.[10] Muffins baked with barley flour were found to have the highest phenolic content (1,687 µg/g) compared to muffins made with corn (1,454 µg/g), oats (945 µg/g), wheat (705 µg/g), or rice (675 µg/g) flour.[11]

Vitamin E

New research indicates that barley is rich in tocopherol (natural vitamin E), a fat-soluble vitamin that exists in eight structurally related compounds: α-, β-, γ- and δ-tocopherols, and α-, β, γ- and δ-tocotrienols. These are collectively referred to as tocochromanols.[12] All tocochromanols have a similar basic chemical structure.

Antioxidant Properties of Vitamin E

Vitamin E is well known for its antioxidant properties.[13] Indeed, all tocochromanols are powerful biological antioxidants protecting cells against the effects of ROS. Both tocopherols and tocotrenols act as radical scavenging antioxidants *in vitro* and *in vivo*; the reactivities toward free radicals decrease in the order of α-, β-, γ- and δ-tocochromanols. Vitamin E can quench and react with free radicals in cell membranes, thus preventing damage to cellular lipids, proteins or DNA. Such oxidative cell damage has been linked to the onset of many degenerative conditions and diseases, including atherosclerosis, cancer, cataracts, arthritis and Alzheimer disease.

A number of clinical studies conducted in the 1990s and 2000s reported that vitamin E exerts antioxidant effects *in vivo* and, therefore, is associated with a decreased risk of chronic diseases. For example, the Women's Health Study found that vitamin E decreased cardiovascular mortality in women overall by 24 per cent and in women over 65 by 49 per cent[14]; the Antioxidant Supplementation Study showed that treatment with vitamins E and C slowed atherosclerotic progression in hypercholesterolemic patients and those with heart transplants[15]; the Cache County Study reported that the use of vitamins E and C was associated with reduced prevalence of Alzheimer disease in the elderly.[16]

However, a few other studies have failed to show significant benefits of vitamin E supplementation in the amelioration of cardiovascular disease in humans.[17,18,19] These inconsistencies might be related to differences in study duration, patient selection and, most importantly, the dosage and source of vitamin E, especially the exclusive use of α-tocopherol and/or synthetic α-tocopherol and not the other forms of vitamin E.[20] These sometimes-discrepant results may indicate that mechanisms other than anti-oxidative effects may be important and clinically relevant.

Functional Uniqueness of Tocotrienols and γ-Tocopherols

Unique biological functions of other vitamin E components have recently been revealed. For example, a role distinct from free radical scavenging has been proposed for γ-tocopherol. In contrast to α-tocopherol, γ-tocopherol traps some carcinogens and may prevent lipid, DNA and protein damage.[21]

In vitro studies indicate that tocotrienols possess powerful neuroprotective, antioxidant and anti-cancer properties.[12] Tocotrienols have been shown to suppress proliferation of a wide variety of tumor cells, including those of the breast, colon, lung and prostate.[12] Tocotrienols have been demonstrated to have cholesterol-lowering properties in animals and humans; micromolar amounts of tocotrienols suppress the activity of HMG-CoA reductase, the hepatic enzyme responsible for cholesterol synthesis, resulting in less cholesterol being manufactured by liver cells.[12] These findings have established the ratio of tocotrienols to tocopherols (T3/T) as an important criterion of the biopotential of grains and other foods considered as sources of vitamin E.

Barley Tocopherols and Tocotrienols

Since only photosynthetic organisms synthesize tocochromanols, humans and animals must obtain vitamin E from foods and supplements. Barley grain is unique as a source of vitamin E because, compared to other cereals and oilseeds, it contains relatively large amounts of all eight tocochromanols, with a favorably high ratio of tocotrienols to tocopherols (Figure 1). By comparison, β-tocotrienol is a major form of tocotrienol found in wheat and γ-tocopherol predominates in corn.[12,22,23] α-Tocotrienol is the most abundant form of tocotrienols in oats, but compared to barley, the overall content of tocochromals is relatively low.[24]

The levels and composition of tocochromals in barley are affected by genetic and environmental factors[25]; however, α-tocotrienol comprises the largest proportion (about 45 per cent) of the total tocochromanols, followed by α-tocopherol and/or β- and γ-tocotrienols, depending on barley genetics.

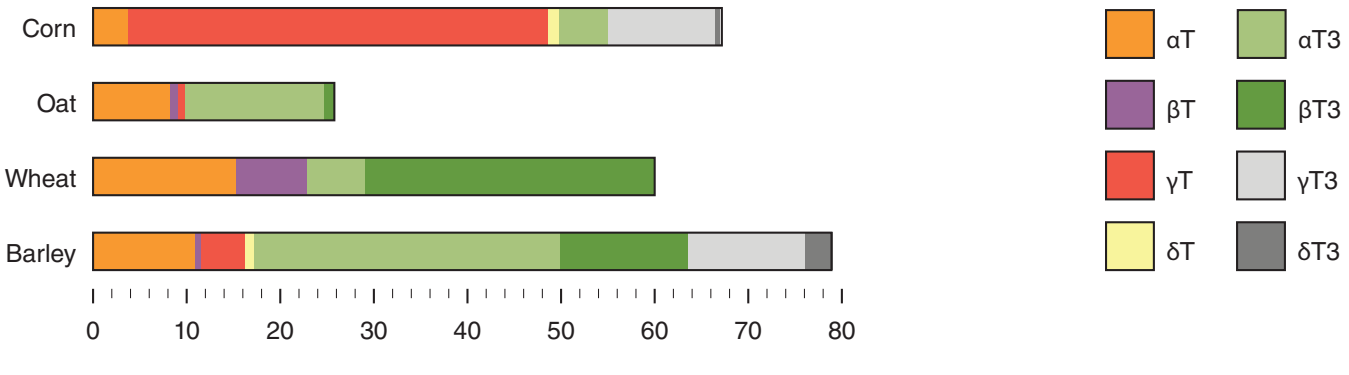

Figure 1. Content and composition of tocochromanols in cereal grains. αT, βT, γT, δT designate α-, β-, γ- and δ-tocopherols, whereas αT3, βT3, γT3, δT3 designate α-, β-, γ- and δ-tocotrienols.

Compared to oat bran or wheat bran, which are popular and readily available food ingredients containing vitamin E, barley fibre fractions are relatively new and not yet commercially available. Barley fibre fractions can be generated by similar processes used in the production of oat or wheat bran, such as roller milling, stone milling or pin milling.[26] As shown in Figure 2 and Table 2, fibre fractions produced from food barley varieties can deliver functional vitamin E analogues as well as β-glucans, other dietary fibre constituents (arabinoxylans), proteins and minerals. They can be easily incorporated into various food and beverage products.

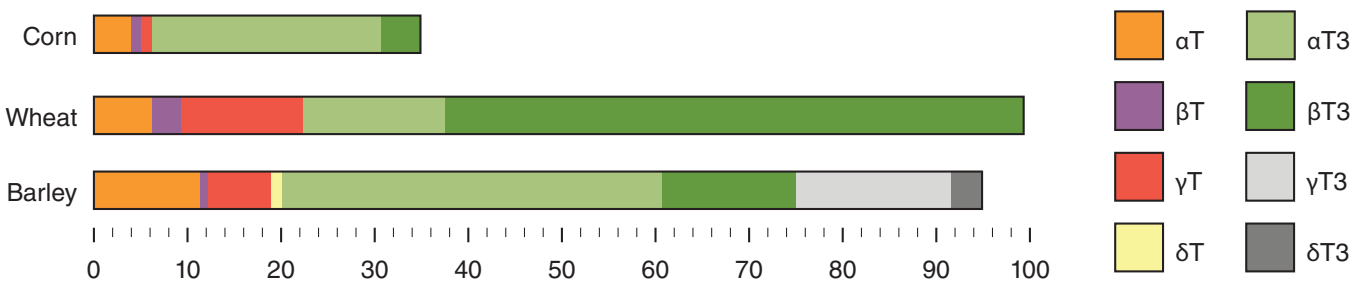

Figure 2. Content and composition of tocochromanols in oat bran, wheat bran and barley fibre fractions.

Table 2. Content of major and minor constituents in barley (CDC Hilose) and in barley fibre fraction obtained by dry milling[26]

Barley (CDC Hilose)		
Phytochemical	Barley	Wheat
Starch (%)	54.2	36.0
Protein (%)	14.9	16.7
β-Glucan (%)	7.0	12.7
Arabinoxylan (%)	5.2	9.3
Dietary Fibre (%)	18.5	35.5
Minerals (%)	1.8	3.0
Vitamin E (μg/g)	78.8	95.0

* dwb, dry weight basis

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References

1. National Academies of Science, Engineering, Medicine. Health and Medicine Division (formerly The Institute of Medicine). Dietary reference intakes: Vitamin C, vitamin E, selenium, and carotenoids. Washington, DC: National Academy Press; 2000.
2. Kandola K, et al. Int J Cosmet Sci. 2015;37 Suppl 2:1-8.
3. Belobrajdic DP, Bird AR. Nutr J. 2013;12:62.
4. Goszcz K, et al. Front Cardiovasc Med. 2015;2:29.
5. Do TD, et al. Food Chem. 2015;187:65-74.
6. Bartlomiej S, et al. Food Sci Technol Int. 2012;18(6):559-568.
7. Ragaee S, et al. Crit Rev Food Sci Nutr. 2014;54(7):837-849.
8. Gangopadhyay N, et al. Molecules. 2015;20(6):10884-10909.
9. Yu L, et al. Cereals and pulses: Nutraceutical properties and health benefits. Ames, IA: John Wiley & Sons Inc.; 2012.
10. Andersson AA, et al. J Agric Food Chem. 2008;56(21):9767-9776.
11. Soong YY, et al. Food Chem. 2014;164:462-469.
12. Sen CK, et al. Mol Aspects Med. 2007;28(5-6):692-728.
13. Colombo ML. Molecules. 2010;15(4):2103-2113.
14. Lee IM, et al. JAMA. 2005;294(1):56-65.
15. Salonen RM, et al. Circulation. 2003;107(7):947-953.
16. Zandi PP, et al. Arch Neurol. 2004;61(1):82-88.
17. Muntwyler J, et al. Arch Intern Med. 2002;162(13):1472-1476.
18. MRC/BHF heart protection study of antioxidant vitamin supplementation in 20,536 high-risk individuals. Lancet. 2002;360(9326):23-33.
19. Lonn E, et al. JAMA. 2005;293(11):1338-1347.
20. Braunstein MH, ed Vitamin E: New research. New York: Nova Science Publishers, Inc.; 2006.
21. Brigelius-Flohe R, Traber MG. FASEB J. 1999;13(10):1145-1155.
22. Panfili G, et al. J Agric Food Chem. 2003;51(14):3940-3944.
23. Nielsen MM, et al. Cereal Chem. 2008;85(2):248-251.
24. Peterson DM, Qureshi AA. Cereal Chem. 1993;70:157-162.
25. Oliver RE, et al. PLoS One. 2014;9(5):e96276.
26. Izydorczyk MS, et al. Can J Plant Sci. 2014;94(3):573-586.

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