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The Soy Connection

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HEALTH AND NUTRITION NEWS ABOUT SOY

Biotechnology's Possibilities for Soyfoods and Soybean Oil

By Susan Harlander, Ph.D.

Soy is a relative newcomer in the U.S. diet – the first soybeans were grown in the U.S. in the early 1800s, and the first uses were for animal feed in which the nutritional quality of the protein-, mineral- and vitamin-rich soybean could be exploited. Conventional breeding has been employed to improve the taste, texture, digestibility and nutritional quality of soybeans, and these changes have enhanced their use in human food. But there are technical limitations as to how much can be accomplished using conventional breeding techniques, and it can take 10-15 years to introduce an improved variety. Biotechnology has emerged as a valuable tool for creating new varieties of soy with enhanced agronomic and nutritional properties. With biotechnology, it is possible to transfer a single gene or a couple of genes in a much more precise, controllable, predictable and time-efficient manner than with conventional breeding. Biotechnology opens up incredible opportunities for improving the food supply.

The first generation of biotechnology-improved soybeans involved improvement of agronomic traits such as herbicide tolerance and disease resistance. The transfer of a single gene that confers resistance to the herbicide RoundUp® has resulted in a 28.7 million lb/year reduction in the use of herbicides and a significant decrease in soil erosion due to decreased tillage.[1] Another improved variety on the horizon is insect resistant soybeans that will reduce the use of insecticides and lessen production costs.[2]

The next generation of biotechnology-improved soybeans will result in oil with improved performance and enhanced nutritional properties. The predominant oil in the U.S. diet is soybean (vegetable) oil (80 percent of the edible oil used in the U.S. in 2003), but there are many opportunities to improve the functional and nutritional quality.[3] Oils are frequently hydrogenated in order to solidify them, which increases shelf life and flavor stability of oils and foods that contain them. Hydrogenation also creates trans fats that elevate LDL ("bad" cholesterol) and increases the risk of coronary heart disease and stroke.[4] It would be desirable to have oil which does not generate trans fatty acids during hydrogenation. One approach to achieving this objective is to decrease the concentration of linolenic acid. Decreasing linolenic acid provides a more stable oil with better flavor and requiring less hydrogenation, which reduces or eliminates trans fatty acids. This variety is expected to be launched commercially in 2006. The next generation improvement, expected to be commercially launched in 2008, will be to increase the concentration of oleic acid (a monounsaturated fatty acid) from 23 percent to 55-60 percent, which will result in a significant improvement in flavor, oxidative stability and shelf life. A subsequent improvement will reduce saturated fat from 15 percent to <3.5

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Research Updates

By Mark Messina, Ph.D.

Qualified Health Claim

The Food and Drug Administration (FDA) now allows qualified health claims for foods. Unlike the FDA-approved health claim for soy protein and coronary heart disease, qualified claims are those whose support is suggestive, but not definitive.

On March 1, 2004, the FDA received a petition for a qualified health claim for soy protein reducing the risk of prostate, breast, and gastrointestinal (GI) cancer. One suggested example of a qualified claim included in the petition is:

Soy protein may reduce the risk of certain cancers. Scientific evidence suggests that the consumption of soy protein may reduce the risk of certain forms of cancer. However, the evidence is not conclusive.

The petition in question was submitted by Solae Co., and the FDA has until November 26, 2004, to arrive at a final decision. The evi-

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percent, making it the lowest saturated fat content available for any natural oil. This variety is expected to be launched in 2011 and will include all of the improvements discussed above.[5-6] Genetically improved soybean varieties of the future will routinely contain "stacked" genes that will include new advancements in combination with previous developments.

During the past few years, there has been an increase in both scientific and public interest in the role of Omega-3 fatty acids (eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]) found in fish and fish oils in the prevention and management of cardiovascular disease.[7] Genetic engineering can be used to enhance the native ability of soybeans to produce stearidonic acid (SDA), a precursor of EPA and DHA, making soy an alternative to fish or fish-derived Omega-3 fats. In foods, SDA has greater oxidative stability than EPA or DHA, and SDA is more rapidly and efficiently converted to EPA than the alternative precursor, alpha linolenic acid.[6] This variety should be available commercially in 2008.

With the 1999 FDA approval of a health claim linking the consumption of soy protein (25 g/day) to a reduced risk of coronary heart disease, soy protein is being incorporated into many food products including soy beverages, nutritional bars and conventional processed foods. In many cases, it is difficult to mask the flavor of high levels of soy protein, so genetic engineering is being used to reduce off flavors. By increasing the concentration of beta-conglycinin, a seed storage protein, solubility and mouth feel, texture and stability against separation are improved. In addition, this protein acts more like casein, which will be beneficial in beverage applications.[6]

In addition to modifications of oil and protein content, there is excitement around the many bioactive phytochemicals present in soybeans including isoflavones, genistein, lignans and phytoestrogens. Compounds in soy have been implicated in relieving some of the symptoms of menopause,[8] reducing the risk of cancer,[9] increasing bone density,[10] reducing cholesterol,[11] facilitating weight management by increasing satiety,[12] and improving muscle recovery following exercise.[13] As the metabolic pathways for these compounds are understood, it will be possible to modulate accumulation of these bioactive compounds.

Finally, genetic engineering can also be used to remove undesirable components in soybeans. For example, it may be possible to reduce the allergenic protein P34 or reduce raffinose, a fermentable sugar that causes some individuals to produce gas.

Scientific organizations around the world agree that biotech crops in the market today are as safe as, or safer than, crops developed through conventional breeding. The ultimate beneficiaries of the technology will be consumers who can look forward to nutritionally improved products that will help them meet their dietary and health goals.

ABOUT THE AUTHOR

Susan K. Harlander, Ph.D., is president of BIOrational Consultants, Inc., a consulting firm specializing in food and agricultural biotechnology issues facing all aspects of the food supply chain. She received her M.S. in microbiology and her Ph.D. in food science from the University of Minnesota, where she later served as an associate professor of food biotechnology.

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Organic Agriculture: Does It Affect Antioxidants and Nutritional Quality?

By Alyson E. Mitchell, Ph.D., and Alexander W. Chassy, B.S.

Consumer awareness of the relationship between foods and health, together with environmental concerns, has led to an increased demand for organically produced foods. In general the public perceives organic foods as being healthier and safer than those produced through conventional agricultural practices.[1] However, controversy remains regarding whether or not organic foods have a nutritional and/or sensory advantage when compared to their conventionally produced counterparts. Advocates for organic produce claim it contains fewer harmful chemicals, is better for the environment and may be more nutritious. There are fundamental differences in organic and conventional production practices, but limited information is available detailing how various practices influence the nutritional quality, especially in terms of health-related antioxidants, of soybeans and other food crops.

Fruits and vegetables are a focal point of this controversy, since these foods are a significant source of phenolic antioxidants, as phenolic acids and flavonoids, in the diet. Epidemiological studies consistently indicate an inverse correlation between the consumption of fruits and vegetables and the risk of human cancers, cardiovascular disease, diabetes and age-related declines in cognition.[2-7] These chronic diseases are linked to the oxidation of critical cellular macromolecules (e.g. proteins, lipids and DNA) by reactive oxygen species (ROS).[8] Phenolic antioxidants are thought to neutralize ROS before they cause damage and lead to diseases. Dietary guidelines set by the USDA now suggest increased consumption of fruits and vegetables (5-11 serving a day). Additionally, reports by WHO and the Food and Agriculture Organization (FAO) of the United Nations emphasize the role of foods and nutrition in the prevention of noncommunicable diseases and point to a role for plant-derived phytochemicals in the prevention of heart disease and cancer.[9-10]

It is important to recognize that both conventional and organic agricultural practices represent dynamic systems that can vary greatly depending upon region, soil quality, prevalence of pests, crop, climate and farm philosophies. This makes comparisons very difficult. Conventional agriculture evolved globally in response to the availability of high-yield crop cultivars, chemical fertilizers and pesticides, and progressing irrigation and mechanization. Organic farming has also evolved, yet must adhere to National Organic Standards set by the USDA in 2000. Accordingly, organic crops must not be genetically engineered, irradiated, or fertilized with sewage sludge. Additionally, farmland used to grow organic crops is prohibited from treatment with synthetic pesticides and herbicides for at least three years prior to harvest. Disease-resistant varieties are often used and plant nutrients are supplied through crop rotation, cover crops and animal manure.

Fertilization is an important aspect to consider when comparing organic and conventional agriculture. Organic fertilization typically does not provide nitrogen in a form that is as readily accessible to plants as conventional fertilizers. The accessibility of nitrogen has the potential to influence the synthesis of phenolic antioxidants and soluble solids. For example, several studies demonstrate there is a decrease in the concentration of phenolic antioxidants in plants with increasing nutrient availability.[11-14] There are various overlapping hypotheses that attempt to explain this relationship including the carbon/nutrient balance (CNB) hypothesis, growth-differentiation balance (GDB) hypothesis and protein competition model (PCM).[15-17] In general, these theories state that high nutrient availability leads to an increase in plant growth and development, and a decreased allocation of resources towards the production of expendable metabolites such as the phenolic antioxidants.

The term phenolic antioxidant refers to both simple phenolic acids and flavonoids. They are products of secondary plant metabolism and are ubiquitous natural components of plants. Secondary plant metabolites are defined as those compounds that are not essential to the life of the plant (e.g. DNA, RNA, chlorophyll, amino acids and starch) and include phytochemicals such as caffeine, isoflavonoids and phenolic antioxidants. Plants produce secondary metabolites as a defense mechanism against photo-oxidation, herbivory (insect and animal predation), and for protection against pathogen attack. Additionally, they are critical components in the health of the plant, and many are pigments that help to attract pollinating insects. The composition of secondary plant metabolites differs between plants and within plant tissues. Genotype (i.e. the cultivar or variety) is the primary determinant of the composition of secondary plant metabolites, although their expression is strongly influenced by environmental pressures, climate and UV-light exposure.[18]

Scientists have recently begun to question whether the levels of phenolic antioxidants are lower in foods grown using conventional agricultural practices, since these practices utilize levels of pesticides and fertilizers that can result in a disruption of the natural production of plant-defense related metabolites. Differences between the content of phenolic metabolites in organically and conventionally produced fruits and vegetables allow for the possibility that organically grown produce may benefit human health more than corresponding conventionally grown produce.

Reviews of existing literature demonstrate inconsistent differences in the nutritional quality of conventionally and organically produced vegetables with the exception of potentially higher levels of certain minerals, ascorbic acid and less nitrates in organic foods.[19-22] However, these data are difficult to interpret, since cultivar selection and growing conditions varied widely and different methods of sampling and analysis were used in the investigations reviewed. Additionally, the majority of these studies did not assess levels of phenolic antioxidants, as their role in human health was not yet appreciated. However, it is generally agreed that the levels of secondary metabolites have the potential to differ the most between these two agricultural

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Frequently Asked Questions About Biotech and Organic Foods

F.Y.D.
From Your Dietitian

Q: What is biotechnology, and is it safe?
A: By a simple definition, biotechnology includes applied life sciences such as fermentation and classic breeding techniques. However, when many people think of biotechnology, they focus on modern methods of altering the genetic composition of living cells, thus changing their function.

Regulatory agencies, including the FDA, EPA and USDA, have reviewed and declared foods and ingredients produced through biotechnology as safe. More than 1,800 scientific evaluations comparing biotech and non-biotech soybeans were performed for the FDA, and researchers concluded that the plants are indistinguishable.[1] Biotech foods appeared 10 years ago in the U.S., where only 2 percent of consumers expressed concerns about the safety of biotechnology in a recent poll.[2] Particularly in Europe, however, questions have been raised about the safety of biotechnology and long-term, unseen effects.

Q: What is organic food?
A: According to the USDA, organic food is produced by farmers who emphasize the use of renewable resources and the conservation of soil and water. Organic food is produced without using most conventional pesticides; synthetic fertilizers or sewage sludge; biotechnology; or ionizing radiation. USDA certifying agents inspect farms where organic food is produced. Companies that handle or process organic food must be certified, too.

Q: How can organic farming benefit the environment? How can biotechnology benefit the environment?
A: Some people choose organic food because organic farming is designed to benefit the environment by conserving water and soil and reducing pollution. At the same time, crops enhanced through biotechnology often require fewer chemicals, like herbicides, than their non-biotech counterparts, and biotech soybeans have increased no-till practices that help improve soil and air quality, too.

Q: Can organic farming produce more nutritious food? Can biotechnology produce more nutritious food?
A: Some studies have shown higher levels of certain nutrients can be found in organic food; other studies have not. More research is needed to establish a consensus regarding a health benefit of organic food. Biotechnology also may produce benefits. For example, scientists are working to develop more nutritious soybeans by increasing levels of Omega-3 fatty acids. Soybeans that produce soy (vegetable) oil with enhanced nutritional properties may also become available in a few years.

Q: What can labels tell me about how a food is produced?
A: Only food labeled "organic" has been certified as meeting the USDA's organic standards. For more detailed information on what to look for on labels, visit the National Organic Program Web site at www.ams.usda.gov/nop. There are no labeling requirements at this time for food made with biotech ingredients.

Q: Where can I learn more?
A: For more information on agricultural biotechnology, visit these Web sites:

- Food and Drug Administration: www.fda.gov/oc/biotech/default.htm
- ADA: www.eatright.org/Public/Other/index_abiotechnology.cfm

For more information on organic farming and food, visit these Web sites:

- USDA National Organic Program: www.ams.usda.gov/nop
- ERS/USDA Briefing Room – Organic Farming & Marketing: www.ers.usda.gov/briefing/organic

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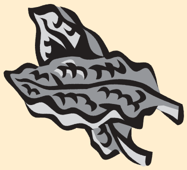
Soy and Spinach Artichoke Dip

Yield: 12 servings



Ingredients:
1 lb. silken tofu, crumbled
1 lb. lowfat cream cheese, cubed
1 cup lowfat mayonnaise
1/2 tsp. ground pepper
1 lb. frozen chopped spinach, thawed, drained
1 lb. marinated artichoke hearts, drained, coarsely chopped
1/2 cup green onions, chopped
Parmesan cheese, grated, for garnish (optional)

Preparation: Beat tofu with a food processor or electric mixer until smooth; mix in cream cheese, mayonnaise and pepper in mixing bowl. Fold in spinach, artichoke hearts and green onions. Divide mixture equally into 12 (4 oz.) au gratin dishes. Sprinkle Parmesan cheese on top, if desired. Bake at 350 degrees for 15-20 minutes or until bubbly and browned on top.

Healthy serving suggestions: Try it with carrot sticks, sweet peppers, celery, mushrooms, and whole grain crackers, bread sticks or toasted pita chips.

Nutrition Facts per serving: **Calories** 62, **Fat** 1.4 g, **Carbohydrate** 5.7 g, **Protein** 6.6 g, **Cholesterol** 3.9 mg, **Dietary Fiber** 1.5 g, **Sodium** 254 mg

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practices, since they are produced in response to stress.[22]

Recent studies (Table 1) have begun to examine the role of agriculture in the context of influencing the production of phenolic antioxidants in plants.[23-28] For example, in two studies conducted by Carbonaro et al., higher levels of total phenolics were found in organic peaches and pears when compared with their conventional counterparts.[23-24] In a study of five vegetables common in the Japanese diet, Ren et al. demonstrated that organically grown spinach contained 120 percent higher antioxidant activity while Welsh onion, Chinese cabbage and qing-gen-cai contained 20-50 percent higher antioxidant activity compared to their conventionally grown counterparts.[25] In our own studies, we have found consistently higher levels of total phenolics and ascorbic acid in organic strawberries, marionberries and sweet corn.[26] Conversely, Häkkinen and Törrönen report that organic cultivation had no consistent effect on the levels of phenolic compounds in strawberries.[27] In more recent, unpublished studies at the University of California Davis, we have found higher levels of total phenolics, soluble solids and ascorbic acid, as well as the flavonoid aglycone quercetin in two organically produced tomato cultivars. Interestingly, the same differences were not seen in organic bell peppers grown concurrently with the tomatoes. This demonstrates the important point that differences in agricultural practices will not affect all plants and all secondary metabolites equally. Research is needed to determine whether differences in agricultural practices affect the levels of phenolic antioxidants in soybeans.

Contemporary literature illustrates an apparent trend toward higher levels of phenolic antioxidants, ascorbic acid and soluble solids in organic foods. However, there are still far too few studies completed to establish a consensus regarding the health benefit of organic foods. Ultimately, more research examining relationships between agricultural production and the synthesis of phytochemicals in specific crops is needed. Future studies should emphasize the potential for agricultural manipulations to alter levels of both beneficial and potentially toxic phytochemicals in foods. The ability to manage and control levels of beneficial phenolic antioxidants in plants through cultivation has the potential to enhance the nutritive quality of foods.

ABOUT THE AUTHORS

Alyson E. Mitchell, Ph.D., is an assistant professor and food chemist at the University of California at Davis. Her lab specializes in assessing phytochemicals in foods and developing strategies to evaluate their role in human health. She received her B.S. with honors in environmental toxicology and her Ph.D. in pharmacology and toxicology from the University of California at Davis.

Alexander W. Chassy, B.S., is a food chemistry Master's student with Dr. Mitchell at the University of California at Davis. His research focuses on the potential differences between organic and conventional agriculture with respect to quality and health. He received his B.S. from the Department of Food Science at the University of Massachusetts at Amherst.

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Table 1. Review of Recent Findings

Study	Experiment Material	Parameters Analyzed	Findings	Reference
Asami et al., 2003	Marionberry, strawberry, corn	Total phenolics (TP), ascorbic acid (AA)	Increased TP and AA in organic and sustainable practices	26
Carbonaro and Mattera, 2001	Peach, pear	Polyphenoloxidase activity (PPO), TP	Increased TP and PPO activity in organic fruit	23
Carbonaro et al., 2002	Peach, pear	PPO activity, TP, AA, citric acid (CA), α-tocopherol (TH)	Increased TP and PPO activity in organic fruit; AA and CA higher in organic peaches, α-TH higher in organic pear and lower in peach	24
Grinder-Petersen et al., 2003	Human excretion metabolites following organic vs conventional diets	Quercetin (Q), kaempferol (K), hesperetin (H), naringenin, isorhamnetin (I)	Organic foods had higher Q, trends of higher K and lower I; higher urinary excretion of Q and K in organic diet	28
Häkkinen and Törrönen, 2000	Vaccinium berries, strawberry	Q, K, ellagic acid, p-coumaric acid	No consistent difference between organic and conventional techniques	27
Ren et al., 2001	Qing-gen-cai, Chinese cabbage, spinach, Welsh onion, green pepper	Antioxidant and antimutagenic activity, flavonoids (Q, K, H, caffeic acid, myricetin, quercitrin, hesperitin, apigenin, baicalein)	Higher antioxidant activity in organic spinach, onion, cabbage, qing-gen-cai, no difference in green pepper; antimutagenic activity higher in organic samples; generally higher flavonoids in organic samples	25

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Research Updates (Continued from Page 1)

dence submitted on behalf of the petition included animal and epidemiologic studies, but not clinical trials.

There were 22, 10, and 29, breast, prostate, and GI epidemiologic studies reviewed, respectively. The pooled odds ratios or relative risks (1.0 equals no effect, 0.5 equals a 50 percent reduced risk) for those three cancers were 0.78, 0.66, and 0.70, respectively. There was also a total of 39 animal studies considered, 33 of which the petition claims are supportive of the anticancer effects of soy.

Isoflavone supplements and the fermented soy product miso were excluded from the petition. As currently written, to qualify for the claim a soy product would need to provide at least 5.0 g soy protein per serving.

A Chemical Factory

The soybean is primarily known for being a good source of high quality protein and as a rich source of isoflavones. But the picture is a lot more complex than that; like all plant foods, the soybean has numerous chemical constituents, but until recently this has not been quantified. To this end, researchers from the University of Arkansas tore apart the soybean and by using liquid chromatography-tandem mass spectrometry methods found that isolated soy protein (ISP) consisted of 136 phytochemicals. More specifically they reported that on a weight/weight basis, fatty acids are the largest group of phytochemicals in the extract (64.13 percent total fat), followed by saponins (21.48 percent), and then isoflavones at 6.82 percent. Of the 56 lysophospholipids identified in ISP, 0.50 percent was lysophosphatidylcholines and 0.23 percent was lysophosphatidylethanolamines.

These results do not include the protein component and, since the test soy product was ISP (≥90 percent protein), which is a fairly refined product, it is likely an even more complex picture would have emerged had the whole soybean been studied. Of course, many of the constituents are likely present in such small amounts they are nutritionally irrelevant. Still, it is hard not to be amazed at the complexity of nature.

PSA Levels

The low Asian prostate cancer mortality rates have stimulated interest in the relationship between soy intake and prostate cancer. The American Cancer Society recommends that men eat soy to reduce risk and a group of European cancer experts concluded that isoflavones stop small tumors from progressing to the more lethal form of prostate cancer. Animal data are quite supportive of the anticancer effects of soy.

One means by which to test this hypothesis in humans is to examine the effect of soy or isoflavones on prostate specific antigen (PSA) levels. PSA is protein secreted by the prostate and can be measured in the serum. Generally, levels above 4 (ng/ml) are considered to be an indicator of prostate cancer but recent research suggests substantial numbers of cancers are missed when this cutoff point is used.

To examine the effects of soy on PSA, researchers from the Fred Hutchinson Cancer Research Center in Seattle provided healthy, older men a soy protein drink containing 83 mg isoflavones per day or a similar drink with the isoflavones removed. In total, PSA levels were measured in 81 men. However, after 12 months there was no effect on serum PSA concentration. These findings agree with those from two other studies also involving healthy men although, as noted in a previous issue of this newsletter (Vol. 11, No. 4), in prostate cancer patients resistant to conventional medical treatment, isoflavone supplements significantly slowed the rise in PSA levels.

Cancer Epidemiol Biomarkers Prev 13: 644-648, 2004; Nutr Cancer 2003;47(2):111-7

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