CENTER FOR AGRICULTURAL POLICY AND TRADE STUDIES
NORTH DAKOTA STATE UNIVERSITY

AGRICULTURAL POLICY BRIEF

No. 7 JANUARY 2005

Status of Selenium Research and Implications for North Dakota Wheat and Beef Producers

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The trace element selenium (Se) was discovered in 1818 by Jöns J. Berzelius. Initially, selenium was reported as a highly toxic element, but this conception changed in 1969 when a research study reported that selenium might prevent cancer, rather than cause it. The geographic distribution of selenium in world's soil is not uniform. High concentrations of selenium have been identified in various regions of China, the former USSR, Colombia, Venezuela, and the Great Plains region of the United States and Canada. While some regions of China have high concentrations of selenium, soil selenium levels are among the lowest in the world in other parts of the country, from the northeast region to the southwest through the provinces of Heliongjian, northern Shaanxi, and Sichuan. Soils in New Zealand, Denmark, and Finland are considered selenium-deficient (Combs, 2001). In the United States, New York state and most of the Northeast have low selenium levels (Powers, 1996).

This paper summarizes existing literature on the health effects of selenium and relates these results to a possible premium on wheat containing high levels of this element.

HEALTH EFFECTS OF SELENIUM

The role of selenium in preventing cancer has received a great degree of attention. One of the most influential experiments was conducted by the Nutritional Prevention of Cancer Trial (NPC Trial by Clark et al. in 1996). In this study, selenium-supplementation was associated with significant reductions in risks of cancers in the lung, colon, and prostate, but the strongest effect was on prostate cancer. As a result of this research, many epidemiological studies, clinical intervention trials, and investigations in laboratory animals have been conducted and have supported the protective role of selenium against the development of cancer. In the medical research environment during the past decade, it was widely accepted that "high-level exposure to at least some selenium compounds can be anti-tumourigenic" to several types of cancer (Combs, 2001). Most of the literature suggested that selenium can reduce cancer risk in two general ways: the first is by functioning as an essential nutrient that provides the catalytic centers of a number of selenium-enzymes with antioxidant and redox-regulatory functions. The other is by serving as a source of anti-tumourigenic selenium-metabolites (Combs et al., 2001). However, the mechanism by which selenium prevents cancer remains unknown (Diwadkar-Navsariwala and Diamond, 2004).

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In addition to being a cancer-preventing agent, selenium has been reported to have positive effects on a wide variety of conditions. For instance, there is evidence that selenium increases immunity against diseases such as diabetes (Faure et al., 2004; Kowluru and Koppolu, 2002), arthritis (Peretz et al., 2001), flu (McVeigh, 2005), and asthma (Linday et al., 2004). Selenium can prevent the progression of Age-related Macular Degeneration (AMD) or provide other ocular health benefits (Stuart, 2004). Additionally, selenium deficiency has been implicated in accelerated disease progression and poorer survival rates among populations infected with HIV (Kupka et al., 2004). Selenium also plays an active role in a mother's defense systems against the toxicity of environmental pollutants and the constituents of cigarette smoke (Kantola et al., 2004).

Recent results in the literature concerning selenium in cancer prevention are generating speculation over the robustness of previously reported findings on prevention of prostate cancer (Duffield-Lillico, 2002; Duffield-Lillico, 2003). These investigations found selenium supplementation to be effective in preventing prostate cancer in subjects that were nutritionally good but deficient with respect to selenium. Dose is also an important concern. Results suggest that higher selenium doses are needed to produce a significant increase in cellular uptake of the element, specially of those metabolites assumed to be highly anti-carcinogenic. From a review of Duffield-Lillico et al., Combs (2004) suggests that basic knowledge is still being developed to understand and evaluate the results related to selenium and its prostate cancer preventing properties. In order to make appropriate inferences from trial results, it is necessary to understand the mechanisms of selenium transport and cellular uptake. Additionally, information needs to be generated on the chemical speciation of selenium in foods so that delivery can be achieved in ways that are effective in reducing cancer risk and are also safe, accessible, and sustainable.

Alternatives for Enhancing Selenium in Food

Because of its anti-cancer properties, many people are seeking to consume supplemental selenium. The daily Recommended Dietary Allowance (RDA) for selenium is 55 micrograms for women and 70 micrograms for men (Powers, 1996). In order to minimize health risks, food systems should provide at least 40 micrograms of selenium per day, and cancer research data have estimated cancer prevention intake levels of around 200-300 micrograms per day (Combs, 2001).

The main food sources of selenium include Brazilian nuts, cereals, meats, and fish (especially oysters, lobsters, crabs, and clams) (Powers, 1996)). Fruits and vegetables are normally low in selenium (Combs 2001), except for Allium and Brassica vegetables (Finley et al., 2004; Combs, 2001). In the United States, beef, pork, chicken, eggs, and white bread constitute 50 percent of total selenium intake (Combs, 2001). In some countries, variations of the selenium content in wheat has been related to changes in sources of wheat imports, in order to provide for selenium intake (Combs, 2001).

Foods contain variable amounts of selenium depending on where they are produced. Wheat, meat, and broccoli are three foods that may accumulate substantial amounts of selenium when produced in high-selenium areas. The use of chemical fertilizers to increase selenium content in soils has been effective in Finland (Mäkelä et al., 1993), but it was a source of water contamination in Tennessee (Lahermo et al., 1998). Selenium-enriched products developed through fertilization include brussels sprouts, broccoli, garlic, onions, mint, chamomile, and mushrooms. Combs (2001) references enhanced selenium functional food categories developed during the last decade, including selenium-fortified table salt and cereal gruel, and beverages such as high-selenium beer. Also, tablets of selenium as selenite or high-selenium yeast have become available for purchase (Hintze et al, 2001).

One important factor to consider is the chemical specification form of selenium in foods, as some forms are not effective in preventing cancer. Wheat products are major sources of dietary selenium for North Americans; however, the effects of selenium from wheat on human health need to be evaluated. Selenium from broccoli is not as well-retained or incorporated into selenoproteins as other forms of selenium, but it may be very effective for reducing the risk of colon cancer (Finley et al., 2004). Selenium from meat has been demonstrated to be well-retained, but its cancer protective benefits are not known. Selenite or selenate mineral supplements are effective for selenium deficiency in livestock; however, these forms have low impact on the selenium content in meats, milk and eggs. In contrast, high-selenium wheat proved to increase the selenium concentration in meat (Hintze et al., 2001 and 2002).

Finley et al. (2004) demonstrate basic differences in the metabolism of selenium from meat and broccoli. Such differences must be taken into account when a food is recommended as a source of supplemental selenium.

Potential for Meat and Wheat Producers in North Dakota

Some areas in North Dakota and South Dakota are naturally high in selenium and therefore provide a natural way to obtain agricultural products with high selenium content. In North Dakota, western Bowman county, and Slope, Sioux, and Williams counties have been associated with high-selenium soils. By contrast, reports from Morton, southern Oliver, and the sandhill region of Richland and Ransom counties have identified these lands as low-selenium soils (Hintze et al., 2001).

Wheat and meat producers have recognized this opportunity for improving the marketability and profitability of their products (USDA-ARS, 2004). However, there is still a great deal of information that needs to be generated in order to determine the viability of businesses oriented toward producing high-selenium functional products. One constraint is the lack of research from the medical field regarding the effectiveness of selenium-rich foods in preventing cancer and the identification of particular chemical specification forms of selenium in foods. Scientific information is needed to ensure the delivery of known and effective forms of selenium in agricultural products. Current investigations on selenium accumulation in vegetables, pinto beans, and wheat are scheduled to be released in 2009 (USDA-ARS, 2004). In the case of meat, Hintze et al. (2001) concluded that a 100 gram serving of high-selenium beef, produced with wheat and hay harvested in North Dakota, could provide 100 percent of the RDA requirements. Additionally, research is in progress which investigates the quality, shelf life, and consumer acceptance of meat produced with high-selenium feed products.

Another constraint is that there is little information available about costs and strategies for producing, handling, and marketing high-selenium differentiated products or the degree of consumer acceptance and willingness to pay for them. In the case of wheat, production practices that deliver a homogeneous product need to be developed (cultivars, fertilization programs, etc.). Additionally, the design of an identity preservation process for segregating differentiated wheat from the producers to processors could involve a significant increase in logistical costs (Schlecht et al., 2004). At this time, information on consumer acceptance and willingness to pay for high-selenium products is not available. Current investigation focuses on genotypic and environmental effects on the selenium content in wheat (USDA-ARS, 2004).

Conclusions

Despite previous evidence of selenium as a cancer-preventing agent, research is still in progress to understand and confirm prior findings. In order to develop high-selenium agricultural products, various points need to be carefully evaluated, including the concentration and functional form of selenium, production techniques, market development, and costs of product delivery to consumers. Currently, the flour milling industry and consumers do not recognize the importance of selenium in human health and are not willing to pay a premium for it. More medical studies are needed to give scientific evidence and outline the benefits of high-selenium foods for human health.

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