

## Brassica studi

### Changes in Glucosinolate Concentrations, Myrosinase Activity, and Production of Metabolites of Glucosinolates in Cabbage (*Brassica oleracea* Var. *capitata*) Cooked for Different Durations

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#### Abstract

In cabbage, glucosinolates such as sinigrin are hydrolyzed by plant myrosinase to allyl isothiocyanate (AITC), allyl cyanide, and, in the presence of an epithiospecifier protein, 1-cyano-2,3-epithiopropene (CEP). Isothiocyanates have been implicated in the cancer-protective effects of *Brassica* vegetables. The effect of processing on the hydrolysis of glucosinolates was investigated in cabbage. Cabbage was steamed or microwaved for six time durations over 7 min. Glucosinolate concentrations were slightly reduced after microwave cooking ( $P < 0.001$ ) but were not influenced after steaming ( $P < 0.05$ ). Myrosinase activity was effectively lost after 2 min of microwave cooking and after 7 min of steaming. Hydrolysis of residual glucosinolates following cooking yielded predominantly CEP at short cooking durations and AITC at longer durations until myrosinase activity was lost. Lightly cooked cabbage produced the highest yield of AITC on hydrolysis in vitro, suggesting that cooking *Brassica* vegetables for a relatively short duration may be desirable from a health perspective.

[Asian Pac J Cancer Prev](#). 2013;14(11):6657-62.

### Cabbage (*Brassica oleracea* L. var. *capitata*) Phytochemicals with Antioxidant and Anti-inflammatory Potential.

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#### Abstract

**Background:** The objective of this study was to investigate antioxidant and anti-inflammatory activity of cabbage phytochemicals. **Materials and Methods:** Color coordinates were evaluated by colorimetry, and the antioxidant and anti-inflammatory activities were analyzed by spectrophotometer for some common cabbage varieties. **Results:** Red heads had the highest total antioxidant contents followed by Savoy, Chinese and green heads. The Chinese variety had the highest ABTS (2,2-azino-di-(3-ethylbenzthiazoline-sulfonic acid) antioxidant activity, was 5.72  $\mu\text{mol TE/g fw}$  (Trolox equivalent). The green variety had the highest DPPH (free radical scavenging activity) antioxidant activity, which was 91.2  $\mu\text{mol TE/g fw}$ . The red variety had the highest FRAP (ferric reducing antioxidant power) antioxidant activity, which was 80.8  $\mu\text{mol TE/g fw}$ . The total phenol amounts were 17.2-32.6 mM trolox equivalent antioxidant capacity (TEAC) and the total flavonoid amounts were 40.0-74.2 mg quercetin per gram. Methanolic extracts of different cabbage heads showed different anti-inflammatory activity values. Chinese, Savoy and green heads had the highest anti-inflammatory activity, while red heads had the lowest. **Conclusions:** The results suggest that these varieties of cabbage heads could contribute as sources of important antioxidant and anti-inflammatory related to the prevention of chronic diseases associated to oxidative stress, such as in cancer and coronary artery disease.

[Phytother Res.](#) 2013 Nov;27(11):1664-70. doi: 10.1002/ptr.4908. Epub 2013 Jan 4.

## **Antioxidant and in vitro anticancer effect of 2-pyrrolidinone rich fraction of *Brassica oleracea* var. capitata through induction of apoptosis in human cancer cells.**

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### **Abstract**

The aim of this study was to analyze if the 2-pyrrolidinone rich fraction of *Brassica oleracea* var. capitata exhibiting antioxidant and in vitro anticancer activities. 2-Pyrrolidinone is an active compound present in *Brassica oleracea* var. capitata. Our findings explored the potential use of 2-pyrrolidinone in cancer treatment. This compound was identified and isolated by gas chromatography-mass spectrometry and high-performance liquid chromatography from the leaf of *Brassica oleracea* var. capitata. The resultant rich active compound exhibited in vitro cytotoxicity in HeLa and PC-3 human cancer cell lines, and it also exhibited antioxidant activity in cell free assays. DAPI staining, an apoptotic analysis and cell cycle analysis were performed to evaluate the anticancer activity of 2-pyrrolidinone against the above cell lines. The IC<sub>50</sub> value of 2-pyrrolidinone was determined to be of 2.5  $\mu\text{g/ml}$  for HeLa, 3  $\mu\text{g/ml}$  for PC-3 cells at 24 h and 1.5  $\mu\text{g/ml}$  for HeLa and 2  $\mu\text{g/ml}$  for PC-3 cells at 48 h, respectively. However, cell cycle analysis revealed that the anti-proliferative effects of the 2-pyrrolidinone were mediated through cell cycle arrest in the G<sub>0</sub>/G<sub>1</sub> phase. These results from the current study suggest that the 2-pyrrolidinone have potential anticancer effects, which will lead to the development of new anticancer agents for arresting cancer cells growth in vitro.

[Malays J Nutr.](#) 2007 Mar;13(1):71-80. Epub 2007 Mar 15.

## **Antioxidant capacity and phenolic content of selected commercially available cruciferous vegetables.**

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## Abstract

Antioxidant activity, free radical scavenging activity and phenolic content of red cabbage (*Brassica oleracea* var. *capitata rubra*), Chinese cabbage (*Brassica rapa pekinensis* var. *cylindrica*), green cabbage (*Brassica oleracea* var. *capitata*), mustard cabbage (*Brassica juncea* var. *rugosa*) and Chinese white cabbage (*Brassica rapa* var. *chinensis*), grown in Malaysia, were evaluated. Red cabbage had the highest antioxidant activity and phenolic content compared to the other cruciferous vegetables studied ( $p < 0.05$ ). The contributions of all cruciferous vegetables to the antioxidant activity was  $>79\%$ . The radical scavenging activity was in the order of Chinese white cabbage  $>$  red cabbage  $>$  mustard cabbage  $>$  Chinese cabbage  $>$  green cabbage. There was a significant difference ( $p < 0.05$ ) in the means of scavenging activity observed between cabbage, Chinese cabbage and Chinese mustard. Phenolic content was significantly different ( $p < 0.05$ ) among all the cruciferous vegetables studied, and was in the order of red cabbage  $>$  Chinese white cabbage  $>$  green cabbage  $>$  Chinese cabbage  $>$  mustard cabbage. The study indicated that red cabbage possessed the highest antioxidant capacity and phenolic compounds concentration among all the cruciferous vegetables studied.

[Postepy Hig Med Dosw \(Online\)](#). 2008 Apr 2;62:125-40.

## [Cancer chemopreventive agents: glucosinolates and their decomposition products in white cabbage (*Brassica oleracea* var. *capitata*)].

[Article in Polish]

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## Abstract

A number of recent epidemiological studies have indicated that high intake of white cabbage may be associated with a lower risk of neoplastic diseases such as cancer of the pancreas, breast, prostate, stomach, and lungs. The anticarcinogenic activity is related to the presence of biologically active components in this vegetable. The chemopreventive effects of cabbage may be connected with modulation of the activity of phase I and II detoxification enzymes and other mechanisms triggered by glucosinolates and products of their decomposition, which are formed as a result of hydrolysis catalyzed by the enzyme myrosinase. The products of glucosinolate decomposition influence a number of cellular processes through the regulation of transcription factor levels, signaling pathways, the cell cycle, and apoptosis. The beneficial activities and especially the chemopreventive effects of the compounds present in cabbage point to the necessity of formulating scientifically based dietary recommendations enabling the optimal exploitation of this vegetable in health protection.

[Mutat Res](#). 2001 Sep 1;480-481:285-97.

## Effects of cruciferous vegetables and their constituents on drug metabolizing enzymes involved in the bioactivation of DNA-reactive dietary carcinogens.

[Steinkellner H](#), [Rabot S](#), [Freywald C](#), [Nobis E](#), [Scharf G](#), [Chabicovsky M](#), [Knasmüller S](#), [Kassie F](#).

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## Abstract

Epidemiological studies give evidence that cruciferous vegetables (CF) protect humans against cancer, and also results from animal experiments show that they reduce chemically induced tumor formation. These properties have been attributed to alterations in the metabolism of carcinogens by breakdown products of glucosinolates, which are constituents of CF. The present article gives an overview on the present state of knowledge on the impact of CF and their constituents on enzymes that are involved in the metabolism of DNA-reactive carcinogens. The development of in vitro models with metabolically competent cell lines led to the detection of potent enzyme inducers contained in CF such as sulforaphane. Recently, we showed that Brassica juices induce glutathione-S-transferases (GST) and cytochrome P-450 1A2 in human hepatoma cells (HepG2) and protect against the genotoxic effects of B(a)P and other carcinogens. Earlier in vivo experiments with rodents indicated that indoles and isothiocyanates, two major groups of glucosinolate breakdown products, attenuate the effects of polycyclic aromatic hydrocarbons (PAHs) and nitrosamines via induction of GST and inhibition of cytochrome-P450 isoenzymes, respectively. Our own investigations showed that CF are also protective towards heterocyclic amines (HAs): Brussels sprouts- and garden cress juices attenuated IQ-induced DNA-damage and preneoplastic lesions in colon and liver of rats. These effects were paralleled by induction of uridine-di-phospho-glucuronosyl transferase (UDPGT) which is very probably the mechanism of protection against HAs by cruciferous vegetables. There is also evidence that consumption of CF might protect humans against cancer. In matched control intervention studies with these vegetables, it was shown that they induce GST-activities in humans but overall, results were inconclusive. Recently, we carried out crossover intervention studies and found pronounced GST-induction upon consumption of Brussels sprouts and red cabbage, whereas no effects were seen with white cabbage and broccoli. Furthermore, we found that the isoenzyme induced was GST-pi which plays an important role in protection against breast, bladder, colon and testicular cancer. No induction of the GST-alpha isoform could be detected. Urinary mutagenicity experiments gave further evidence that CF affect drug metabolism in humans. Consumption of red cabbage led to changes in the pattern of meat-derived urinary mutagenicity. Overall, CF are among the most promising chemopreventive dietary constituents and further elucidation of their protective mechanisms and the identification of active constituents may contribute to the development of highly protective Brassica varieties.

[Carcinogenesis](#). 1995 Sep;16(9):2125-8.

## Effects of consumption of Brussels sprouts on intestinal and lymphocytic glutathione S-transferases in humans.

[Nijhoff WA](#), [Grubben MJ](#), [Nagengast FM](#), [Jansen JB](#), [Verhagen H](#), [van Poppel G](#), [Peters WH](#).

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### Abstract

A high intake of glucosinolate-containing cruciferous vegetables, such as Brussels sprouts (*Brassica oleraceae*), has been linked to a decreased cancer risk, but the underlying mechanism is still unclear. The aim of this study was to reveal possible modulating effects of consumption of Brussels sprouts on duodenal, rectal and lymphocytic (i) glutathione S-transferase (GST) enzyme activity, (ii) GST isozyme levels and (iii) glutathione (GSH) content. Ten healthy non-smoking volunteers were randomly assigned to two groups in a cross-over design. Five persons started on a glucosinolate-free diet (control period), while the other five consumed 300 g/day cooked Brussels sprouts, at the expense of 300 g glucosinolate-free vegetables (sprouts period). After 7 days the regimen was changed for a further week. At the end of both periods blood samples and duodenal and rectal biopsies were taken. Mean GST activity showed marked differences between duodenal, rectal and lymphocytic cytosols (737  $\pm$  54, 321  $\pm$  29 and 154  $\pm$  14 nmol/min/mg protein respectively), but was uninfluenced by the dietary regimen. Isozyme distribution varied greatly between the tissues. In duodenum GST-alpha, -pi, and -mu isozymes were expressed in considerable amounts (8441  $\pm$  1365, 3002  $\pm$  223 and 536  $\pm$  248 ng/mg protein respectively). Rectal biopsies also contained above three GST classes, but here GST-pi was the most pronounced expressed isozyme (2849  $\pm$  246) followed by GST-mu (495  $\pm$  242), while GST-alpha was only present in minor quantities (149  $\pm$  31). In lymphocytes only GST-pi (755  $\pm$  96) and GST-mu (83  $\pm$  54) could be detected. As a result of the

dietary regimen rectal GST-alpha and -pi levels were slightly increased at the end of the sprouts period, by 30 and 15% respectively. GSH contents were uninfluenced by the dietary regimen. In conclusion, consumption of glucosinolate-containing Brussels sprouts for 1 week results in increased rectal GST-alpha and -pi isozyme levels. We hypothesize that these enhanced detoxification enzyme levels may partly explain the epidemiological association between a high intake of glucosinolates (cruciferous vegetables) and a decreased risk of colorectal cancer.

[Adv Exp Med Biol.](#) 1999;472:159-68.

## **Brassica vegetables and cancer prevention. Epidemiology and mechanisms.**

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### **Abstract**

This paper first gives an overview of the epidemiological data concerning the cancer-preventive effect of brassica vegetables, including cabbages, kale, broccoli, Brussels sprouts, and cauliflower. A protective effect of brassicas against cancer may be plausible due to their relatively high content of glucosinolates. Certain hydrolysis products of glucosinolates have shown anticarcinogenic properties. The results of six cohort studies and 74 case-control studies on the association between brassica consumption and cancer risk are summarized. The cohort studies showed inverse associations between the consumption of brassica's and risk of lung cancer, stomach cancer, all cancers taken together. Of the case-control studies 64% showed an inverse association between consumption of one or more brassica vegetables and risk of cancer at various sites. Although the measured effects might have been distorted by various types of bias, it is concluded that a high consumption of brassica vegetables is associated with a decreased risk of cancer. This association appears to be most consistent for lung, stomach, colon and rectal cancer, and least consistent for prostatic, endometrial and ovarian cancer. It is not yet possible to resolve whether associations are to be attributed to brassica vegetables per se or to vegetables in general. Further epidemiological research should separate the anticarcinogenic effect of brassica vegetables from the effect of vegetables in general. The mechanisms by which brassica vegetables might decrease the risk of cancer are reviewed in the second part of this paper. Brassicas, including all types of cabbages, broccoli, cauliflower, and Brussels sprouts, may be protective against cancer due to their glucosinolate content. Glucosinolates are usually broken down through hydrolysis catalysed by myrosinase, an enzyme that is released from damaged plant cells. Some of the hydrolysis products, viz. indoles, and isothiocyanates, are able to influence phase 1 and phase 2 biotransformation enzyme activities, thereby possibly influencing several processes related to chemical carcinogenesis, e.g. the metabolism, DNA-binding, and mutagenic activity of promutagens. Most evidence concerning anticarcinogenic effects of glucosinolate hydrolysis products and brassica vegetables has come from studies in animals. In addition, studies carried out in humans using high but still realistic human consumption levels of indoles and brassica vegetables have shown putative positive effects on health. The combination of epidemiological and experimental data provide suggestive evidence for a cancer preventive effect of a high intake of brassica vegetables.

[Cancer Epidemiol Biomarkers Prev.](#) 1996 Sep;5(9):733-48.

## **Epidemiological studies on brassica vegetables and cancer risk.**

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## Abstract

This paper gives an overview of the epidemiological data concerning the cancer-preventive effect of brassica vegetables, including cabbage, kale, broccoli, Brussels sprouts, and cauliflower. The protective effect of brassicas against cancer may be due to their relatively high content of glucosinolates. Certain hydrolysis products of glucosinolates have shown anticarcinogenic properties. The results of 7 cohort studies and 87 case-control studies on the association between brassica consumption and cancer risk are summarized. The cohort studies showed inverse associations between the consumption of cabbage, cauliflower, and broccoli and risk of lung cancer; between the consumption of brassicas and risk of stomach cancer; between broccoli consumption and risk of all cancers taken together; and between brassica consumption and the occurrence of second primary cancers. Of the case-control studies, 67% showed an inverse association between consumption of total brassica vegetables and risk of cancer at various sites. For cabbage, broccoli, cauliflower, and Brussels sprouts, these percentages were 70, 56, 67, and 29%, respectively. Although the measured effects might have been distorted by various types of bias, it is concluded that a high consumption of brassica vegetables is associated with a decreased risk of cancer. This association appears to be most consistent for lung, stomach, colon, and rectal cancer and least consistent for prostatic, endometrial, and ovarian cancer. It is not yet possible to resolve whether associations are to be attributed to brassica vegetables per se or to vegetables in general. Further epidemiological research should separate the anticarcinogenic effect of brassica vegetables from the effect of vegetables in general.

[Chem Biol Interact.](#) 1997 Feb 28;103(2):79-129.

## A review of mechanisms underlying anticarcinogenicity by brassica vegetables.

[Verhoeven DT](#), [Verhagen H](#), [Goldbohm RA](#), [van den Brandt PA](#), [van Poppel G](#).

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## Abstract

The mechanisms by which brassica vegetables might decrease the risk of cancer are reviewed in this paper. Brassicas, including all types of cabbages, broccoli, cauliflower and Brussels sprouts, may be protective against cancer due to their relatively high glucosinolate content. Glucosinolates are usually broken down through hydrolysis catalyzed by myrosinase, an enzyme that is released from damaged plant cells. Some of the hydrolysis products, viz. indoles and isothiocyanates, are able to influence phase 1 and phase 2 biotransformation enzyme activities, thereby possibly influencing several processes related to chemical carcinogenesis, e.g. the metabolism, DNA-binding and mutagenic activity of promutagens. A reducing effect on tumor formation has been shown in rats and mice. The anticarcinogenic action of isothiocyanates and indoles depends upon many factors, such as the test system, the target tissue, the type of carcinogen challenge and the anticarcinogenic compound, their dosage, as well as the timing of the treatment. Most evidence concerning anticarcinogenic effects of glucosinolate hydrolysis products and brassica vegetables has come from studies in animals. Animal studies are invaluable in identifying and testing potential anticarcinogens. In addition, studies carried out in humans using high but still realistic human consumption levels of indoles and brassica vegetables have shown putative positive effects on health.

[Mol Nutr Food Res.](#) 2009 Sep;53 Suppl 2:S219. doi: 10.1002/mnfr.200800065.



# Glucosinolates in Brassica vegetables: the influence of the food supply chain on intake, bioavailability and human health.

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## **Abstract**

Glucosinolates (GLSs) are found in Brassica vegetables. Examples of these sources include cabbage, Brussels sprouts, broccoli, cauliflower and various root vegetables (e.g. radish and turnip). A number of epidemiological studies have identified an inverse association between consumption of these vegetables and the risk of colon and rectal cancer. Animal studies have shown changes in enzyme activities and DNA damage resulting from consumption of Brassica vegetables or isothiocyanates, the breakdown products (BDP) of GLSs in the body. Mechanistic studies have begun to identify the ways in which the compounds may exert their protective action but the relevance of these studies to protective effects in the human alimentary tract is as yet unproven. In vitro studies with a number of specific isothiocyanates have suggested mechanisms that might be the basis of their chemoprotective effects. The concentration and composition of the GLSs in different plants, but also within a plant (e.g. in the seeds, roots or leaves), can vary greatly and also changes during plant development. Furthermore, the effects of various factors in the supply chain of Brassica vegetables including breeding, cultivation, storage and processing on intake and bioavailability of GLSs are extensively discussed in this paper.

[IARC Sci Publ.](#) 1996;(139):61-90.

# Vegetables, fruit and phytoestrogens as preventive agents.

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## **Abstract**

The practice of medicine-both past and present-often involves the prescription of specific foods (almost always plants) or their potent derivatives, to treat a wide spectrum of illnesses. Foods that have been ascribed healing properties include the Cruciferae, the allium family, celery, cucumber, endive, parsley, radish and legumes. Review of the epidemiological data, including both cohort and case-control studies, of all cancer sites strongly suggests that plant foods also have preventive potential and that consumption of the following groups and types of vegetables and fruits is lower in those who subsequently develop cancer: raw and fresh vegetables, leafy green vegetables, Cruciferae, carrots, broccoli, cabbage, lettuce, and raw and fresh fruit (including tomatoes and citrus fruit). Other data suggest that foods high in phytoestrogens, particularly soy (which contains isoflavones), or high in precursor compounds that can be metabolized by gut bacteria into active agents, particularly some grains and vegetables with woody stems (which contain precursors to lignans), are plausibly associated with a lower risk of sex-hormone-related cancers. The human evidence for these latter associations is not strong. There are many biologically plausible reasons why consumption of plant foods might slow or prevent the appearance of cancer. These include the presence in plant foods of such potentially anticarcinogenic substances as carotenoids, vitamin C, vitamin E, selenium, dietary fibre (and its components), dithiolthiones, isothiocyanates, indoles, phenols, protease inhibitors, allium compounds, plant sterols, and limonene. Phytoestrogens are also derived from some vegetables and berries as well as grains and seeds. Most of the data for the observations on the

anticarcinogenic potential of all of these compounds have come from animal and in vitro studies. At almost every one of the stages of the cancer process, identified phytochemicals are known to be able to alter the likelihood of carcinogenesis-occasionally in a way that enhances risk but usually in a favourable direction. For example, glucosinolates and indoles, thiocyanates and isothiocyanates, phenols, and coumarins can induce a multiplicity of phase II (solubilizing and usually inactivating) enzymes; ascorbate and phenols block the formation of carcinogens such as nitrosamines; flavonoids and carotenoids act as antioxidants, essentially disabling the carcinogenic potential of specific compounds; lipid-soluble compounds such as carotenoids and sterols may alter membrane structure or integrity; some sulphur-containing compounds suppress DNA and protein synthesis; carotenoids can suppress DNA synthesis and enhance differentiation; and phytoestrogens compete with estradiol for estrogen receptors in a way that is generally antiproliferative. Consumption of diets low in plant foods results in a reduced intake of a wide variety of those substances that can plausibly lower cancer risk. In the presence of a diet and lifestyle high in potential carcinogens (whether derived from fungal contamination, cooking or tobacco) or high in promoters (such as salt and alcohol), overall risk of cancer at many epithelial sites is elevated. Plant foods appear to exert a general risk-lowering effect; the patterns of exposure to cancer initiators and promoters and of genetic susceptibility may determine the variations in the site-specific risks of cancer seen across populations.

[Nat Toxins](#). 1998;6(2):51-9.

## **Phytoestrogens and human health effects: weighing up the current evidence.**

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### **Abstract**

Phytoestrogens are naturally occurring plant compounds which have oestrogenic and/or anti-oestrogenic activity. They are present in many human foodstuffs including beans, sprouts, cabbage, spinach, soyabean, grains and hops. The main classes are the isoflavones, coumestans and lignans. This review assesses the evidence that these substances may have adverse and/or beneficial impacts on the risk of several hormone-dependent diseases in humans. Evidence from studies of various animal species has demonstrated that ingestion of high levels of phytoestrogens can produce adverse effects on reproductive endpoints including fertility. Studies in laboratory animals have also shown that exposure to high doses of phytoestrogens during development can adversely affect brain differentiation and reproductive development in rodents, but may also have possible beneficial effects. In humans, there is a lack of information concerning the possible effects of high doses of phytoestrogens in infants and this should be addressed as a matter of priority so that any risks (or benefits) can be established. In adults, no current data exist to suggest that consumption of phytoestrogens at the levels normally encountered in the diet is likely to be harmful. Epidemiological studies suggest that foodstuffs containing phytoestrogens may have a beneficial role in protecting against a number of chronic diseases and conditions. For cancer of the prostate, colon, rectum, stomach and lung, the evidence is most consistent for a protective effect resulting from a high intake of grains, legumes, fruits and vegetables; it is not possible to identify particular food types or components that may be responsible. Dietary intervention studies indicate that in women soya and linseed may have beneficial effects on the risk of breast cancer and may help to alleviate postmenopausal symptoms. For osteoporosis, tentative evidence suggests phytoestrogens may have similar effects in maintaining bone density to those of the related pharmaceutical compound ipriflavone. Soya also appears to have beneficial effects on blood lipids which may help to reduce the risk of cardiovascular disease and atherosclerosis. Generally, however, little evidence exists to link these effects directly to phytoestrogens; many other components of soya and linseed are biologically active in various experimental systems and may be responsible for the observed effects in humans. It is concluded that dietary phytoestrogens may have a role in the prevention of several types of chronic disease including certain cancers. However, at present the evidence is not sufficient to recommend particular dietary practices or changes. Encouraging findings from laboratory and clinical studies indicate the need for further research to clarify the biological activities of phytoestrogens in humans.



