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Letter to the editor:

CURRENT POTENTIAL HEALTH BENEFITS OF SULFORAPHANE

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Dear Editor,

Sulforaphane [SFN: 1-isothiocyanato-4-(methylsulfinyl)butane] belongs to the isothiocyanate class of phytochemicals. Glucoraphanin, a glucosinolate precursor of SFN, is a glucosinolate found in cruciferous vegetables such as broccoli, cabbage, cauliflower, and kale. All glucosinolates are composed of a basic structure consisting of a β-D-thioglucose group, a sulfonated oxime group, and an amino acid-derived side chain. Glucosinolates are activated by enzyme-dependent hydrolysis to their respective isothiocyanates. SFN (molecular formula $C_6H_{11}NOS_2$) is the biologically active isothiocyanate produced by the metabolism of glucoraphanin by the enzyme myrosinase (Fahey et al., 2015).

SFN is one of the most frequently studied plant-derived isothiocyanate organosulfur compounds. It has been reported to exhibit a wide range of biological effects including antioxidant (Fahey and Talalay, 1999), antimicrobial (Johansson et al., 2008), anticancer (Amjad et al., 2015), anti-inflammatory (Greaney et al., 2016), anti-aging (Sikdar et al., 2016), neuroprotective (Tarozzi et al., 2013), and antidiabetic (Lee et al., 2012).

SFN shows a range of biological activities and health benefits in humans, has been found to be a very promising chemopreventive agent against not only a variety of cancers such as breast, prostate, colon, skin, lung, stomach, and bladder but also against cardiovascular and neurodegenerative diseases and diabetes (Yang et al., 2016). In this present study, we reviewed the most recent studies on the biological and pharmacological activities of SFN (Table 1).

Table 1: Recent studies on biological and pharmacological activities of sulforaphane (SFN)

Key findings	Reference
The immunomodulatory effects of SFN clearly indicate that it alleviates chronic inflammatory diseases by targeting monocytes/macrophages.	Pal and Konkimalla, 2016
SFN attenuates experimental contrast-induced nephropathy in vitro and in vivo. This effect is suggested to be mediated by activation of the nuclear factor erythroid-derived 2-like 2 (Nrf2) antioxidant defence pathway.	Zhao et al., 2016

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SFN inhibited hepatocellular carcinoma cell proliferation in a dose- and time-dependent manner. All our findings indicate that SFN is a promising and safe strategy for treating hepatocellular carcinoma.	Wu et al., 2016
SFN treatment increases the liver 3α-hydroxysteroid dehydrogenases, accelerates the degradation of blood dihydrotestosterone (DHT), and subsequently blocks the suppression of hair growth by DHT.	Sasaki et al., 2016
The chemopreventive effect of SFN is associated with its inhibition of histone deacetylase (HDAC) activity, which attenuates lung cancer growth. These findings suggest that SFN may be a promising therapeutic agent for lung cancer by the inhibition of HDAC.	Jiang et al., 2016
Treatment with SFN could be useful for improving cognitive function in patients with cirrhosis with minimal or clinical hepatic encephalopathy.	Hernández-Rabaza et al., 2016
The use of SFN as a protective agent against ultraviolet damage is a novel application, and it appears to be a very promising emerging ingredient in anti-aging drugs and cosmetics.	Sikdar et al., 2016
SFN protects cardiomyocytes from hypoxia/reoxygenation injury in vitro, most likely by activating the silent information regulator 1 (Sir1) pathway and subsequently inhibiting endoplasmic reticulum (ER) stress-dependent apoptosis.	Li et al., 2016
SFN epigenetically stimulates osteoblast activity and diminishes osteoclast bone resorption, thereby shifting the bone homeostasis balance to favor bone acquisition, mitigation of bone resorption, or both in vivo. Thus, SFN is a member of a new class of epigenetic compounds that could be considered novel strategies to counteract osteoporosis.	Thaler et al., 2016
SFN remarkably suppressed cell growth and enhanced cell death in chemoresistant xenografts in the nude mouse model. Collectively, the present study suggests that the clinical efficacy of temozolomide-based chemotherapy of temozolomide-resistant glioblastoma may be improved by combination therapy with SFN.	Lan et al., 2016
SFN ameliorates the progression of high cholesterol diet-induced atherosclerotic lesions and vascular dysfunction, possibly via its lipid-lowering and antioxidant effects and suppression of nuclear factor-kappa B (NF-κB)-mediated inflammation.	Shehatou and Suddek, 2016
SFN is a beneficial supplement that may be useful for reducing microglial-mediated neuroinflammation and the oxidative stress associated with aging.	Townsend and Johnson, 2016
SFN exerts protective effects against lipopolysaccharide-induced acute lung injury through the nuclear factor-erythroid 2-related factor 2 (NFE2L2)/antioxidant response element (ARE) pathway. Thus, SFN may be a potential candidate for use in the treatment of acute lung injury.	Qi et al., 2016
The SFN-mediated modification of chromatin composition and structure associated with target gene expression provides a new mechanism by which dietary phytochemicals may exert their chemopreventive activity.	Abbas et al., 2016
Dietary supplementation with broccoli sprout extract containing the SFN precursor, glucoraphanin, is likely to be highly effective in improving liver function through the reduction of oxidative stress.	Kikuchi et al., 2015
Glucoraphanin supplementation for a few weeks is safe but may not be sufficient to produce changes in breast tissue tumor biomarkers. Future studies using larger sample sizes should evaluate alternative dosage regimens to improve dietary SFN strategies for breast cancer chemoprevention.	Atwell et al., 2015
SFN suppresses the inflammatory response by inhibiting the NF-κB signaling pathway in a rat model of focal cerebral ischemia and, therefore, may be a potential therapeutic agent for the treatment of cerebral ischemia injury.	Ma et al., 2015

Key findings	Reference
SFN may inhibit human colon cancer progression and cancer cell angiogenesis by inhibiting hypoxia inducible factor-1α (HIF-1α) and vascular endothelial growth factor (VEGF) expression. Taken together, these results indicate that SFN is a new and potent chemopreventive drug candidate for treating patients with human colon cancer.	Kim et al., 2015
SFN attenuated the cytotoxicity of cadmium selenide (CdSe) quantum dots (QDs) in both human hepatocytes and the mouse liver, and this protection was associated with the induction of the Nrf2 pathway and autophagy.	Wang et al., 2015
SFN activates DNA methylation-silenced tumor suppressor genes in breast cancer cells. Therefore, SFN may be a supportive adjuvant therapy with the anticancer drug, clofarabine and, therefore, might increase its effectiveness in solid tumor treatment.	Lubecka-Pietruszewska et al., 2015
The potential usefulness of the blockade of bronchoconstrictor hyperresponsiveness in some types of asthmatics by phytochemicals such as SFN has been reported.	Brown et al., 2015
The antioxidant effects of SFN in mouse plasma and hippocampal formations is evidenced by the increased catalase and superoxide dismutase activity, as well as the increased adenosine triphosphate (ATP) production by hippocampal mitochondria. Furthermore, these effects likely underlie SFN's anticonvulsant mechanisms of action.	Carrasco-Pozo et al., 2015
In vehicle-treated mice, ischemia/reperfusion (I/R) injury produced a marked thinning of the inner retinal layers, which, however, appeared to be significantly reduced following SFN treatment. Therefore, SFN may be beneficial in the treatment of retinal disorders associated with I/R injury.	Ambrecht et al., 2015
SFN reversed the iron-induced decrease in the mitochondrial fission protein, DNM1L, as well as hippocampal synaptophysin levels, leading to a recovery of the associated recognition memory impairment. These findings suggest that SFN should be further investigated as a potential agent for the treatment of cognitive deficits associated with neurodegenerative disorders.	Lavich et al., 2015
SFN does not directly stimulate autophagy or cell death in metastatic prostate cancer cells under physiologically relevant conditions. However, it supports the involvement of important in vivo effectors that mediate its prostate cancer suppression.	Waston et al., 2015
SFN may have prophylactic and therapeutic effects on cognitive impairment in schizophrenia. Therefore, the dietary intake of SFN-rich broccoli sprouts during the juvenile and adolescent stage may prevent the onset of adult psychosis.	Shirai et al., 2015
SFN was also found to efficiently scavenge hydrogen peroxide by converting it into water. Thus, the mechanism of action of SFN as an excellent antioxidant has been revealed.	Prasad and Mishra, 2015
SFN protected the vascular endothelial cells against lysophosphatidylcholine-induced injury by enhancing the antioxidative capabilities mediated by Nrf-2 translocation.	Li et al., 2015
Daily administration of free SFN shows promise in managing biochemical recurrences of prostate cancer after radical prostatectomy.	Cipolla et al., 2015
SFN demonstrates pleiotropic behavior, owing to its effects on different cellular targets, suggesting a potential role in preventing or counteracting multifactorial neurodegenerative disorders such as Alzheimer's disease (AD).	Angeloni et al., 2015
SFN reduced the liver oxidative stress induced by I/R injury. Furthermore, histological injury of the liver was reduced by SFN administration. However, SFN showed no significant effects on the remote organ injuries induced by IR.	Oguz et al., 2015
SFN plays a protective role against acetaminophen-mediated hepatotoxicity through antioxidant effects mediated by heme oxygenase-1 (HO-1) induction. SFN has preventive actions against oxidative stress-mediated liver injury.	Noh et al., 2015

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Key findings	Reference
SFN ameliorated experimental diabetic nephropathy, at least in part, via the glycogen synthase kinase 3-beta (GSK3β)/Fyn (tyrosine kinase)/Nrf2 signaling pathway.	Shang et al., 2015
Combined treatment of cells with SFN and 3-methyladenine (3-MA) proved to be effective in decreasing cell viability, through a mechanism that may involve early SFN-induced autophagy, followed by induction of apoptosis and inhibition of autophagy by 3-MA.	Horwacik et al., 2015
SFN showed more potent renoprotection against I/R injury than ischemic preconditioning (Ipre) did, and this effect might involve synergism between them at the molecular but not functional level.	Shokeir et al., 2015
SFN stimulates suicidal erythrocyte death or eryptosis, which may, at least partially, be due to the stimulation of $Ca^{(2+)}$ entry and ceramide formation.	Alzoubi et al., 2015
SFN stimulates proteasome activity and autophagy in normal and Hutchinson-Gilford progeria syndrome (HGPS) fibroblast cultures. Specifically, SFN enhances progerin clearance by autophagy and reverses the phenotypic changes that are the hallmarks of HGPS. Therefore, SFN is a promising therapeutic strategy for children with HGPS.	Gabriel et al., 2015
SFN has the potential to prevent cardiac hypertrophy by downregulating the transcription factors GATA-binding factor 4/6 (GATA4/6) and mitogen-activated protein kinase (MAPK) signaling pathways.	Kee et al., 2015
Both SFN and klotho, a protein with multiple pleiotropic effects associated with anti-aging, enhance the antioxidant defenses, which may protect against vascular smooth muscle cell dysfunction in age-related cardiovascular diseases.	Rizzo et al., 2014
SFN showed protective effects against retinal I/R, which could be attributed, at least in part, to the activation of the Nrf2/HO-1 antioxidant pathway.	Pan et al., 2014
SFN alleviates D-galactosamine/lipopolysaccharide-induced liver injury, possibly by exerting antioxidant, anti-inflammatory, and antiapoptotic effects and modulating certain antioxidant defense enzymes.	Sayed et al., 2014
Dietary SFN is recognized to have low toxicity and was identified for its ability to reverse abnormalities associated with autism spectrum disorder. The abnormalities included oxidative stress and lowered antioxidant capacity, depressed glutathione synthesis, reduced mitochondrial function and oxidative phosphorylation, increased lipid peroxidation, and neuroinflammation.	Singh et al., 2014
Blockade of the advanced glycation end product (AGE)-receptor for AGE (RAGE) axis in pericytes by SFN might be a novel therapeutic target for the treatment of diabetic retinopathy.	Maeda et al., 2014
SFN ameliorates neurobehavioral deficits by reducing cholinergic neuron loss in the brains of AD-like mice, and the underlying mechanism may be associated with neurogenesis and aluminum load reduction. These findings suggest that the phytochemical, SFN has potential usefulness in AD therapy.	Zhang et al., 2014
SFN-enhanced autophagy flux provided protection against prion-mediated neurotoxicity, which was regulated by adenosine monophosphate (AMP)-activated protein kinase (AMPK) signaling pathways in human neuronal cells. This data also suggests that SFN has potential value as a therapeutic tool in neurodegenerative disorders including prion diseases.	Lee et al., 2014
SFN might set the stage for the development of a novel therapeutic principle that complements the growing armature against malignancies, which would encourage the exploration of its efficacy in a broader population of patients with leukemia.	Fimognari et al., 2014
SFN has antitumor effects against bladder cancer cells mediated through a reactive oxygen species (ROS)-mediated intrinsic apoptotic pathway, which suggest that ER stress and Nrf2 may represent strategic targets for SFN-induced apoptosis.	Jo et al., 2014

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Conflict of interest

The authors declare no conflict of interest

REFERENCES

Abbas A, Hall JA, Patterson III WL, Ho E, Hsu A, Al-Mulla F, et al. Sulforaphane modulates telomerase activity via epigenetic regulation in prostate cancer cell lines 1. Biochem Cell Biol. 2016;94:71-81.

Alzoubi K, Calabrò S, Faggio C, Lang F. Stimulation of suicidal erythrocyte death by sulforaphane. Basic Clin Pharm Toxicol. 2015;116:229-35.

Ambrecht LA, Perlman JI, McDonnell JF, Zhai Y, Qiao L, Bu P. Protection of retinal function by sulforaphane following retinal ischemic injury. Exp Eye Res. 2015;138:66-9.

Amjad AI, Parikh RA, Appleman LJ, Hahm E-R, Singh K, Singh SV. Broccoli-derived sulforaphane and chemoprevention of prostate cancer: from bench to bedside. Curr Pharmacol Rep. 2015;1:382-90.

Angeloni C, Malaguti M, Rizzo B, Barbalace MC, Fabbri D, Hrelia S. Neuroprotective effect of sulforaphane against methylglyoxal cytotoxicity. Chem Res Toxicol. 2015;28:1234-45.

Atwell LL, Zhang Z, Mori M, Farris PE, Vetto JT, Naik AM, et al. Sulforaphane bioavailability and chemopreventive activity in women scheduled for breast biopsy. Cancer Prev Res. 2015;8:1184-91.

Brown RH, Reynolds C, Brooker A, Talalay P, Fahey JW. Sulforaphane improves the bronchoprotective response in asthmatics through Nrf2-mediated gene pathways. Resp Res. 2015;16:1.

Carrasco-Pozo C, Tan KN, Borges K. Sulforaphane is anticonvulsant and improves mitochondrial function. J Neurochem. 2015;135:932-42.

Cipolla BG, Mandron E, Lefort JM, Coadou Y, Della Negra E, Corbel L, et al. Effect of sulforaphane in men with biochemical recurrence after radical prostatectomy. Cancer Prev Res. 2015;8:712-9.

Fahey J, Talalay P. Antioxidant functions of sulforaphane: a potent inducer of Phase II detoxication enzymes. Food Chem Toxicol. 1999;37:973-9.

Fahey JW, Holtzclaw WD, Wehage SL, Wade KL, Stephenson KK, Talalay P. Sulforaphane bioavailability from glucoraphanin-rich broccoli: control by active endogenous myrosinase. PloS One. 2015;10: e0140963.

Fimognari C, Turrini E, Sestili P, Calcabrini C, Carulli G, Fontanelli G, et al. Antileukemic activity of sulforaphane in primary blasts from patients affected by myelo-and lympho-proliferative disorders and in hypoxic conditions. PloS One. 2014;9:e101991.

Gabriel D, Roedl D, Gordon LB, Djabali K. Sulforaphane enhances progerin clearance in Hutchinson–Gilford progeria fibroblasts. Aging Cell. 2015;14:78-91.

Greaney AJ, Maier NK, Leppla SH, Moayeri M. Sulforaphane inhibits multiple inflammasomes through an Nrf2-independent mechanism. J Leukoc Biol. 2016;99:189-99.

Hernández-Rabaza V, Cabrera-Pastor A, Taoro-González L, Malaguarnera M, Agustí A, Llansola M, et al. Hyperammonemia induces glial activation, neuroinflammation and alters neurotransmitter receptors in hippocampus, impairing spatial learning: reversal by sulforaphane. J Neuroinflamm. 2016;13:1.

Horwacik I, Gaik M, Durbas M, Boratyn E, Zając G, Szychowska K, et al. Inhibition of autophagy by 3-methyladenine potentiates sulforaphane-induced cell death of BE (2)-C human neuroblastoma cells. Mol Med Rep. 2015;12:535-42.

Jiang LL, Zhou SJ, Zhang XM, Chen HQ, Liu W. Sulforaphane suppresses in vitro and in vivo lung tumorigenesis through downregulation of HDAC activity. Biomed Pharmacother. 2016;78:74-80.

Jo GH, Kim GY, Kim WJ, Park KY, Choi YH. Sulforaphane induces apoptosis in T24 human urinary bladder cancer cells through a reactive oxygen species-mediated mitochondrial pathway: the involvement of endoplasmic reticulum stress and the Nrf2 signaling pathway. Int J Oncol. 2014;45:1497-506.

Johansson NL, Pavia CS, Chiao JW. Growth inhibition of a spectrum of bacterial and fungal pathogens by sulforaphane, an isothiocyanate product found in broccoli and other cruciferous vegetables. Planta Med. 2008;74:747-50.

Kee HJ, Kim GR, Kim IK, Jeong MH. Sulforaphane suppresses cardiac hypertrophy by inhibiting GATA4/GATA6 expression and MAPK signaling pathways. Mol Nutr Food Res. 2015;59:221-30.

Kikuchi M, Ushida Y, Shiozawa H, Umeda R, Tsuruya K, Aoki Y, et al. Sulforaphane-rich broccoli sprout extract improves hepatic abnormalities in male subjects. World J Gastroenterol. 2015;21:12457.

Kim DH, Sung B, Kang YJ, Hwang SY, Kim MJ, Yoon JH, et al. Sulforaphane inhibits hypoxia-induced HIF-1α and VEGF expression and migration of human colon cancer cells. Int J Oncol. 2015;47: 2226-32.

Lan F, Yang Y, Han J, Wu Q, Yu H, Yue X. Sulforaphane reverses chemo-resistance to temozolomide in glioblastoma cells by NF-κB-dependent pathway downregulating MGMT expression. Int J Oncol. 2016;48:559-68.

Lavich I, De Freitas B, Kist L, Falavigna L, Dargél V, Köbe L, et al. Sulforaphane rescues memory dysfunction and synaptic and mitochondrial alterations induced by brain iron accumulation. Neuroscience. 2015;301:542-52.

Lee JH, Moon MH, Jeong JK, Park YG, Lee YJ, Seol JW, et al. Sulforaphane induced adipolysis via hormone sensitive lipase activation, regulated by AMPK signaling pathway. Biochem Biophys Res Commun. 2012;426:492-7.

Lee JH, Jeong JK, Park SY. Sulforaphane-induced autophagy flux prevents prion protein-mediated neurotoxicity through AMPK pathway. Neuroscience. 2014;278:31-9.

Li B, Tian S, Liu X, He C, Ding Z, Shan Y. Sulforaphane protected the injury of human vascular endothelial cell induced by LPC through up-regulating endogenous antioxidants and phase II enzymes. Food Funct. 2015;6:1984-91.

Li YP, Wang SL, Liu B, Tang L, Kuang RR, Wang XB, et al. Sulforaphane prevents rat cardiomyocytes from hypoxia/reoxygenation injury in vitro via activating SIRT1 and subsequently inhibiting ER stress. Acta Pharmacol Sin. 2016;37:344-53.

Lubecka-Pietruszewska K, Kaufman-Szymczyk A, Stefanska B, Cebula-Obrzut B, Smolewski P, Fabianowska-Majewska K. Sulforaphane alone and in combination with clofarabine epigenetically regulates the expression of DNA methylation-silenced tumour suppressor genes in human breast cancer cells. J Nutrigenet Nutrigenom. 2015;8:91-101.

Ma LL, Xing GP, Yu Y, Liang H, Yu TX, Zheng WH, et al. Sulforaphane exerts neuroprotective effects via suppression of the inflammatory response in a rat model of focal cerebral ischemia. Int J Clin Exp Med. 2015;8:17811.

Maeda S, Matsui T, Ojima A, Takeuchi M, Yamagishi SI. Sulforaphane inhibits advanced glycation end product–induced pericyte damage by reducing expression of receptor for advanced glycation end products. Nutr Res. 2014;34:807-13.

Noh JR, Kim YH, Hwang JH, Choi DH, Kim KS, Oh WK, et al. Sulforaphane protects against acetaminophen-induced hepatotoxicity. Food Chem Toxicol. 2015;80:193-200.

Oguz A, Kapan M, Kaplan I, Alabalik U, Ulger BV, Uslukaya O, et al. The effects of sulforaphane on the liver and remote organ damage in hepatic ischemia-reperfusion model formed with pringle maneuver in rats. Int J Surg. 2015;18:163-8.

Pal S, Konkimalla VB. Sulforaphane regulates phenotypic and functional switching of both induced and spontaneously differentiating human monocytes. Int Immunopharmacol. 2016;35:85-98.

Pan H, He M, Liu R, Brecha NC, Yu ACH, Pu M. Sulforaphane protects rodent retinas against ischemia-reperfusion injury through the activation of the Nrf2/HO-1 antioxidant pathway. PloS One. 2014;9: e114186.

Prasad AK, Mishra P. Mechanism of action of sulforaphane as a superoxide radical anion and hydrogen peroxide scavenger by double hydrogen transfer: a model for iron superoxide dismutase. J Phys Chem B. 2015;119:7825-36.

Qi T, Xu F, Yan X, Li S, Li H. Sulforaphane exerts anti-inflammatory effects against lipopolysaccharide-induced acute lung injury in mice through the Nrf2/ARE pathway. Int J Mol Med. 2016;37:182-8.

Rizzo B, Maltese G, Paraskevi MP, Hrelia S, Mann G, Siow R. OP1-6-Induction of antioxidant genes by sulforaphane and klotho in human aortic smooth muscle cells. Free Rad Biol Med. 2014;75:S14-5.

Sasaki M, Shinozaki S, Shimokado K. Sulforaphane promotes murine hair growth by accelerating the degradation of dihydrotestosterone. Biochem Biophys Res Commun. 2016;472:250-4.

Sayed RH, Khalil WK, Salem HA, El-Sayeh BM. Sulforaphane increases the survival rate in rats with fulminant hepatic failure induced by D-galactosamine and lipopolysaccharide. Nutr Res. 2014;34:982-9.

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Shang G, Tang X, Gao P, Guo F, Liu H, Zhao Z, et al. Sulforaphane attenuation of experimental diabetic nephropathy involves GSK-3 beta/Fyn/Nrf2 signaling pathway. J Nutr Biochem. 2015;26:596-606.

Shehatou GS, Suddek GM. Sulforaphane attenuates the development of atherosclerosis and improves endothelial dysfunction in hypercholesterolemic rabbits. Exp Biol Med. 2016;241:426-36.

Shirai Y, Fujita Y, Hashimoto R, Ohi K, Yamamori H, Yasuda Y, et al. Dietary intake of sulforaphane-rich broccoli sprout extracts during juvenile and adolescence can prevent phencyclidine-induced cognitive deficits at adulthood. PloS One. 2015;10:e0127244.

Shokeir AA, Barakat N, Hussein AM, Awadalla A, Harraz A, Khater S, et al. Activation of Nrf2 by ischemic preconditioning and sulforaphane in renal ischemia/reperfusion injury: a comparative experimental study. Physiol Res. 2015;64:313.

Sikdar S, Papadopoulou M, Dubois J. What do we know about sulforaphane protection against photoaging? J Cosmet Dermatol. 2016;15:72-7.

Singh K, Connors SL, Macklin EA, Smith KD, Fahey JW, Talalay P, et al. Sulforaphane treatment of autism spectrum disorder (ASD). Proc Natl Acad Sci USA. 2014;111:15550-5.

Tarozzi A, Angeloni C, Malaguti M, Morroni F, Hrelia S, Hrelia P. Sulforaphane as a potential protective phytochemical against neurodegenerative diseases. Oxid Med Cell Longev. 2013;2013:415078.

Thaler R, Maurizi A, Roschger P, Sturmlechner I, Khani F, Spitzer S, et al. Anabolic and antiresorptive modulation of bone homeostasis by the epigenetic modulator sulforaphane, a naturally occurring isothiocyanate. J Biol Chem. 2016;291:6754-71.

Townsend BE, Johnson RW. Sulforaphane induces Nrf2 target genes and attenuates inflammatory gene expression in microglia from brain of young adult and aged mice. Exp Gerontol. 2016;73:42-8.

Wang W, He Y, Yu G, Li B, Sexton DW, Wileman T, et al. Sulforaphane protects the liver against CdSe quantum dot-induced cytotoxicity. PloS One. 2015; 10:e0138771.

Watson GW, Wickramasekara S, Fang Y, Palomera-Sanchez Z, Maier CS, Williams DE, et al. Analysis of autophagic flux in response to sulforaphane in metastatic prostate cancer cells. Mol Nutr Food Res. 2015;59:1954-61.

Wu J, Han J, Hou B, Deng C, Wu H, Shen L. Sulforaphane inhibits TGF-β-induced epithelial-mesenchymal transition of hepatocellular carcinoma cells via the reactive oxygen species-dependent pathway. Oncol Rep. 2016;35:2977-83.

Yang L, Palliyaguru DL, Kensler TW. Frugal chemoprevention: targeting Nrf2 with foods rich in sulforaphane. Semin Oncol, 2016;43:146-53.

Zhang R, Zhang J, Fang L, Li X, Zhao Y, Shi W, et al. Neuroprotective effects of sulforaphane on cholinergic neurons in mice with Alzheimer's disease-like lesions. Int J Mol Sci. 2014;15:14396-410.

Zhao Z, Liao G, Zhou Q, Lv D, Holthfer H, Zou H. Sulforaphane attenuates contrast-induced nephropathy in rats via Nrf2/HO-1 pathway. Oxid Med Cell Longev. 2016;2016:9825623.