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The Antioxidant Power of Purple Corn

A Research Review

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Purple corn, also known as *maize morado* in Spanish is the same species as the corn that we consume in the United States. These species of corn are botanically know as *Zea mays* L., and purple corn has one of the deepest shades of purple found in the entire plant kingdom. While this corn is not consumed like regular table corn, it has a long history of use by the people of the Peruvian Andes because of this corn's health benefits and beautiful color. The Peruvian Andians prepare a drink with the corn that they call *chicha morada*.[1]

This review paper examines the research on the potential health benefits of purple corn. The vast amount of the research on this corn so far has consisted of animal and in vitro studies, but it has been used for centuries by the indigenous population and is a powerful antioxidant with important benefits for human health.

Anthocyanins and Antioxidant Potential

Anthocyanins are colored flavonoids that are water-soluble pigments responsible for the purple, blue, and red colors in plants. These substances belong to the class of flavonoids known as phenolic compounds and are present in beans, fruits, vegetables, and red wines.[2]

Researchers at the Horticultural Department of Texas A & M University in College Station, Texas, quantified the mean anthocyanin content of whole fresh purple corn and compared it to blueberries (one of the richest sources of this compound). The anthocyanin and total phenolic contents for whole purple corn were 1642 mg per 100 g and 1756 mg per 100 g, respectively. The anthocyanin and total phenolic contents of blueberries ranged from 138–385 mg per 100 g to 292–672 mg per 100 g, respectively.*

The kernel pericarp (the outer layer of the kernel) of purple corn had the greatest concentration of anthocyanins. When the antioxidant activity of purple corn was compared with that of blueberry against the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical, purple corn had, significantly, 3.8 times the total antiradical capacity of blueberry.*

This is quite interesting because blueberry has shown one of the greatest antioxidant values of any other commercial food plant. The most abundant anthocyanin in purple corn 3-O-beta-D-glucoside for the same thing (C3G), according to the results of another study.[3] The researchers concluded that the higher phenolic antioxidant capacity of purple corn compared with blueberries, "indicate that these crops have the potential to be considered as important novel natural antioxidant sources for functional foods and dietary supplement markets."[3]

C3G was shown to have a protective effect on DNA cleavage, a dose-dependent free-radical scavenging activity, and significant inhibition of xanthine oxidase activity. Compared with 13 other anthocyanins in the oxygen radical absorbance capacity assay (ORAC), C3G had the highest value. The strength of C3G was 3.5 times that of trolox, a synthetic and potent analogue of vitamin E.[4] The antioxidant activity of C3G has been demonstrated in approximately one dozen assays.[1–4] These effects suggest that anthocyanins are promising as a useful treatment for pathologies in which free-radical production plays a key role.[4]

Cancer Research

The potential of purple corn color to modify colorectal carcinogenesis was investigated in male F344/DuCrj rats, initially treated with 1,2-dimethylhydrazine (DMH), and then receiving 2-amino-1-methyl-6-phenylimidazo[4,5-b]pyridine (PhIP) in the diet to induce the cancer. After DMH initiation, purple corn was given at a dietary level of 5.0 percent in combination with PhIP until week 36.[5]

No adverse effects of purple corn were found in any of the animals. Incidence and tumor load of colorectal adenomas and carcinomas in rats initiated with DMH were clearly increased by PhIP. In contrast, lesion development was suppressed by purple

*This study was conducted under a special grant (c G).

corn ingestion. Furthermore, in the non-DMH initiation groups, induction of aberrant crypt foci by PhIP was decreased by the purple corn supplementation.[5]

The results showed that, while PhIP has a promoting effect on DMH-induced colorectal carcinogenesis, 5.0 percent of purple corn in the diet could reduce significantly the incidence of colorectal carcinogenesis and aberrant crypt foci in these animals.[5]

In another study, researchers investigated the antioxidative, radical-scavenging, and inhibitory effects on lipid peroxidation by ultraviolet (UV) light irradiation of three anthocyanin pigments—pelargonidin 3-O-beta-D-glucoside (P3G), C3G, and delphinidin 3-O-beta-D-glucoside (D3G)—isolated from the *Phaseolus vulgaris* L. seed coat, and their aglycons—pelargonidin chloride (Pel), cyanidin chloride (Cy), and delphinidin chloride (Del). All pigments had strong antioxidative activity in a liposomal system and reduced the formation of malondialdehyde by UV-B irradiation. This suggests a potential antiaging and protective effect of C3G on skin cancers.[6]

Purple corn may have an important role in preventing and reducing inflammation caused by severe oxidative stress.

In yet another study, the antimutagenic and antioxidant properties of various phenolic fractions obtained from Andean purple corn were examined by the Ames test and the DPPH antiradical assay.[7] An anthocyanin-rich water fraction (WF) and an ethyl acetate fraction (EAF) showed dose-dependent antimutagenic behavior against the food mutagen Trp-P-1 with IC_{50} values of 321.7 ±21.36 and 95.2 ±10.95 μg of chlorogenic acid equivalent per plate, respectively, indicating that EAF was a more potent antimutagen.

The antioxidant activities for WF and EAF were 1.019 ± 0.05 and 0.838 ± 0.11 μg of Trolox equivalent per μg of phenolics, respectively. Further fractionation of WF and EAF revealed an ethyl acetate subfraction, EA-IV, with a high antimutagen potency that contained a quercetin derivative.[7]

The mechanism of antimutagenic action of the WF is predominantly a blocking effect on the S-9 Mix activation system of the mutagen, whereas for the EAF, it is a dual mechanism involving blocking of the S-9 Mix and a scavenging action on Trp-P-1 electrophiles. This provides further evidence of antimutagenic phenolics compounds contained in purple corn.[7]

Inflammation and Tissue Injury

Researchers have shown that the orally administered C3G attenuates the hepatic ischemia-reperfusion (I/R) injury in rats via a decrease in neutrophil chemoattractant production.[8] The rats were subjected to hepatic I/R at 30 minutes after the administration of C3G (0.9 mmol per kg body weight) or vehicle. I/R treatment resulted in the elevation of oxidative stress marker (liver thiobarbituric acid-reactive substance, Nepsilon-[hexanonyl] lysine and dityrosine) levels in the liver and of the serum activities of marker enzymes for liver injury. The administration of C3G significantly suppressed these elevations, which had been caused by hepatic I/R.

Liver myeloperoxidase activity, a useful marker for neutrophil infiltration into tissues, and the plasma and liver concentration of cytokine-induced neutrophil chemoattractant-1 (CINC-1), which has a potent chemotactic activity, were markedly elevated in the control group after hepatic I/R. However, these elevations were significantly suppressed in the C3G group. C3G and its metabolites in the plasma and liver were detected in the C3G group after hepatic I/R.[8]

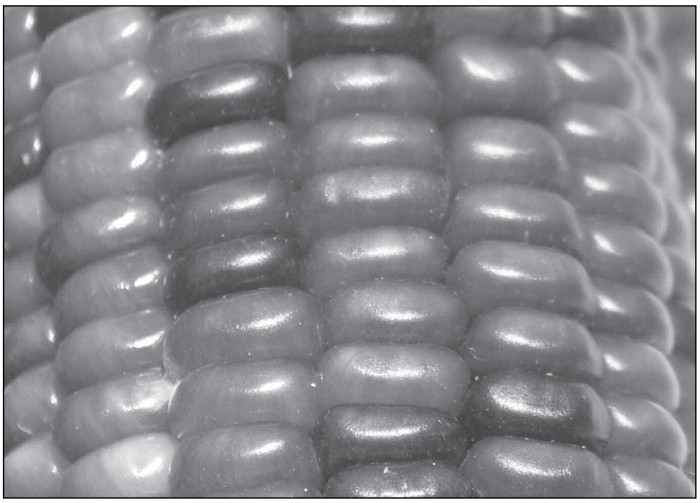
These results indicate that the absorbed C3G and/or its metabolites can act as antioxidants in the blood and liver, scavenge the reactive oxygen species (ROS), and cause a decrease in neutrophil infiltration into the liver via suppression of CINC-1 production and the tissue damage caused by neutrophils after I/R is attenuated.[8] In addition, these results suggest an important role for purple corn for preventing and reducing inflammation, I/R injury, liver injury, and other tissue damage caused by severe oxidative stress.

In another study, C3G suppressed the zymosan-induced inflammatory response in rats when C3G was orally administered.[9] The elevation of the peritoneal exudate nitrogen monoxide and nitrogen dioxide (NOx), tumor necrosis factor (TNF) alpha interleukin-1beta (IL-1beta), IL-6, and the CINC-1 concentrations were significantly suppressed by the administration of C3G. The zymosan treatment resulted in an increase in the serum alpha2-macroglobulin and decreases in the serum albumin and transferrin levels, which are recognized as acute phase proteins.[9]

However, these levels were normalized by the administration of C3G. The inducible nitric oxide synthase (iNOS) protein level in the peritoneal exudate cells was markedly elevated in the control group treated with zymosan. However, the administration of C3G significantly reduced the level of iNOS in the peritoneal exudate cells. Taken all together, these findings provide a biochemical basis for the use of C3G as a functional food factor and can also have important implications for preventing nitric oxide (NO)–mediated inflammatory diseases.[9]

The effect of dietary C3G on the generation of thiobarbituric-acid reactive substances (TBARS) during serum formation ex vivo and susceptibility of serum to further lipid peroxidation was studied in rats.[10] Rats were fed a diet containing C3G (2 g per kg) for 14 days.

Feeding C3G resulted in a significant decrease in generation of TBARS during serum formation. The serum from the C3G-fed group showed a significantly lower susceptibility to further lipid peroxidation provoked by 2,2′-azobis(2-amidinopropane) hydrochloride or Cu2+ than that of the control group. No significant differences were observed in serum phospholipid, triglyceride, esterified cholesterol, and free fatty-acid concentrations between the control and the C3G-fed groups.[10]




Purple corn is a rich source of antioxidants and has important health benefits.

Concentrations of endogenous antioxidants remaining in the serum after blood coagulation were not affected by the C3G feeding. These results showed that feeding C3G increases the ex vivo oxidation resistance of the serum without affecting serum endogenous antioxidant levels, and reduces the TBARS generated during serum formation, without changing the concentrations of serum lipids. The increase in the resistance of serum lipids to oxidation by C3G suggests that it may play a role in cardiovascular disease (CVD) prevention.[10]

Obesity and Diabetes

Mice were fed a control, a C3G-rich purple corn color (PCC), a high-fat (HF) or a HF + PCC diet for 12 weeks.[11] Dietary PCC significantly suppressed the HF diet-induced increase in body weight gain, and white and brown adipose tissue weights. Feeding the mice the HF diet markedly induced hypertrophy of the adipocytes in the epididymal white adipose tissue compared with the effects of the control diet in control group. In contrast, the induction did not occur in the HF + PCC group. The HF diet induced hyperglycemia, hyperinsulinemia, and hyperleptinemia. These perturbations were completely normalized in rats fed HF + PCC.

The rats who received the HF + PCC diet developed significantly less obesity compared to the group that did not receive any PCC. In addition, an increase in TNF-alpha mRNA level occurred in the HF group and was normalized by dietary PCC.[11]

These results suggest that dietary PCC may ameliorate HF diet-induced insulin resistance in mice. PCC suppressed the mRNA levels of enzymes involved in fatty-acid and triacylglycerol synthesis and lowered the sterol regulatory element binding protein-1 mRNA level in white adipose tissue. Such downregulations may contribute to triacylglycerol accumulation in white adipose tissue. These findings provide a biochemical and nutritional basis for using PCC or anthocyanins as functional food factors that may help prevent obesity and diabetes.[11]

Adipocyte dysfunction is strongly associated with the development of obesity and insulin resistance. It is accepted that the regulation of adipocytokine secretion or the adipocyte-specific gene expression is one of the most important targets for preventing obesity and amelioration of insulin sensitivity. Plasma and gene expression levels of adiponectin are decreased in obese mice and humans in insulin resistant states.

Another study showed that anthocyanins (cyanidin or C3G) have the potency of a unique pharmacologic function in isolated rat adipocytes.[12] Treated adipocytes with anthocyanins enhanced adipocytokine (adiponectin and leptin) secretion and upregulated the adipocyte-specific gene expression without activation of PPARgamma in isolated rat adipocytes. The gene expression of adiponectin was also upregulated in white adipose tissue in mice fed an anthocyanin supplemented diet.

Given that one of the possible mechanisms, AMP-activated protein kinase activation would be associated with these changes, nevertheless, the AMP:ATP ratio was decreased significantly by administration of the anthocyanins. These data suggest that anthocyanins have a potency of unique therapeutic advantage and also have important implications for preventing obesity and diabetes.[12]

Summary

The major anthocyanin, C3G and total phenolics found in purple corn have been covered in numerous scientific papers, with impressive and compelling results. Purple corn has been shown to have an antioxidant and free-radical scavenging capacity that is superior to blueberries, which until recently, were considered to have the highest values for these effects of any common food plant.[3] C3G has been shown to have the highest ORAC value compared with 13 other common anthocyanins found in food.[4]

Purple corn has demonstrated excellent potential in preventing colon cancer and UV-B–induced radiation damage to skin cells in animal experiments suggesting the corn may protect against skin

cancer and skin aging.[5,6] This corn was also shown to have antimutagenic effects via the Ames test.[7] More studies are needed to elucidate purple corn's potentially preventive and therapeutic effects on other cancers.

Purple corn's potential to ameliorate inflammation, I/R injury, or damage to liver cells is also of great interest because of the possible applications to human disease and suffering.[8,9] The increase in the resistance of serum lipids to oxidation by C3G suggests that it may also play a role in cardiovascular disease prevention.[10]

Purple corn color was shown to have a potentially novel therapeutic effect on metabolic syndrome, diabetes, and obesity.[11,12] Animals fed a high fat diet who were also given purple corn color had amelioration of hyperglycemia, hyperinsulinemia, and hyperleptinemia (abnormally high leptin levels) and significantly less obesity.[11] Adipocytes treated with C3G had enhanced secretion of adiponectin and leptin and normalized these levels and upregulated the adipocyte specific gene expression.[12]

Conclusions

It appears as though purple corn color may act as a biologic response modifier with respect to normalizing abnormal levels of adiponectin and leptin, whether they be too high or too low. These are compelling results, indicating that purple corn may be one of the key natural products for treating and preventing obesity, diabetes, metabolic syndrome, and related disorders.

Purple corn's bioactive components, including the total phenolic concentration, the anthocyanin concentration, and, in particular, the C3G concentration have been shown to be superior to blueberries and other foods that were considered to have the greatest antioxidant and free-radical scavenging activities. Purple corn is, thus far, the richest natural source of anthocyanins.

The promising data in animal research suggest that purple corn may have beneficial effects in human health. These data also confirm many of the traditional health benefits that have been attributed to purple corn. Modern research suggests that purple corn may have great potential as an important novel natural antioxidant source for functional foods and dietary-supplement markets and may prove to be a very vital antioxidant. □

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