Review Article

New Insights into the Therapeutic Effects of Phenolic Acids from Sorghum Seeds

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Abstract

This paper reviewed the beneficial effects of the major phenolic acid compounds of *Sorghum bicolor* seeds. Different studies were reviewed to determine the major phenolic acid components of sorghum seeds. Several kinds of literature were then analyzed to discuss the different beneficial effects of these molecules. *S. bicolor* is an important source for food and feed. It is among the top five crops regarding its production and consumption throughout the world. Till date, many studies highlighted different aspects of the biochemical and physiological properties of sorghum grain. However, studies concerning the pharmacological properties of sorghum grain are scarce. The predominant phenolic acids of sorghum seeds are ferulic, *p*-coumaric, and protocatechuic acids. The bioactive effects of these phenolic acids are mainly related to their antioxidant, antitumor, antidiabetic, antimicrobial, cardiovascular, and gastrointestinal activities. The data collected from recent studies indicate that these molecules have a promising future as natural agents for the treatment of various diseases, and this is particularly due to their strong antioxidant properties. This review provides evidence for the importance of sorghum seeds and their phenolic compounds in the prevention and treatment of several diseases. This work showed that sorghum grains are a good source of beneficial and therapeutic molecules. It also recommended the addition of sorghum grains to human diet as other cereals because of its high nutritional value.

Keywords: *Ferulic acid, p-coumaric acid, pharmacological effects, phenolic compound, protocatechuic acid, sorghum grain*

Introduction

According to the United Nations Food and Agriculture Organization, sorghum (*Sorghum bicolor* L. Moench) is the 5th most important cereal in the world after rice, wheat, corn, and barley.[1,2] In 2015, the world sorghum production was estimated at 66 million tones.[3] This drought-resistant crop is of great nutritional interest, particularly in dry regions, where food security is most at risk and where this plant is one of the main foodstuffs. In these hot regions, sorghum is grown for both its grain for human food and straw for livestock feed.[4] Like all cereals, sorghum grains are mainly composed of starch, protein, nonstarch polysaccharides, and fatty acids.[5] However, sorghum grains do not contain gluten and constitute therefore an important cereal for people intolerant to gluten. Furthermore, sorghum grains are of the same nutritional quality as maize grains [Table 1].[6-8] For all these important characteristics, sorghum would be a grain of the future and could replace or supplement other cereals in the human diet.

Unlike primary metabolites (amino acids, lipids, sugars, and nucleotides), which are directly implicated in plant growth and development, secondary metabolites are molecules indirectly essential to the life of plants. In fact, secondary metabolites may act as structural elements or as important tools in the adaptation of plants to their environment.[9,10] They thus participate in the tolerance of plants to various stresses as follows: pathogenic attacks of bacteria and fungi, predation of insects, drought, and ultraviolet (UV) light.[9,11,12] Secondary metabolites can be divided into three major chemical groups in plants: nitrogen compounds, terpenes, and phenolic compounds.[13]

Nitrogen-containing secondary metabolites are molecules with a basic character and are characterized by the presence of nitrogen within their structures. The most common nitrogen compounds in plants are alkaloids,

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Table 1: Comparison of sorghum and maize grain contents

Component	Content (%)	
	Sorghum	Maize
Starch	63-68	60-64
Proteins	9-13	8-11
Crude fiber	1.5-2	1.5-2
Other organics	8-12	8-12

Source:[6,8]

glycosides, and nonprotein amino acids.[14,15] These metabolites play an important role in plant defense against mammals and insects. For humans, most alkaloids are very toxic; however, these molecules may have a therapeutic effect at low doses. In fact, from prehistory to the present day, alkaloids or alkaloids-containing extracts have been used as muscle relaxants, analgesics, and tranquilizers.[16]

Terpenes are organic molecules derived from 5 carbon isoprene units as a building block. Terpenes can be subdivided in monoterpenes (C10), sesquiterpenes (C15), diterpenes (C20), triterpenes (C30), tetraterpenes (C40), and the polyterpenes with more than 40 carbons.[14,17] Volatile monoterpenes and sesquiterpenes are the main components of essential oils.[18,19] The most common terpenes are triterpenes, tetraterpenes, and polyterpenes.[14] These metabolites serve as anti-herbivore defense compounds in plants; however, some terpenes are also important for plant development such as gibberellins, carotenoids, and brassinosteroids.[15,20,21]

Phenolic compounds are aromatic molecules consisting of a phenyl (C6) group attached to a hydroxyl (−OH) group. The structure of these molecules varies from simple molecules (simple phenolic acids) to highly polymerized molecules (condensed tannins). Phenolic compounds can be classified into five subgroups: lignins, flavonoids, tannins, phenolic acids, and coumarins.[12] In addition to their implication in plant structure development; phenolic compounds are associated with several physiological processes such as defense against pathogens, insects, and other animals.[9,12] Phenolic compounds may also be attractive to insects and other animals and act as pollinators. These compounds are also known for their antioxidant, anti-inflammatory, antiatherogenic, antithrombotic, analgesic, antibacterial, antiviral, anticancer, cardiovascular, and gastrointestinal activities.[22-26]

Search Method

A search was carried out to identify appropriate published articles on electronic databases including Science Direct, PubMed, and Google Scholar. The search was conducted using the following strings in the title/abstract/Keyword: "sorghum AND polyphenols, sorghum AND phenolic acids, phenolic acids AND antioxidant activity, phenolic acids AND therapeutic, ferulic acid AND therapeutic, ferulic acid AND antioxidant, Ferulic acid AND anticancer, ferulic acid AND antidiabetic, ferulic acid AND cardiovascular diseases, ferulic acid AND gastrointestinal diseases, *p*-coumaric acid AND therapeutic, *p*-coumaric acid AND antioxidant, *p*-coumaric acid AND anticancer, *p*-coumaric acid AND antidiabetic, *p*-coumaric acid AND cardiovascular diseases, *p*-coumaric acid AND gastrointestinal diseases, protocatechuic acid AND therapeutic, protocatechuic acid AND antioxidant, protocatechuic acid AND anticancer, protocatechuic acid AND antidiabetic, protocatechuic acid AND cardiovascular diseases, protocatechuic acid AND gastrointestinal diseases." Results were obtained from the year 1983 to 2017. Depending on the title and the abstract, the most relevant articles were analyzed and references in the obtained publications were analyzed too, to identify other relevant publications.

Phenolic Compounds in Sorghum Grain

The bioactive effects of sorghum grain are mainly related to its antioxidant, anticarcinogenic, hypolipidemic, antimutagenic, antimicrobial, and antitumor activities.[27-34] A very large number of studies associate these beneficial effects of sorghum with molecules belonging to the group of polyphenols. In fact, sorghum contains high levels of phenolic acids, flavonoids, and anthocyanins, which represent the main groups of polyphenols present in this cereal.[35,36] In sorghum grains, polyphenols are mainly located in the layers of pericarp, testa, and aleurone.[37]

Phenolic Acids in Sorghum Grain

Phenolic acids are phenylpropanoids characterized by an aromatic ring attached to three carbon side chains. The phenolic acids are mostly derived from cinnamic acid and benzoic acid.[38] They are generally subdivided into hydroxybenzoic and hydroxycinnamic acids. Despite their distribution in different organ of sorghum plants, the phenolic acids are mainly present in the stalks, sheaths, and grains.[39] In grains, several phenolic acids have been reported and are listed in Table 2 and Figure 1. The predominant phenolic acids reported are ferulic acid, p-coumaric acid, and protocatechuic acid.[45]

Ferulic acid

Ferulic acid (FA, 4-hydroxy-3-methoxycinnamic acid) is widely distributed in plants and was first isolated from *Ferula foetida* in 1866.[46] FA which is one of the most abundant phenolic acids in sorghum grains, is reported to possess different biological effects.

p-coumaric acid

p-Coumaric acid (*p*-CA, 4-Hydroxycinnamic acid) is one of the three isomers of coumaric acid (*o*-coumaric, *m*-coumaric, and *p*-coumaric acids). *p*-CA is the most abundant isomer in nature and it is synthesized from cinnamic acid by the action of 4-cinnamic acid

Table 2: A list of the phenolic acids reported in sorghum grains

Phenolic acid	Chemical formula	Reference
Hydroxybenzoic acids		
Gallic	$C_7H_6O_5$	[40-42]
Protocatechuic	$C_7H_6O_4$	[40-42]
p-hydroxybenzoic	$C_7H_6O_3$	[40,43,44]
Gentisic	$C_7H_6O_4$	[42,44]
Salicylic	$C_7H_6O_3$	[44]
Vanillic	$C_8H_8O_4$	[41,43]
Syringic	$C_9H_{10}O_5$	[42,44]
Hydroxycinnamic acids		
Ferulic	$C_{10}H_{10}O_4$	[40,41,44]
Caffeic	$C_9H_8O_4$	[40,42]
p-Coumaric	$C_9H_8O_3$	[40,41]
Cinnamic	$C_9H_8O_2$	[40,43,44]
Sinapic	$C_{11}H_{12}O_5$	[43,44]

hydroxylase.[47] This molecule is widely found in fruits, vegetables, and cereals such as sorghum, maize, wheat, and oats. It has been shown that *p*-CA provides protection against different pathological conditions.

Protocatechuic acid

Protocatechuic acid (PCA, 3,4-dihydroxybenzoic acid) is a major phenolic acid that is found in fruits, medicinal plants, nuts, and vegetables.[48] PCA has been shown to have different beneficial health activities which are almost related to its antioxidant, anticancer, and antidiabetic activities.[49-51]

In this review, we will focus solely on these three molecules because of their beneficial pharmacological properties.

Main Pharmacological Mechanisms of Most Relevant Phenolic Acids in Sorghum

Different studies have outlined the importance of the phenolic acids in the prevention of different chronic diseases, including cancers, diabetes, cardiovascular diseases, and gastrointestinal diseases. In this section, we discuss the most relevant pharmacological effects of the main phenolic acid compounds found in sorghum grains and which are ferulic acid, *p*-coumaric acid, and protocatechuic acid.

Antioxidant activity

Many studies reported the high antioxidant capacities and the excellent free radical scavenger effects of the FA, *p*-CA, and PCA.[52-57] Their antioxidant effect may be directly related to the number and the position of the hydroxyl groups.[52,56-59]

FA's ability to reduce oxidative stress has been shown to have a therapeutic effect on several chronic diseases associated with oxidative damage. In fact, it was reported that FA might play a neuroprotective role. This effect has

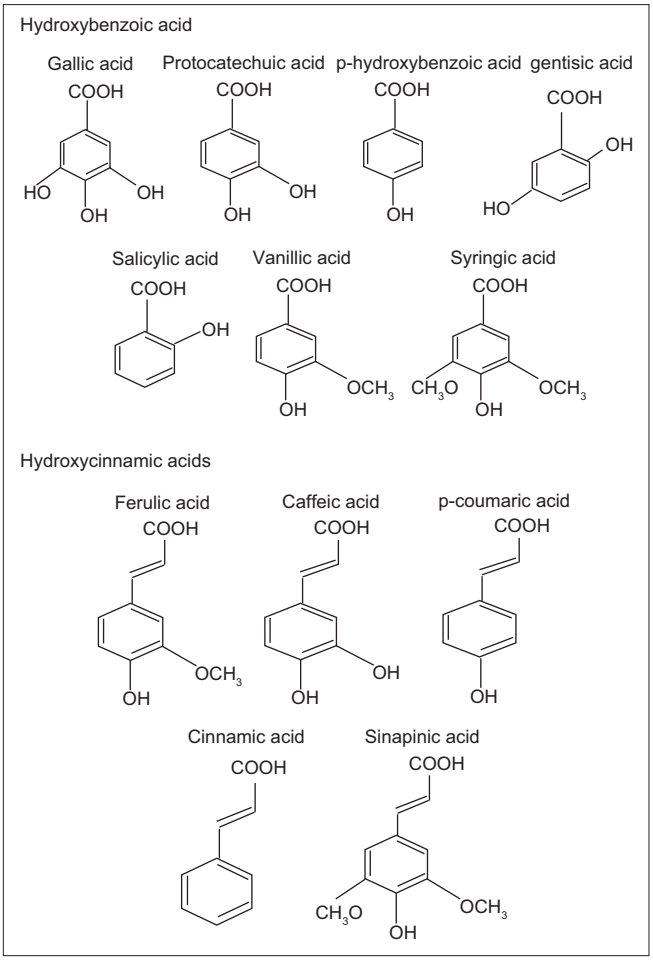

Figure 1: Structure of the phenolic acids reported in sorghum seed

been observed in a study carried out on rats, in which, FA significantly reduces cerebral infarction and neurological deficit through the inhibition of superoxide radicals.[60] It was also reported that FA has a protective and therapeutic effect on diabetic nephropathy by reducing oxidative stress and inflammation.[61] Recently, it was suggested that the beneficial effects of FA might also be due to the aptitude of this phenolic acid to interact with several cellular mechanisms (including regulation of signaling pathways), which can be simultaneously and synergistically implicated in its biologic effect.[62]

As for FA, the antioxidant effect of *p*-CA makes from this compound an important protective molecule against different diseases. In fact, *p*-CA has shown a protective effect against heart disease through its ability to enhance the resistance of low-density lipoproteins to cholesterol oxidation and to reduce lipid peroxidation.[54,63] Another study conducted by Masek *et al*.[56] has confirmed the antioxidant activity of *p*-CA and also showed its ability to reduce iron and copper ions. Compared to ferulic acid, *p*-CA showed similar or even higher ability to eliminate reactive oxygen species in human lung (A549) and colon adenocarcinoma (HT29-D4) cell lines.[64]

It is currently well established that PCA is a natural compound with high antioxidant capacity. The activity of PCA is due to its capacity of sequestration of transition metals ions that are responsible for free radicals and its potent radical scavenging ability.[65] The antioxidant activity of PCA is associated with its potential to prevent oxidative damage of the DNA and to decrease lipid peroxidation in *in vitro* studies.[66,67] In the other hand, some studies showed that PCA exerts an indirect antioxidant effects through the induction of genes that are involved in the endogenous defense system. This includes antioxidant enzymes such as catalase, superoxide dismutase, glutathione (GSH) reductase, and GSH peroxidase as well as nonenzymatic antioxidants which play an important role in protecting the cell against oxidative damage.[50,68]

Anticancer activity

Free radicals play an important role in cancer, especially in invasive and metastatic tumors.[69,70] Thereby, phenolic acids, such as FA, *p*-CA, and PCA have been studied for a long time for their probable beneficial effects on many diseases including cancer, due to their radical scavenging properties.

Various studies have shown the anticancer effect of FA against different types of cancer such as colon, lung, osteosarcoma, and melanoma cancer.[71-74] The study conducted by Zhang *et al*.[75] showed that FA leads to decreased viability, increased apoptosis, and suppression of metastatic potential in the MDA-MB-231 breast cancer cell line.[76] showed that FA could also significantly decrease the cell viability of osteosarcoma through the apoptosis pathway. In fact, in this study, the authors showed that FA activates the pro-apoptotic genes, caspase-3, and Bax and inactivates the anti-apoptotic gene, Bcl-2. The anticancer activity of FA was also attributed to its ability to inhibit cyclooxygenase-2, which is overexpressed in several types of cancer and which is considered as a target for the development of the anticancer drug.[71] It was also reported that FA might inhibit proliferation and induce apoptosis via inhibition of the proliferation-related pathway, phosphoinositide 3-kinase/protein kinase B (Akt), in osteosarcoma cells or through the release of cytochrome C.[74,77]

The *in vitro* evaluation of the activity of *p*-CA on the growth of certain cell lines showed a moderate inhibition capacity of this molecule. However, this phenolic acid leads to a significant decrease in the viability of neuroblastoma N2a cells and cancer stem cells[78-80] highlighted the effect of *p*-CA on the colorectal cancer cells and showed an effective activity of this compound in killing cancer cells.[80] In another study, Kong *et al*.[47] showed that the effect of *p*-CA is due to the inhibition of the signaling pathways responsible for angiogenesis (Akt and extracellular-regulated kinase), and also, to the reduction of the expression of two of the most important angiogenic factors that stimulate proliferation, migration, and tube formation of endothelial cells (vascular endothelial growth factor-A and basic fibroblast growth factor).[47]

Many published studies highlighted the antiproliferative capacity of PCA on multiple human cell lines such as gastric adenocarcinoma cells MKN45, breast cancer cells T47D and lung cancer cells A549 and H3255[81-84] reported that PCA has a protective effect and can prevent osteoclast differentiation via regulating inflammation and oxidative stress and by inducing apoptosis in RAW264.7 murine macrophage cells. PCA was also evaluated for its role as a chemopreventive agent in different types of induced carcinogenesis in laboratory mice and rats.[85,86] Moreover, PCA can also suppress the expression of the necrosis factor (tumor necrosis factor alpha which is involved in carcinogenesis.[87] Moreover, PCA may affect enzyme activities implicated in carcinogen metabolism and also counteracts the effect of reactive intermediate metabolites by preventing their binding to DNA and thus, preventing DNA mutations which may lead to tumor initiation.[88] In another study, PCA showed to inhibit the progression of cancer cells through the repression of migration of B16/F10 melanoma cells to the liver in mice.[89]

Antidiabetic activity

FA, p-CA, and PCA, which are widely present in fruits, vegetables and cereals are good competitors for the actual drug treatments used against diabetes and its complications.[45,48,90,91]

Concerning the effects of FA, a study conducted by Balasubashini *et al*.[92] showed that treatment of diabetic rats with this phenolic acid decreased blood glucose levels and free fatty acids, and increased reduced GSH levels in the liver of these diabetic animals. In another study, Ohnishi *et al*.[93] demonstrated that FA also inhibited lipid peroxidation in the brown adipose tissue of diabetic mice. Other studies have shown that FA could regenerate pancreatic β-cells and regulate glucose levels by increasing the activity of glucokinase and the production of glycogen[94-96] showed that FA has protective and therapeutic effects on diabetic nephropathy through reducing inflammation and oxidative stress. Recently, Sompong *et al*.[97] showed that FA inhibited methylglyoxal-induced protein glycation and oxidative protein denaturation in bovine serum albumin.These authors also showed that FA reduced mg-induced cell apoptosis in pancreatic β-cells.[97]

It was observed that *p*-CA might regulate the expression of adiponectin (participate in the modulation of insulin sensitivity) in 3T3-L1 adipocytes after exposure for 24 h to this molecule.[98] It was also reported that *p*-CA and its conjugates might bind to glucosidases and thus decrease their enzymatic activities.[99] In diabetic rats, *p*-CA improves plasma insulin levels and also regulates glucose levels.[100] In 2016,[101] have shown that the anti-diabetic activity of

p-CA plays a protective role in the β-pancreatic of diabetic rat cells by improving the antioxidant status and reducing ROS-induced oxidative stress. These authors suggest that *p*-CA regulates the glucose metabolism through activation of the glucose transporter (GLUT-2) in the pancreas.[101] The study conducted by[102] on diabetic rats to evaluate the effect of *p*-CA on type 2 diabetes-induced neurodegeneration, revealed that the treatment of these animals with *p*-CA significantly improved glucose tolerance and decreased the brain oxidative stress of these rats. The *p*-CA was also responsible for the decrease of inflammation and the inhibition of apoptosis in the hippocampus, suggesting a beneficial role of this molecule in the attenuation of type 2 diabetes-induced neurodegeneration.[102]

It was highlighted that PCA is a phenolic compound which is widely present in plant foods and medicinal plants and which may be useful for diabetic patients.[90,91] The treatment of diabetic rats by PCA for 45 days revealed that this molecule could prevent the increase in blood glucose by increasing the secretion of insulin and the glycogen synthesis enzymes.[103] The same study demonstrated that PCA could alleviate hyperlipidemia. PCA has also the ability to stimulate the insulin signaling pathway by increasing the GLUT-4 translocation and glucose uptake in human adipocytes.[91] The study conducted by Semaming *et al*.[104] showed that PCA is an important molecule for diabetic patients because of its ability to reduce vascular complications, which is mainly due to its antioxidant activity. In fact, in a study conducted *in vivo*, Lin *et al*.[105] showed that PCA dietary supplement leads to a decrease in the level of hepatic and cardiac triglycerides. PCA also decreases the oxidative and inflammatory stress in the kidneys and heart of the diabetic mice used for this study.[105]

Cardiovascular activity

It was reported that salt of FA can: (1) inhibit myocardial cell death after anoxia/reoxygenation by reducing Ca^{2+} overload,[106] (2) reduce the area of experimental myocardial infarction,[107] and (3) decrease the oxygen consumption of guinea pig myocardial homogenates.[107] Salt of FA also has a clear protective effect in experimental myocardial ischemia.[108] In fact, the mechanisms of salvia fruticosa-induced protection from myocardial ischemia/reperfusion injury appear to involve inhibition of arachidonic acid metabolism, inhibition of the oxygen free radicals and of subsequent lipid peroxidation.[108] Another study conducted by Carpita *et al*.[109] has confirmed that the blood pressure was decreased in both stroke-prone spontaneously hypertensive rats (SHRSP) and spontaneously hypertensive rats (SHR) with a maximum effect (−34 mmHg) after 2 h of oral intake of FA (1–100 mg/kg body weight).

p-coumaric acid (*p*-CA) with its potent antioxidant potential shows potential cardioprotective effects against Doxorubicin (DOX)-induced oxidative stress in rat's heart[110] and attenuates ROS-induced cardiomyoblast damage when pre-treated or co-treated with DOX.[111] In another study, the combination of PC and naringenin may act as a hydrogen-donating radicals scavenger by scavenging lipid alkoxyl and peroxyl radical and protect myocardium from DOX-induced injury.[112] It was reported that pCA exerts a protective effect on the alterations in the gene-expression profile in sodium arsenite-induced cardiotoxicity in rats.[113] *p*CA also increased the myocardial expression of Bax, caspase-8, caspase-9, and Fas genes and showed a decrease in the myocardial expression of Bcl-2 and Bcl-xL genes.[114]

PCA has been reported to improve cardiac function, cardiac autonomic balance and prevent cardiac mitochondrial dysfunction in STZ-induced type 1 diabetes mellitus rats.[115] PCA has also shown beneficial effects in acute myocardial infarction with propranolol in dogs.[51] Previous studies indicate that PCA could reduce myocardial infarcts and interfere with the following MI/R pathogenic procedures including the inflammatory response, platelet aggregation, and cardiomyocyte apoptosis.[116] 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin cardiotoxicity in 3–4 months old rats was studied and protocatechuic acid treatment at the dose of 100 mg/kg for 45 days was found to decrease the levels of Thiobarbituric acid reactive substances, while increasing those of GSH, catalase, GSH peroxidase, and superoxide dismutase.[117]

Gastrointestinal activity

It was observed that FA pretreatment significantly attenuated the effects of heat stress on the small intestine, including the increased FD4 permeability, disrupted tight junctions and microvilli structure and reduced occludin, ZO-1, and E-cadherin expression[118,119] suggested that the gastrokinetic activity of FA may be partially mediated via interference with nitric oxide (NO) production, and NO plays a key role in the regulation of gastrointestinal motility by its smooth muscle relaxing and vasodilating activity. In another study[120] have shown that effects caused by cisplatin (plays an important role in the treatment of malignant diseases), namely, severe nausea, and vomiting, accompanying gastrointestinal symptoms such as abdominal discomfort in the patients were significantly reversed by pretreatment by ferulic acid. The beneficial effect of FA could be attributed at least partly to its stimulant effect on the gastrointestinal tract and its antioxidant effect.

p-CA has been reported to decreases effectively oxidative DNA damage in rat colonic mucosa. *p*-CA exerts this effect by the increased expression of Glutathione S-Transferase Mu 2 (GST-M2), an important isoform of GST[121,122] have observed that *p*-CA inhibits the lesion area of ethanol-induced ulcer, indomethacin-induced gastric ulcers, stress-induced gastric ulcers by 83.3%, 55%, and 73%, respectively.[123-126] demonstrated that the high concentration

of *p*-CAconjugates reaching the colon produces various physiological actions aimed at the colon microbiota. The colon microbiota plays a role in the trophic effects on intestinal epithelia, immunological function, and protection against invasion of alien microbes and colon cancer[122] have observed that treatment using doses of 50 and 250 mg/kg *p*-coumaric significantly diminished the lesion index, the total area of the lesion and the percentage of the lesion in comparison with the negative control groups (omeprazole or cimetidine).

Kore *et al*.[127] have demonstrated that PCA ethyl ester administered at the dose of (30 mg/kg and 60 mg/kg i. p.) 30 min before ulcer induction was found to possess the significant antiulcer property, and the ulcer index was significantly less in comparison control animals. The mechanism of action of PCA ethyl ester may be due to strengthening the gastric mucosa thereby enhancing mucosal defense. In another study, Ma *et al*.[128] have observed that PCA pretreatment had significant restraining effects on p66shc messenger RNA expression and protein phosphorylation after intestinal I/R in the intestine accompanied by p66shc-related oxidative stress regulators and apoptotic protein alteration. It was also reported that severe intestinal mucosal lesions occurred after intestinal I/R decreased significantly by PCA pretreatment,[128] suggesting that PCA can improve morphological alterations in the intestinal mucosa in a murine model of intestinal I/R.

Other Beneficial Effects of Ferulic Acid p-Coumaric Acid, and Protocatechuic Acid

The list of the beneficial effects of FA, *p*-CA, and PCA that was given above is not exhaustive. In fact, these natural molecules have a broad spectrum of activities against several other diseases and have many other beneficial activities.

FA, *p*-CA, and PCA have been reported to exhibit a wide range of antimicrobial activities against bacteria and yeasts.[129-137] One of the possible mechanisms leading to this effect is through causing changes in cellular morphology and cell membrane dysfunction.[131,133] The antibacterial activity may also be due to the capability of these compounds to stop bacterial growth and their ability to enhance the synergistic effects of antibiotics which reduce the possibility of antibiotic resistance as it was reported for the PCA.[138]

Another important effect of these three molecules concerns their anti-inflammatory activity which makes from them potent molecules for the regulation of the inflammatory response.[139-142] Moreover, studies reported on the effect of FA and *p*-CA on UV radiation have shown that these molecules are potent UV absorber.[143-145] In addition, it has been shown that FA pretreatment of human dermal fibroblasts protects cells against UV-A irradiation by inducing proliferation and progression of cell cycle.[146]

FA, *p*-CA, and PCA have also been proved to have anti-atherogenic and anti-atherosclerotic effects.[147-150] The FA and *p*-CA were also reported to have the ability to inhibit platelet aggregation via the reduction of thromboxane B2 production and the inhibition of platelet–leucocyte interactions.[148,151-153]

Concluding Remarks

Dietary polyphenols as one of the main components of sorghum bicolor grains have demonstrated multiple beneficial activities against several human diseases. In fact, analysis of the published work indicated that the efficacy of three phenolic acids reported in sorghum grains which are FA, *p*-CA, and PCA in the treatment of gastrointestinal disorders, cardiovascular, diabetic, and cancer diseases and as potent molecules to be used as antioxidant, antimicrobial and anti-inflammatory. Therefore, a higher intake of *Sorghum bicolor* can ensure a healthy diet and would have good beneficial pharmacological properties throughout its grain. Thus, the addition of sorghum to human diet as other cereals is of great importance. Further studies in future will be important to evaluate other compound extracts from grain, leaf as well as the root of sorghum plants.

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Conflicts of interest

There are no conflicts of interest.

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