ECRONICON OPEN ACCESS

EC GASTROENTEROLOGY AND DIGESTIVE SYSTEM

Review Article

Revisiting an Old Friend: The Gastrointestinal Benefits of Regular Popcorn Consumption

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Received: March 12, 2022; **Published:** May 31, 2022

DOI: 10.31080/ecgds.2022.09.00923

Abstract

Corn is the third most commonly consumed cereal grain worldwide. It is used to prepare a variety of traditional and modern human meals. Popcorn is a form of flint corn that pops when heated. It has been enjoyed for millennia and is one of the most popular snacks globally. Popcorn is rich in phytonutrients, minerals, and vitamins. Also, it is considered tasty delicious and a great source of fiber. Popcorn's health benefits include essential nutrients (complex carbohydrates, vitamins, and minerals) and distinctive phytoconstituents (polyphenolic compounds). The nutritional benefits of popcorn were highlighted in the 1980s, ensuring its continued use. Popcorn intake is associated with a lower risk of chronic illnesses, such as cardiovascular disease, type 2 diabetes, obesity, several malignancies, and improved gastrointestinal system health. This paper is a comprehensive review of the history of popcorn, from its first reported consumption to the present, and its health benefits, focusing on its gastrointestinal health.

Keywords: *Diabetes Treatment; High Fiber Food; Lowering Cardiovascular Disease Risk; Natural Constipation Cure*

Abbreviations

CV: Cardiovascular; NIDDM: Non-Insulin-Dependent Diabetic Mellitus; PFA: Polyfluoroalkyl Substances

Introduction

Corn, also known as maize, may have begun its long history as a type of grass [1]. It first appeared on the Mexican plains between 7000 and 10,000 years ago. Archaeological evidence suggests that corn was introduced between 2000 and 2500 BCE [1]. The earliest paleoethnobotany proof of corn cultivation is found at an archaeological site called "Nac Neish"—located in the southern section of the Mexican state of Tamaulipas. Three hypotheses regarding the evolutionary origins of corn were proposed. The first hypothesis suggests that maize crossed teosinte (parent plant of modern maize) with *Tripsacum* (genus of plants in the grass family). The second hypothesis proposes that it is derived from tunicated maize. The third hypothesis implies that corn derived from teosinte [2].

The first reference to popcorn popping was in the 1820s [3]. Various types of corn, especially popcorn, were produced in the Americas by the Aztecs and Mayans in Mexico and Central America, and then by the Incas in South America. A popcorn rope was used to embellish the Aztec Gods of Rain and Maize. It was known as *totopoca* by the Aztecs. North American Indians used the burst kernels as decorations and personal ornamentation, hanging them on grass cords. Archaeologists have found popped corn in dwelling caves in New Mexico, estimating it to be about 5,600 years old. It has been proposed that popcorn's origin was in Mexico approximately 8000 years ago.

Before Europeans visited America, popcorn was prevalent in India, Sumatra, and China. However, the routes and modes of its distribution and the rationale for its presence in specific locations and not others remain unknown. In 1612, French explorers reported seeing the Iroquois people popping corn in earthen pots [1]. In the early nineteenth century (approximately 1820s), popcorn was marketed across the eastern United States under pearl or nonpareil's brand names. Its influence quickly extended all through the south. By the 1840s, its presence had started to grow in America [3].

Charlie Cretors built the first steam-powered, automated popcorn popper in 1885. Before this innovation, street sellers burst corn in wire cages by direct heat. In the 1890s, the crystal popper machine with its kerosene burner became a famous fixture at circuses, amusements, carnivals, local markets, and small village sidewalks where popcorn merchants sold bags of popcorn as evening fell, and was first bagged for home consumption in 1914 [2].

The American Dental Association has recommended popcorn as a sugar-free snack and highlighted the benefits of its high-fiber content in preventing certain types of cancer. Popcorn cooked without oil is recommended over most other snacks for its high nutritional content. Weight-watchers consume popcorn as a substitute for high-calorie, low-nutrition snacks for weight loss and maintaining ideal weight [4].

Consuming popcorn is associated with several health benefits, including improved digestive health. Popcorn is a potent antioxidant, aids in metabolic activities, provides energy, decreases anxiety, and promotes bone health. In addition, it regulates blood glucose levels, fights tumor cells, reduces food cravings, slows aging, lowers blood cholesterol, controls anemia, and relieves constipation [5]. However, there was no evidence on the history of any known medical benefits of popcorn.

Corn is used to make numerous and diverse products, including gas, polymers, syrup, soap, oil, dextrin, starch, and bran [6]. However, plain popcorn's health benefits (with no added butter, salt, or other toppings) seem undervalued.

Discussion

Corn, often known as maize (scientific name: *Zea mays* subsp. Mays), is a member of the family Poaceae (Phylum: Spermatophyta: Subphylum: Angiospermae). With about 12,000 species, the grass family is found ubiquitously [7]. All corn currently known to humanity evolved in Mexico from a single-stalked, grassy teosinte. A teosinte ear is only 2–3 inches in length and has 5–12 kernels, compared to a corn ear, which has a 12-inch ear with > 500 kernels [8].

Corn begins to pop at around 177°C, corresponding to a pressure of 135 psi within the kernel [9]. The moisture content of a popcorn kernel is an essential factor because the small-scale bursting of the kernel will not proceed until the moisture content is ideal (16–20% moisture). The liquid in the kernel may expand and create internal pressure without seeping out because of the shell. When the corn kernels are cooked, the corn shell acts like a pressure cooker, trapping moisture inside. The liquid inside the protective shell warms up as the kernels are heated. As the heated moisture attempts to escape, it causes an increase in pressure.

If the pressure within the kernel is sufficient, the outer shell breaks away, and the kernel bursts, converting most of the superheated fluid to vapor. The starch within the protective shell of the kernel also serves a function. It does not burst as the vapor inside the kernel bursts through the shell. Instead of expanding into thin, jelly-like bubbles, these semisolid starch granules swell into thin, spongy bubbles. Like a sink full of soapsuds, neighboring bubbles merge and solidify, generating a three-dimensional structure. Subsequently, it cools to produce the puffy white solid called popcorn (Figure 1) [10]. However, at a temperature of <177°C, the proportion of exploded kernels decreases significantly [9].

Figure 1: *Popcorn kernel—adapted from "Popcorn recipe" [11].*

The nutrients in popcorn differ from those in raw and cooked corn. Table 1 provides a comparison of the nutritional value and chemical content of raw edible corn parts, air-popped popcorn, and oil-popped popcorn (per 100g) is provided in Table 1 [12–16].

Nutrients	Raw corn/maize	Air-popped popcorn	Oil-popped popcorn
Carbohydrate	71.88g	77.9g	57.2g
Protein	8.84g	12.9g	9.0g
Sodium	1 mg	4 mg	884 mg
Water	75.96g	4.1g	2.8g
Energy	86 kcal	382 kcal	500 kcal
Saturated fat	0.2g	0.57g	1.41g
Monosaturated fat	0.4g	1.10g	4.08g
Polyunsaturated fat	0.6g	1.90g	3.57g
Calcium	10 mg	10 mg	10 mg
Iron	2.3 mg	2.66 mg	2.78 mg
Thiamine	0.42 mg	0.20 mg	0.13 mg
Riboflavin	0.10 mg	0.28 mg	0.14 mg
Niacin	1.77 mg	1.94 mg	1.55 mg
Folate	42 mcg	23 mcg	17 mcg
Vitamin A	9 mcg	10 mcg	9 mcg
Potassium	270 mg	329 mg	241 mg

Table 1*: Comparison of nutritional value and chemical composition between raw edible portions of corn, air-popped popcorn, and oil-popped popcorn (per 100g).*

Dietary fiber in popcorn versus other common high-fiber foods

A comparison of dietary fiber in popcorn versus other common high-fiber foods or supplements is provided in Table 2 [13,17].

Fiber Source	Fiber Content (in grams) per 100g	Fiber Source	Fiber Content (in grams) per 100g
Pears	3.1	Split peas	8.3
Strawberries	2	Chickpeas	7
Avocado	6.7	Cooked black beans	8.7
Apples	2.4	Cooked lima beans	7
Raspberries	6.5	Baked beans	5.5
Banana	2.6	Quinoa	2.8
Carrot	2.8	Oats	10.1
Beetroot	2.8	Raw corn	7
Broccoli	2.6	Air-popped popcorn	15.1
Artichoke	5.4	Oil-popped popcorn	10.0
Brussels sprouts	3.8	Almonds	13.3
Kale	3.6	Chia seeds	34.4
Spinach	2.2	Fresh coconut	9
Tomatoes	1.2	Pistachios	10.3
Lentils	7.3	Walnuts	6.7
Kidney beans	6.8	Sunflower seeds	11.1
Sweet potatoes	2.5	Pumpkin seeds	6.5

Table 2*: Comparison of diet fiber in popcorn versus other common high-fiber foods or supplements.*

Health benefits of popcorn

The nutritional benefits of popcorn can primarily be attributed to its high-fiber, phytoconstituent, antioxidant, B-complex vitamin, manganese, and magnesium content [18]. Also, according to a research study by Joe Vinson—a pioneer in analyzing healthful components in chocolate, nuts, and other common foods—popcorn contains a significant proportion of polyphenols [19], which are associated with several health benefits (such as improved blood circulation, enhanced digestion, and reduced risk of several ailments) [20].

Consumption of corn as cob or popcorn provides a healthy and high quantity of fiber, with 7g of total fiber per 100g serving. A single cup (approximately 164g) of maize has 18.4% of the recommended daily fiber intake. It ameliorates constipation and lowers overall "bad" cholesterol. The high-fiber content modulates the release and maintenance of glucose levels. The low caloric content and anti-aging properties make it a perfect snack for patients with diabetes (by minimizing blood sugar variations), patients with cancer, and those aiming to lose weight [18,21].

The resistant starch content of corn endosperm is 39.4 mg/100g. The resistant starch is not digested, helping to maintain a healthy gut microbiome, lowering cholesterol, improving fecal excretion, increasing fermentation, enhancing short-chain fatty acid production in

the large intestine, and alleviating diarrheal symptoms—all of which minimize the risks of cecal cancer and coronary artery diseases, and complications related to weight gain [12].

Diverticulitis prevention: Corn intake protects against specific digestive diseases, such as diverticulitis, characterized by irritation of the gastrointestinal tract. An 18-year study involving 47,228 men found that popcorn intake possibly prevented diverticulitis. A 28% lower risk of developing diverticulitis was observed in individuals with a higher popcorn intake than those with a lower intake [22,23].

Weight gain promotion: A 24-year Harvard study of 133,468 people revealed that every increased daily serving of corn was associated with a weight increase of 2.0–3.15 lb (0.9 kg) at each 4-year interval compared to potatoes, peas, and other starchy vegetables [24].

Other benefits

Cardiovascular (CV) health: Nguyen., *et al*. (2012) found that popcorn intake as a snack is more effective than potato chips in lowering the risk of CV events in humans. The corn kernels have fewer calories and more nutrients than vegetables, fruits, and other whole grains, such as wheat [25].

Eye health: Corn's xanthophylls (lutein and zeaxanthin) play significant and particular biological roles. For example, lutein promotes tumor latency, decreases mammary tumor development, boosts lymphocyte proliferation, decreases the risk of a palpable tumor, and greatly protects cells from oxidant-induced damage [12].

A study involving 356 middle-aged and elderly participants reported a 43% decreased risk of eye diseases in those with a high carotenoid (particularly lutein and zeaxanthin) intake than those with a low carotenoid intake [26].

Management of diabetes: Siyuan., *et al*. (2018) reported that intake of whole-grain corn was associated with a lower risk of type-2 diabetes [27]. Kwon., *et al*. (2007) noted that corn consumption could aid in treating non-insulin-dependent diabetic mellitus (NIDDM). It may be helpful against high blood pressure due to the phenolic phytonutrients [28]. According to Dembinska-Kiec., *et al*. (2007), phytonutrients regulate the absorption and secretion of insulin, lowering the risk of spikes and dips in sugar levels of diabetic patients, thereby improving their adherence to a healthy lifestyle [29].

Healthy bone function: Phosphorus in popcorn supports bone formation and regulates cell function. In addition, magnesium in popcorn strengthens the bones [5].

Reduced craving for food: A cup (approximately 164g) of organic popcorn (non-genetically modified snack food; free from synthetic commercial pesticides) is an exceptional replacement snack as high-fiber helps reduce cravings for less healthy snacks [5].

Reduced age-related complications: Popcorn has anti-aging properties. Free radicals are associated with age-related symptoms, such as skin wrinkles, dark circles under the eyes, vision problems, cataracts, cognitive decline, osteoarthritis, Alzheimer's disease, schizophrenia, and hair loss. The potent antioxidants in popcorn help fight the effects of free radicals, providing feelings of strength and joy well into old age [5].

Reduced depression: Vitamin B3, known as niacin, naturally alleviates sadness, making popcorn a "comfort food" [5].

Other: The B-complex vitamins in corn are beneficial to the skin, hair, and brain. These vitamins improve joint motion, helping reduce rheumatic symptoms. The presence of vitamins A, C, and K, beta-carotene, and selenium the endocrine endocrine gland and immune functions. Potassium, which has diuretic characteristics, is a vital component of corn [12].

Shelf life of popping corn kernels

The shelf life of popcorn is determined by the dates of manufacture and packaging, and the storage method (Figure 2) [30].

Figure 2: *Shelf life of popping corn kernels.*

Oil choice for popping corn

Popping corn in oil is an excellent method to get a healthy dose of fat and keep hunger at bay. Oils commonly used to make popcorn are shown in Figure 3 [31,32].

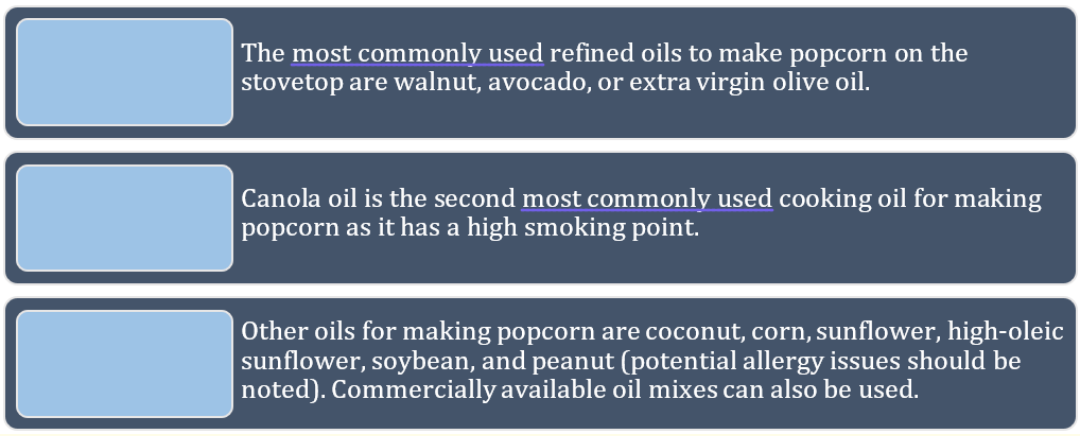

Figure 3: *Oil choice for popping corn.*

The Center for Science in the Public Interest (USA) raised an essential concern in the mid-1990s regarding commercial popcorn, which is provided in Figure 4 [4].

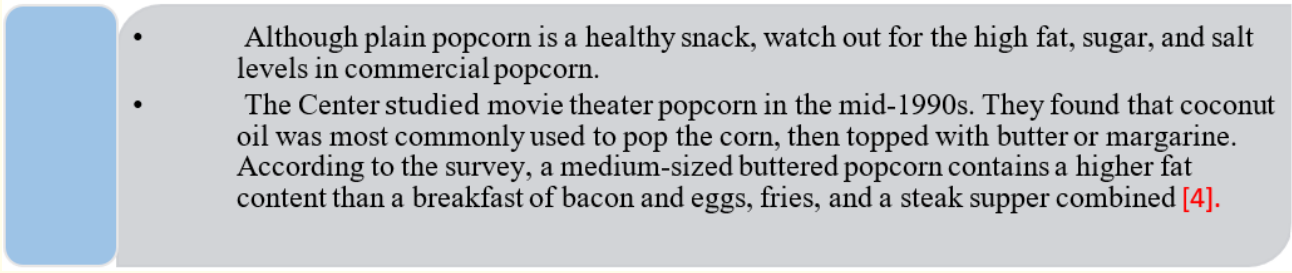

Figure 4: *Concern raised by Center for Science in the Public Interest (USA) regarding commercial popcorn.*

Toxicity concerns during popcorn production

Dust, dirt, water, insects, animals, bacteria, people, storage, transportation, and handling and processing equipment are possible sources of corn kernel contamination [33].

The overall mineral content of popcorn kernels can also be affected by environmental factors (such as the use of irrigation versus rainfall, fertilizer content, and the nature of the soil) [34]. Several agricultural areas receive minerals from various sources, including nitrogen fertilizers and organic sources, such as farmyard manure, plant waste, and compost of multiple origins. In many locations, compost made from municipal solid waste is a crucial source of organic soil amendment.

This compost may introduce metal contaminants into the agroecosystem. However, information on the bioavailability of potentially toxic elements and health risks associated with eating popcorn kernels collected from municipal solid waste compost-fertilized fields is limited [35].

Air pollution reduces the quality of the popcorn kernel. Air quality is affected by fertilizers, gas use, pesticide manufacture, and dust thrown up by tilling. The most significant contributor to corn's air pollution footprint was ammonia from fertilizer application [36,37].

Packaging may have a detrimental effect on popcorn kernels. Many studies have found that flavoring compounds, such as diacetyl and other compounds used in microwaveable popcorn bags, are hazardous to health, increasing the risk of irreversible lung and cancer problems [38].

A 2020 study examined microwavable popcorn wrap and 407 samples of paper, including paperboard meal wrappers, tainted with five polyfluoroalkyl substances (PFAS). Chemicals used to make fluoropolymer coatings and products resist heat, oil, stains, grease, and water and, thus, are utilized by fast-food restaurants. Participants who regularly consumed microwaveable popcorn manufactured for grocery stores had higher serum levels of PFAS [39].

Adding dollops of butter or salt while preparing popcorn for taste appeal negates its nutritional advantages. High salt intake in the diet can lead to hypertension and other health concerns.

Butter has a high level of saturated fats, producing a "sweet fat" when coupled with carbohydrates. This highly appealing combination can lead to overeating, impairing the body's ability to control food intake and increasing food cravings. Combining carbohydrates and

saturated fats can cause the body to store fat. Similarly, using a high amount of margarine to make popcorn is unhealthy as it contains saturated fat, contributing to cardiac diseases [40–42]. Also, over processing the popcorn kernels can negatively affect dietary fiber digestion.

Homemade popcorn and modern "air popping" versus oil popping

Homemade popcorn is superior to store-bought popcorn because the commercial toppings are avoided, and hazardous components are reduced or nonexistent. Popcorn prepared using a dry technique (campfire, coal burner, or hot air popper) is the healthiest alternative. In this technique, unpopped grains are placed in a wire cage agitated over a heating element, allowing the corn to pop. Unflavored air-popped popcorn is minimal in calories, sugar, and fat, and high in fiber [40].

In the wet-popping method, corn is placed in a fixed bottom vessel, and oil is applied to disperse heat, helping the kernels pop [43]. The most common popcorn-to-oil ratio is 3:1, with a popping cycle of 2.5–3 min [12]. The fat concentration present in air-popped *vs*. oil-popped popcorn is provided in Figure 5 [40].

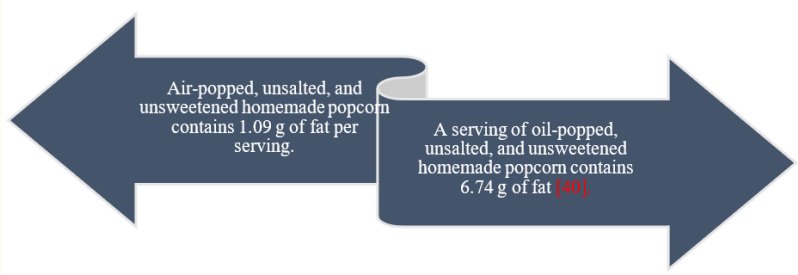

Figure 5: *The fat concentration present in air-popped vs. oil-popped popcorn.*

Corn varieties

Different varieties of corn are used as food, classified as various subspecies based on the amount of starch (Figure 6) [44].

Amylomaize	Zea mays
Dent Corn	Zea mays var. indntata
Flint Corn	Zea mays var. indntata
Popcorn	Zea mays var. everta
Flour Corn	Zea mays var. amylacea
Pod Corn	Zea mays var. eunicata
Sweet corn	Zea mays var. saccharata and Zea mays var. rugosa
Waxy Corn	Zea mays var. ceratina
Striped maize	Zea mays var. japonica

Figure 6: *Different varieties of corn.*

Zea mays var. everta—a variety of flint corn with hard kernels and no soft starch—could be the best form for creating popcorn [45–47]. However, sweet corn does not pop and, thus, is not used to make popcorn [46].

Corn consumption: indications versus contraindications

Corn has a high nutritional value, consisting of 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar, and 1.7% ash. Therefore, eating corn in moderation with a balanced diet has several benefits. However, overeating corn can have adverse effects. The indications and contraindications of corn consumption are provided in Figure 7 [48,49].

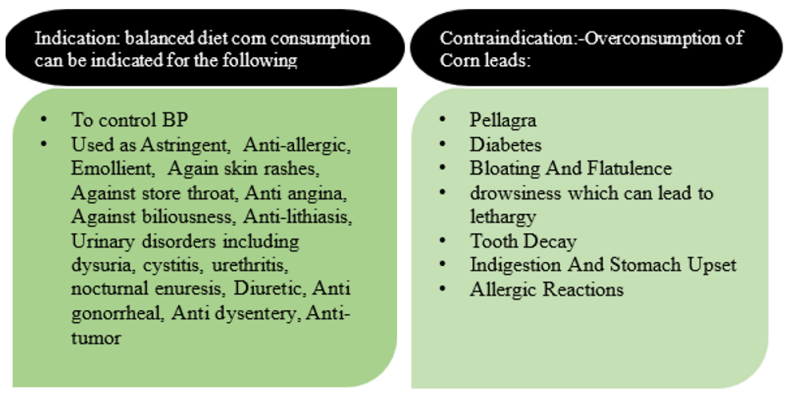

Figure 7: *Indications and contraindications of corn consumption.*

Other poppable or popped seeds and kernels

Besides maize, various kernels and millets, including rice, wheat, sorghum, finger millet, and foxtail millet, are used for popping or puffing. However, only a few of them pop nicely. Season, varietal differences, and grain properties (such as moisture level, grain composition, physical traits, varieties of endosperm, and popping procedure) play a role in the popping process [50]. These kernels' nutrients and fiber levels compared to popcorn are detailed in Table 3 [40,51–54].

Food	Protein (g)	Fat (g)	Fiber (g)	Carbohydrate (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Rice bran	16.5	21.3	25.3	49.4	359	80	11.0	3.0	0.4	43
Wheat bran	14.1	5.5	12	26.8	348	30	3.5	0.41	0.1	5.1
Sorghum	10.4	3.1	2.0	70.7	329	25	5.34	0.38	0.15	4.3
Finger millet	7.7	1.5	3.6	72.6	336	350	3.9	0.42	0.19	1.1
Foxtail millet	11.2	3.3	6.7	63.2	351	31	2.8	0.59	0.11	3.2
Ragi	7.16	1.92	11.18	66.82	320	364	4.62	0.37	0.17	1.34
Popcorn (air-popped)	12.94	4.54	14.5	77.78	387	7	3.19	0.104	0.083	2.308

Table 3: *Comparison of nutrients and fiber content in popcorn versus other kernels.*

Future for popcorn

Corn products are distinguished by a particular flavor unmatched by any other grain products. When popcorn's nutritional benefits were highlighted in the 1980s, its future as a "health food" seemed assured. However, information on the health benefits of popcorn is limited. Regular consumption of maize and its related whole grain products is associated with a lower risk of chronic illnesses, including cardiovascular diseases, impaired glucose tolerance, obesity in human trials, epidemiological research, and certain animal studies.

In addition, the high content of amylose, which is resistant to digestion, in corn improves digestive health by delivering bioactive molecules to the colon. Because of the increased production of current hybrids and variety of specialty corns for distinct food purposes, the future of popcorn seems optimistic, particularly for the growing population living in developing nations across the world.

Conclusion

Corn consumption dates to the fourteenth century. Popcorn has attracted attention for its high content of minerals, bioactive compounds, and phytochemicals, as well as possible health benefits discovered in recent decades. Popcorn is a popular food high in nutrients and functional characteristics. As a result, it has grown in popularity over time. It is a healthy grain snack packed with essential minerals and high-fiber content. Thus, popcorn can be recommended as part of a regular diet.

Conflict of Interest Statement

The authors declare that this paper was written without any commercial or financial relationship that could be construed as a potential conflict of interest.

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Volume 9 Issue 6 June 2022