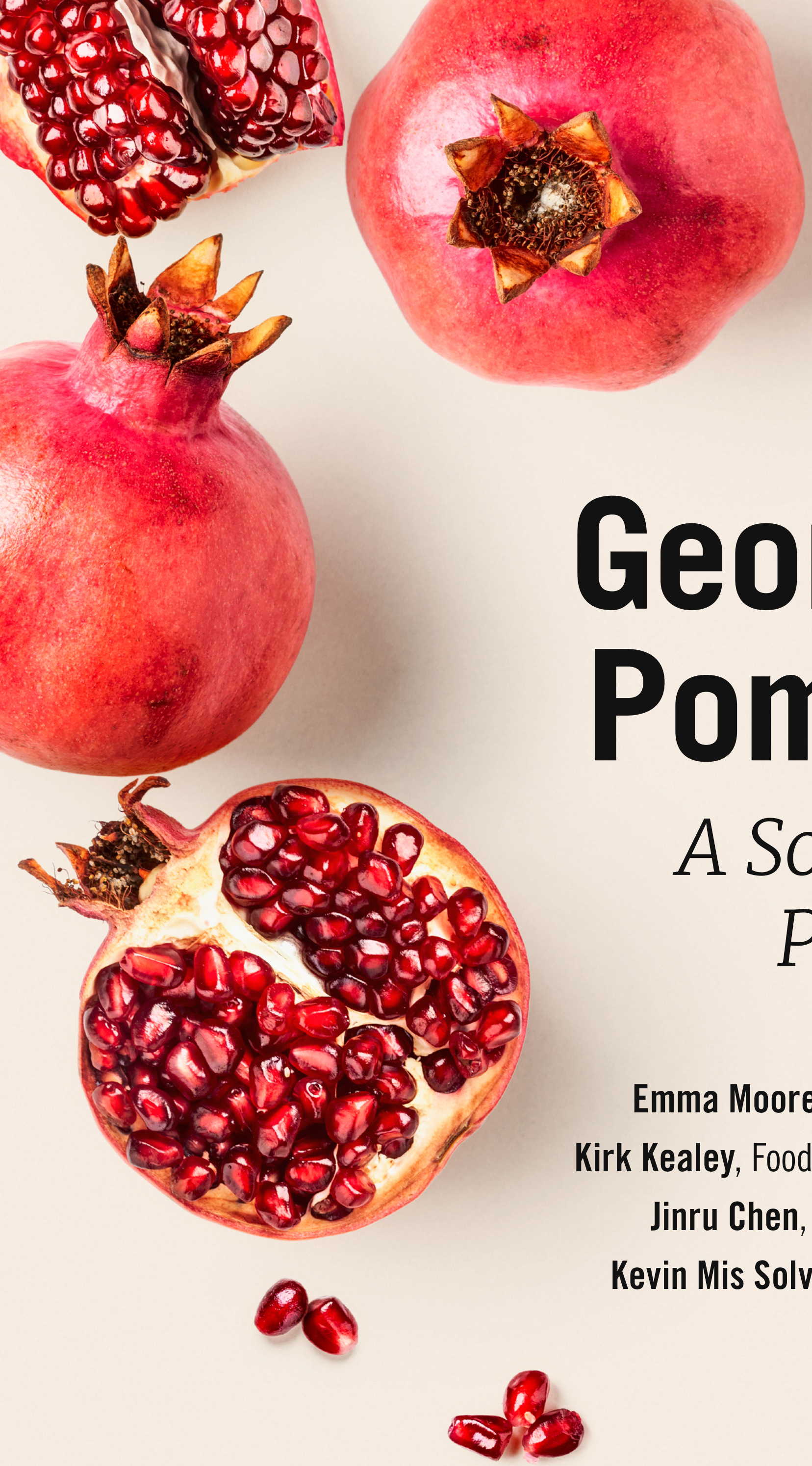

Georgia-Grown Pomegranates

A Source of Powerful Phytonutrients

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Introduction and History

The growing demand for more clean-labeled foods (foods that are made with fewer ingredients, no artificial or synthetic additives, and with ingredients that are recognized by consumers as healthy) is pressing the U.S. food industry to use alternative ingredients rich in vitamins, minerals, and phytochemicals from natural sources. This includes ingredients derived from locally grown fruits and vegetables with antioxidant and antimicrobial properties. Pomegranates (*Punica granatum* L.) are polyphenol-rich fruits that belong to the plant family Punicaceae (Caligiani, 2016; Kandylis & Kokkinomagoulos, 2020).

The origins of pomegranates have been debated for years, but most scholars believe that pomegranates originated from Central Asia approximately 4,000 years ago, and then spread to neighboring regions such as East Asia and the Mediterranean coast. Spanish sailors are given the credit for introducing pomegranates to North America in the 18th century (Caligiani, 2016; Holland et. al., 2009).

Currently, California is the largest grower of pomegranates in the United States (National Agricultural Statistics Services [NASS], 2018). In Georgia and other neighboring states such as Florida, pomegranate is an emerging crop that has been experiencing a significant expansion in the cultivated area driven by the recent interest in plant-based and functional foods. Specifically, local blueberry and peach growers are evaluating pomegranate trees to expand on their current crops (Schupska, 2010).

Nutritional Composition of Pomegranates

Pomegranates can be separated into edible and nonedible components, each of which represent half of a single fruit's weight. The edible part of pomegranates is made up of hundreds of juice-filled and seed-containing arils which are found on the inside of the fruit (Dadashi et. al., 2013; Sreekumar et. al., 2014). These arils contain 85% water, 10% fructose and glucose, and 1.5% pectin, with the reminder comprised of insoluble fiber, vitamins, minerals, and phytochemicals (Sharma et. al., 2017). The intact peel or skin is often considered the nonedible portion of the pomegranate, and can be separated into *pericarp* (outer layer) and *endocarp* (inner layer) (Sreekumar et al., 2014). Both the arils and peels are rich in nutrients and phytochemicals. Many factors can affect the exact nutrient and chemical composition of pomegranates, such as the cultivar type, soil condition, climate, ripening stage, and processing and storage conditions (Dadashi et al., 2013).

Tables 1 and 2 summarize the approximate *micronutrients*, or vitamins and minerals, contained in pomegranate arils and dried pomegranate peels that represent a percentage of recommended dietary allowances (RDA) or adequate intakes (AI). Although intact pomegranate peels are considered inedible, they contain significant amounts of potentially edible components such as soluble fiber, vitamins, and minerals that could be isolated and used as novel food ingredients.

Table 1. Levels of micronutrients found in pomegranate arils.

Micronutrient	Content (mg/100g)	% of RDA or AI* met
Calcium	12.39	0.95–1.24
Potassium	247.79	5.06–5.27*
Iron	0.53	2.94–6.63
Vitamin C**	11.50	12.78–25.56

Note: Levels are indicated as a percentage of the recommended dietary allowance (RDA) or adequate intake (AI). Unless otherwise noted, the data in the third column is the percentage of the RDA. RDA is considered the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97–98%) healthy individuals in a group. Estimated average requirement (EAR) is used to calculate the RDA. An AI is used when there is insufficient evidence to establish an EAR for a specific micronutrient. The percentage of RDA or AI met is based on different age groups and presented as a range for simplification.

* indicates a percentage of the AI value instead of the RDA.

** Pomegranate arils are a good source of vitamin C.

Table data compiled from National Agricultural Library (2011) and the nutrition facts label from POM Wonderful (2021).

Table 2. Levels of micronutrients found in dried pomegranate peels.

Micronutrient	Content (mg/100g)	% of RDA or AI* met
Calcium**	342	26.3–48.9
Potassium	150	2.9–5.0*
Phosphorus	120	9.6–26.1
Sodium	68	3.7–6.8*
Magnesium	56	13.3–70.0
Iron**	6.11	22.6–87.3
Vitamin C**	13.26	11.0–88.4
Vitamin E**	4.13	21.7–68.8

Note: Levels are indicated as a percentage of the recommended dietary allowance (RDA) or adequate intake (AI). Unless otherwise noted, the data in the third column is the percentage of the RDA. RDA is considered the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97–98%) healthy individuals in a group. Estimated average requirement (EAR) is used to calculate the RDA. An AI is used when there is insufficient evidence to establish an EAR for a specific micronutrient. The percentage of RDA or AI met is based on different age groups and presented as a range for simplification.

* indicates a percentage of the AI value instead of the RDA.

** According to Omer et. al. (2019), dried pomegranate peels are a good source of calcium, iron, vitamin C, and vitamin E (a fat-soluble antioxidant).

Table data compiled from National Agricultural Library (2011) and Omer et. al. (2019).

The macro- and micronutrients of pomegranates could easily be incorporated into a healthy diet (U.S. Department of Agriculture [USDA], 2020). According to *Dietary Guidelines for Americans 2020–2025*, a healthy diet includes fruits and vegetables, whole grains, proteins from a variety of sources, low-fat or fat-free dairy products, lactose-free foods, and/or fortified soy products (USDA & U.S. Department of Health and Human Services, 2020). These guidelines are designed to help consumers focus on incorporating nutrient-dense foods and reducing the intake of foods and beverages that are higher in added sugars, saturated fat, and sodium.

Pomegranates are considered *functional foods* because they can provide several vitamins, minerals, and powerful phytonutrients that can promote health and aid in the prevention of chronic diseases such as cardiovascular disease, neurodegenerative disease, cancer, and diabetes (Kandylis & Kokkinomagoulos, 2020; Les et al., 2017). *Phytonutrients* are bioactive compounds found in plant-based foods that may supply health benefits. For example, *polyphenols* are a type of phytonutrient with antioxidant and anti-inflammatory activities (Gupta & Prakash, 2014). Pomegranates have considerable amounts of polyphenols that can be classified into hydrolyzable tannins (ellagitannins), condensed tannins, flavonoids (anthocyanins), and phenolic acids (ellagic acid and gallic acid; Kandylis & Kokkinomagoulos, 2020). Most of the pomegranate polyphenols are found in the peels; the most predominant type of polyphenol is punicalagin, a type of ellagitannin with strong antioxidant activity (Fischer et. al., 2011). Punicalagin represents approximately 77% of the total polyphenols found in the peel of some pomegranate cultivars (Caligiani, 2016; Li et al., 2015).

Table 3 shows the types of polyphenols and a range of the quantities found in each part of the pomegranate fruit. In addition, Figure 1 shows a more detailed understanding of which polyphenol classes, as well as macro- and micronutrients, are found in each part of the pomegranate fruit.

Table 3. Approximate ranges of polyphenol content found in pomegranate components.

Pomegranate peel		Pomegranate juice		Pomegranate seeds	
Polyphenol class	Quantity	Polyphenol class	Quantity	Polyphenol class	Quantity
Hydrolysable tannins Ellagitannins: punicalagin*	1–20 g/kg	Flavonoids Anthocyanins*	110–1960 mg/L	Lignans Syringaresinol	23.5 µg/g
Flavonoids Anthocyanins	50–500 mg/L	Hydrolysable tannins Ellagitannins: punicalagin	4–600 mg/L		
Phenolic acids Ellagic acid	35–500 mg/100 g	Phenolic acids Ellagic acid	0–450 mg/L		
Gallic acid	100–130 mg/100 g	Gallic acid	2–75 mg/L		
Lignans Isolariciresinol	5–10.5 µg/g	Lignans Pinoresinol	2.1 µg/g		
Pinoresinol	3.3 µg/g				

Table data was derived from Caligiani (2016).
*Indicates richest source of polyphenol for that part of the pomegranate.

Figure 1. Approximate nutrients found in the various parts of the pomegranate fruit.

Note: Phytonutrients include carbohydrates, fatty acids, organic acids, and alkaloids. Vitamins C and E also are considered phytonutrients because they exhibit antioxidant properties. Polyphenols include hydrolysable tannins, flavonoids, lignan, and phenolic acids.

* most abundant phytonutrient in that part of the pomegranate fruit.

This figure was created with information reported by other authors (Caligiani, 2016; Kandylis & Kokkinomagoulos, 2020; Omer et al., 2019; Wu & Tian, 2017).

polyphenol

phytonutrient

Juice

Phenolic acids: Ellagic, gallic
Flavonoids: Anthocyanins
Hydrolysable tannins: Ellagitannins (punicalagin)
Lignan: Pinoresinol

Carbohydrate: Glucose, fructose
Organic acids: Malic, citric, oxalic, tartaric

Arils

Flavonoids*
Lignan: Syringaresinol

Fatty acids: Punicic acid**, linolenic acid, linoleic acid, oleic acid, palmitic acid, stearic acid
Carbohydrates: Crude fiber
Tocopherol (vitamin E): Alpha and gamma

Protein: Amino acids

Seeds

Flavonoids
Lignan: Syringaresinol

Fatty acids: Punicic acid*, linolenic acid, linoleic acid, oleic acid, palmitic acid, stearic acid
Protein: Amino acids
Carbohydrates: Crude fiber
Tocopherol (vitamin E): Alpha and gamma
Vitamin C

Minerals: Potassium, calcium, iron

Pomegranate Peels

Pericarp (outer layer)

Hydrolysable tannins: Ellagitannins (punicagalin)*

Vitamins C, E
Carbohydrates: Dietary fiber

Minerals: Calcium, potassium, phosphorus, magnesium, sodium, iron

Endocarp (inner layer)

Flavonoids: Anthocyanins
Lignans: Isolariciresinol, pinoresinol
Phenolic acids: Ellagic acid, gallic acid

Alkaloids: Punigratane

Health Benefits Associated With the Consumption of Pomegranates

As previously mentioned, pomegranates are an excellent source of important phytonutrients, vitamins, and minerals that may aid in the prevention and management of several diseases while reducing oxidative stress in the body. *Oxidative stress* is linked with the pathology of chronic diseases such as cardiovascular disease, kidney disease, and cancer, and is characterized by an increase in available *reactive oxygen species* (ROS; Cai & Harrison, 2000). ROS are unstable oxygen-containing molecules that can easily attack and damage the biomolecules—lipids, carbohydrates, proteins, and DNA—found in human cells (Cai & Harrison, 2000). Antioxidants help scavenge, or bind up, these ROS and decrease their reactivity in the body, thus decreasing oxidative stress (Cai & Harrison, 2000; Caligiani, 2016). One research study has reported a decrease in oxidative stress in rats with obesity-related nonalcoholic fatty liver disease when they were given pomegranate extract-enriched punicalagin (Zou et al., 2014).

Pomegranate juice consumption also has been associated with reductions in systolic and diastolic blood pressure (Caligiani, 2016). Hypertension, or high blood pressure, is a major risk factor for cardiovascular disease, and pharmacological agents often are recommended as a first-line treatment along with lifestyle and dietary modifications to reduce the risk of this disease.

Angiotensin converting enzyme (ACE) inhibitors are medications often prescribed to those with hypertension to help lower their blood pressure (Mayo Clinic, 2019). These ACE inhibitors prevent the formation of angiotensin II, a peptide hormone that causes the contraction of blood vessels, and reduce blood pressure by relaxing blood vessels (Mayo Clinic, 2019). A study conducted by Asgary et al. (2014) reported a reduction of systolic and diastolic blood pressures and ACE activity in hypertensive patients who consumed 150 ml (approximately 0.6 cups) of pomegranate juice per day for 2 weeks. This effect may be attributed to the main polyphenols, anthocyanins and ellagitannins, found in pomegranate juice. Furthermore, antioxidants such as ellagic acid (found in the juice) and punicalagin (found in the peels) have been shown to inhibit fat deposition in humans and may help prevent obesity (Les et al., 2017).

Recent studies have investigated more natural ways to maintain and/or reduce fasting blood glucose to healthy levels. Fasting blood glucose levels below 100 mg/dl are considered normal for healthy people; meanwhile, fasting blood glucose levels of 100–125 mg/dl and higher than 125 mg/dl often are observed in prediabetic and diabetic individuals, respectively. Type 2 diabetes is characterized by *hyperglycemia*, or elevated levels of blood glucose, which occurs because of a decrease in insulin activity and secretion (Khajebishak et al., 2019). Insulin is a hormone that helps distribute glucose to muscle, fat, and liver cells when blood glucose levels are high. However, when insulin activity or secretion is low, glucose is not effectively delivered to the cells, which causes high blood glucose levels and can lead to serious complications such as cardiovascular disease when uncontrolled (Gharib & Kouhsari, 2019)—therefore, it is important for people with type 2 diabetes to monitor and control their blood glucose levels.

Metformin is a medication that usually is prescribed to control blood glucose in patients with type 2 diabetes, but it can lead to serious side effects such as diarrhea, loss of appetite, and abdominal pain (National Library of Medicine, 2020). Alternative and more-natural approaches are being investigated; in one research study, participants with type 2 diabetes showed a decrease in fasting blood glucose levels after being given a pomegranate seed oil supplement. Pomegranate seed oil has high amounts of punicic acid, an unsaturated fatty acid that may have caused this decrease (Khajebishak et al., 2019). In another study, participants with type 2 diabetes were given a supplement of pomegranate peel extract for 8 weeks and researchers found that it significantly reduced their hemoglobin A1c (HbA1c) levels (Grabež et al., 2020). HbA1c is a measure of the average blood glucose level over the past 2 to 3 months, which can indicate good or poor glycemic control (Mayo Clinic, 2021). The investigators suggested that the pomegranate peel extract supplement may reduce blood glucose levels by inhibiting the activities of the enzymes alpha-glucosidase and alpha-amylase (Grabež et al., 2020). Inhibiting these enzymes can reduce the spike in blood glucose levels observed after consuming a carbohydrate-rich meal, thus promoting good glycemic control (Tundis et. al., 2010).

Because pomegranate arils and peels are good sources of vitamin C, their consumption also may support a healthy immune system. Vitamin C cannot be synthesized in the body and must be obtained from the diet. Vitamin C has important biological functions as it helps heal wounds, promote growth, and repair tissue, and keeps bones, teeth, and skin healthy. Vitamin C also is a strong antioxidant that can scavenge free radicals and ROS and make them less reactive. This may aid in the prevention of skin, breast, and prostate cancer as well as heart disease (Carr & Maggini, 2017). Additionally, pomegranate peels and seeds are rich in vitamin E, a fat-soluble vitamin and antioxidant that can prevent blood clot formation and enhance the immune system (Office of Dietary Supplements, 2020b).

Pomegranate peels are rich in *nonheme iron*, a type of iron found in plant-based foods that is not as readily absorbed by the human body as *heme iron*, which is found in foods of animal origin. Consuming vitamin C along with nonheme iron can increase its *bioavailability* (absorption by the body). Dietary iron is needed for the production of hemoglobin, a protein that transports oxygen from the lungs to the rest of the body (Office of Dietary Supplements, 2020a). Because of the characteristics of its nutritional profile, pomegranate often is considered a superfruit with great potential to play a key role in healthy diets (Dasenaki et. al., 2019).

Applications of Pomegranates in Foods

Pomegranates are known not only for their numerous health benefits but also their sensory attributes—color and aroma—which make the fruit attractive to the modern food industry. The fruit is multifunctional: Pomegranate arils are consumed fresh and make a tasty topping for salads, protein bowls, and yogurt, and the fruit is used for flavor or color in many food products such as juices, concentrates, wines, syrups, jellies, jams, sauces, smoothies, and granola bars (Kandylis & Kokkinomagoulos, 2020; Singh & Singh, 2004). Additionally, pomegranate fruit extracts have been used as a natural source of antioxidants and antimicrobials (Dib et al., 2018; Molva & Baysal, 2015).

Pomegranate polyphenols may prevent lipid oxidation in foods because of their antioxidant properties. Lipid oxidation occurs when foods high in polyunsaturated fats are exposed to oxygen, light, heat, ionizing radiation, or metal ions (Alamed et. al., 2009). Oxidation reduces the quality and shelf life of foods, producing undesirable flavors and odors. Polyphenols act as primary antioxidants by scavenging free radicals, which are highly reactive because they contain unpaired electrons. Primary antioxidants can delay or inhibit lipid oxidation by decreasing the amount of volatile decomposition products in foods that lead to the oxidation of fats, also known as rancidity. The food industry normally controls lipid oxidation by adding synthetic chemical additives. However, there has been interest recently in exploring plant-based and natural alternatives, and researchers are evaluating the performance in food products of antioxidants extracted from fruits and vegetables, including pomegranates.

The research has revealed some challenges when directly adding plant-based polyphenol-containing extracts to foods. For example, phenolic compounds may degrade because of environmental factors—oxygen, light, and suboptimal temperatures and pH ranges—which can lead to undesirable flavors, colors, and the loss of antioxidant activity (Đorđević et al., 2015). Furthermore, an enzyme that is widely distributed in many fruits and vegetables, polyphenol oxidase, is not released until a plant cell wall becomes damaged. Polyphenol oxidase reduces the natural antioxidant activity of polyphenols and may cause undesirable browning (Caligiani, 2016). In addition, polyphenols have low bioavailability in the body, so to be of any use their structures must remain unaltered from their isolation to the point of consumption. To protect polyphenols from environmental factors, *microencapsulation* (incorporating the compounds into a protective matrix) can be used to stabilize and protect bioactive compounds that are highly prone to degradation. Research has found that microencapsulation of polyphenol extracts can help mask unwanted flavors and textures, protect antioxidant activity, and provide controlled release as well as targeted delivery (Đorđević et al., 2015).

Enhancing the nutritional value of food products is necessary in some instances, such as with gluten-free diets. Research has identified beneficial effects of adding pomegranate extracts and derivatives into several foods (Kandylis & Kokkinomagoulos, 2020). Gluten-free products are crucial for people who suffer from celiac disease, an autoimmune disorder in which the consumption of gluten damages the intestinal lining, or those with gluten sensitivities that require special diets (Dib et al., 2018). Gluten-free foods often are lower in some nutrients, such as B vitamins, iron, and protein, and enhancing the nutritional value of gluten-free products is a current challenge for the food industry. Studies have investigated improving the nutritional value of gluten-free pasta by adding pomegranate seed powder, which is a good source of fiber and antioxidants (Dib et al., 2018). When low levels of pomegranate seed powder were added to gluten-free pasta, it provided similar sensory attributes with higher nutritional value—including higher fiber and antioxidant content—than regular gluten-free pasta. However, elevated levels of seed powder affected the color and texture of the gluten-free pasta, which led to lower consumer acceptability. This example shows the potential uses of and need for more research into pomegranate derivatives to enhance the nutritional value of foods.

U.S. Pomegranate Industry

Kandylis and Kokkinomagoulos (2020) reported that there are over 500 cultivars of pomegranates around the globe. However, not all pomegranate cultivars can be found in the United States because some cultivars are better suited for certain climates. The best climates for optimal growth of pomegranates seem to be those with high sunlight exposure, dry summers, and mild winters, which mimic the climatic conditions of the Mediterranean. Table 4 shows a summary of main pomegranate cultivars found in the United States.

Table 4. Pomegranate cultivars currently grown in the United States.

Cultivar	Location(s) grown
'Wonderful'	Arizona, California, Florida, Hawaii, Texas
'Foothill'	California
'Granada'	California, Hawaii
'Cranberry'	Georgia
R9	Georgia
R18	Texas
R19	Georgia
'Girkanets'	Florida
'Kazake'	Florida
'Al-sirin-nar'	Florida, Texas
'Medovyi Vasha'	Florida
'Salavatski'	Texas

Table data compiled from Diaz-Perez et. al., 2010; Love et. al., 2007; Schalau, 2001; Stein et. al., 2013; University of California, Davis, 2020; University of Florida, n.d.).

According to a 2017 agricultural census (NASS, 2019), there were 1,502 total pomegranate farms (both of bearing age and nonbearing age) spanning a total of 31,472 acres with 29,992 acres bearing production in the country. Interestingly, the number of pomegranate farms has seen a marked increase since 2012 when there were just 1,056 total farms (NASS, 2019). As of 2017, California held 29,714 of the 29,992 acres bearing production in the United States and produced more than 90% of the country's pomegranates (Marzolo, 2015). Georgia reported only 11 acres bearing production across 19 farms and ranked seventh out of the 22 states with farms bearing production (NASS, 2019). Table 5 shows the number of farms and acres bearing production for each U.S. state that had at least one farm in 2017. Production total and value of each state's market were unable to be obtained for this report.

Table 5. Summary of information on U.S. pomegranate farms of bearing age in 2017.

State	Farms (bearing production)	Acres (bearing production)*
Alabama	3	—
Arizona	24	6
California	753	29,714
Colorado	1	—
Florida	56	48
Georgia	19	11
Hawaii	27	5
Louisiana	3	**
Maryland	1	—
Mississippi	5	3
Nevada	9	20
New Mexico	33	9
New York	2	—
North Carolina	7	—
Ohio	1	—
Oklahoma	1	—
Pennsylvania	2	—
South Carolina	7	2
Tennessee	1	—
Texas	80	75
Utah	6	2
Virginia	2	—

* a long dash indicates data that was withheld to avoid disclosing data for individual farms.
** less than half an acre.
Adapted from "Fruits and nuts: 2017 and 2012," by U.S. Department of Agriculture National Agricultural Statistics Services, 2019, in 2017 Census of Agriculture - State Data*, p. 584 (https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_0031_0031.pdf). Copyright 2019 by USDA.*

Commercial Opportunities for Georgia-Grown Pomegranates

Developing novel food ingredients from underutilized fruits and the inedible parts of pomegranates, such as peels and seeds, would be an innovative way to use Georgia-grown pomegranates and encourage the expansion of this emerging industry within the state. Consumers desire more plant-based foods and more natural antioxidants and antimicrobials. Extracting polyphenols from pomegranate peels may be a new way to add plant-based antioxidants into food products to prevent lipid oxidation (Alamed et al., 2009). Microencapsulation could be used to protect the pomegranate polyphenols from degradation and allow them to exert their antioxidant effects in food products. Moreover, pomegranate fruit juice powder can be used as a dry ingredient in several food applications including dairy, confectionery, and bakery products.

Ellagic acid, found in pomegranate juice and peels, has been found to be an effective antimicrobial that controls the growth of microorganisms that cause spoilage and illness, and thus extends the shelf life of food products (Juneja et. al., 2016). Ellagic acid potentially can be extracted from Georgia-grown pomegranates and then used as a plant-based antimicrobial. Plant-based antioxidants and antimicrobials have attracted the interest of the food industry because of recent consumer concerns over the use of their synthetic counterparts. Juneja et al. (2016) reported that when pomegranate powder (70% ellagic acid) was added to ground chicken, *Escherichia coli* O104:H4 (a very dangerous pathogen) became less resistant to heat, and the addition of 1% pomegranate powder to ground chicken reduced the time needed to cause a 5-log reduction in the population of *E. coli*. Similarly, Molva and Baysal (2015) found that adding pomegranate extract to apple juice reduced nonpathogenic bacteria; researchers found that an extract containing less than 30% punicalagin and less than 5% ellagic acid in concentrations of 2.5, 5, 10, 20, and 40 µg/ml reduced the initial log count of *Alicyclobacillus acidoterrestris* (a nonpathogenic bacterium commonly found in fruit juices) vegetative cells by 2.84, 3.26, 3.32, 3.46, and 3.56 log colony forming units per milliliter, respectively. Furthermore, the pomegranate extracts were able to inhibit the spore germination of *A. acidoterrestris* in apple juice. These studies provide a promising outlook for pomegranate derivatives to act as natural plant-based antimicrobials in the future. Consumer interest in plant-based antioxidants and antimicrobials offer a fantastic opportunity for the Georgia pomegranate industry to diversify its portfolio of products and provide alternatives to the fresh-fruit market, which may help ensure the long-term sustainability of this emerging industry and increase revenue.

Conclusions

Health-conscious consumers are interested in including more plant-based ingredients in their diets. Antioxidant-rich foods such as pomegranates may be used by the U.S. food industry as a source of natural ingredients to meet the demands of modern consumers. So far, limited studies have reported on the efficacy of adding pomegranate derivatives to foods. More research still is needed to identify additional potential uses of Georgia-grown pomegranates as a source of plant-based bioactives and functional ingredients. Consuming pomegranates provides numerous health benefits, and pomegranate derivatives have the potential to improve the sensory properties and shelf life of food products. This is a wonderful opportunity for the local Georgia pomegranate industry to grow and increase their profits.

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