

A Mini-Review on Almonds and Cashew Nuts: Processing Impact, Phytochemical and Microbiological Properties, and Implications on Human Health

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Received November 04, 2022; Revised December 07, 2022; Accepted December 18, 2022

Abstract Consumers are becoming vegan, vegetarian, or flexitarian due to the factors such as a healthy lifestyle, and growing environmental concerns. Circumstances like this have cumulatively driven the global nuts and dried fruits market. Thereby, this study aims to review two nuts (almond and cashew nut) in terms of processing effect on their quality attributes, nutritional value, phytochemical composition, and significant health advantages. Almonds are rich in phenolic extract, which is useful in preventing or slowing down the processes of various oxidative stress-related diseases. Additionally, studies have indicated that the regular consumption of this nut may modulate intestinal microbiota. Its nutritional properties can also facilitate contamination by pathogens and their growth (for instance, *E. coli* O157:H7, *Salmonella enterica*, and *L. monocytogenes*) during production steps or storage. In turn, the cashew nut is a food that promotes the reduction of LDL cholesterol, improvement in the cardiovascular system, and control of diabetes. Allergenic proteins are found in both nuts, although some studies demonstrated a considerable decrease in allergenicity after submitting samples to high-pressure treatments at high temperatures. Finally, we consider that there are still several research opportunities in the field, mainly related to microbiology, allergenicity, and sustainable production. Thus, the consumption of these nuts in the world could be consolidated, taking into account that in various regions of the globe, they are expensive foods and therefore not accessible to several populations.

Keywords: bioactive compounds, antioxidants, roasting treatment, industrial processes, cashew nut protein

Cite This Article: Adriana Dantas, and Diogo Pontes Costa, "A Mini-Review on Almonds and Cashew Nuts: Processing Impact, Phytochemical and Microbiological Properties, and Implications on Human Health." *American Journal of Food Science and Technology*, vol. 10, no. 5 (2022): 233-238. doi: 10.12691/ajfst-10-5-4.

1. Introduction

According to a recent survey performed by the Fortune Business Insights company [1], consumers are becoming vegan, vegetarian, or flexitarian due to the factors such as a healthy lifestyle, and growing environmental concerns. Allied with that, there is an increase in government initiatives, leading to the introduction of plant-based food to the mainstream populations by major food players. In this context, Duthie *et al.* [2] discussed that consuming fruits and vegetables is one way to prevent noncommunicable diseases, pointing out that 3–5 servings of fruits and vegetables per day (that is, at least 400 g) can help this purpose. These circumstances have cumulatively driven the global dried fruits and nuts market. Particularly, the consumption of nuts and peanuts is widespread throughout the world due to their beneficial effects on human health and high organoleptic value [3]. The differentiation was made (between nuts and peanuts) because "nuts" is

popularly understood as a simplification of the term tree nuts, which is a collective used to describe nuts that grow on trees, such as hazelnuts (*Corylus avellana*), almonds (*Prunus dulcis*), walnuts (*Juglans regia*), cashews (*Anacardium occidentale*), pistachio nuts (*Pistacia vera*), and Brazil nuts (*Bertholletia excelsa*) [4]. All of them are fruits consisting of a hard nutshell protecting the kernel. Peanuts, on the opposite, are not tree nuts, but groundnuts, and are also classified as legumes [5].

Nuts are presented in raw or roasted forms, and they can be used in a variety of ways in the food, including dessert preparation, to enhance flavor and nutrients. Or, they can be eaten as unique food, in the morning or at any time because they digest quickly and easily within 2–3 hours without causing digestive problems. The population that stands out as a good consumer of nuts is pregnant and nursing moms, as they like the contoured shape, crisp texture, and flavor, as well as the various health aspects (for example, antioxidants presence, and anti-inflammatory agents). Another prominent consumer group is that formed by students and athletes, given the

presence in these foods of protein, multivitamins, and other micronutrients, and the high quantity of calories, providing instant energy [6]. Nevertheless, nuts are widely consumed by people of all ages across the world. In an industrial context, these foods are commonly used as the main ingredient in plant-based bars and healthy snack formulations. Moreover, nuts are often present in the composition of beverages, bakery and cereals products, processed dairy products, and salads, which denotes their versatility.

Nuts intake is frequently associated with health advantages for the heart, brain, skin, hair, cholesterol, muscles, and bone [6]. Therefore, this study reviews the nutritional value, phytochemical composition, significant health advantages, and effects of the processing of two nuts (almond and cashew nut). An overview of this work is presented in Figure 1.

2. Almond (*Prunus dulcis*)

The cultivated sweet almond (*Prunus dulcis*) is a nutritionally vital and lucrative specialty crop grown for household consumption and commerce in many temperate and subtropical regions around the world [7]. Albala [8] commented that this nut has been known and cultivated for thousands of years for medicinal and food purposes. In this context, ancient texts of medical and scientific character were found. From Greece and Persia, and later from traditional Chinese medicine, these reports described certain properties of the almond, such as “cleansing”, “nourishing”, “hot” or “heating”, and “strengthening mental functions”. Thus, the authors emphasized that these ideas were only adapted and/or modified as almonds were introduced from western to eastern Asia. Today, we also have this nut as an important component of Indian Ayurvedic medicine.

Regarding the market, almond demand continues to increase internationally. For instance, in Europe, almonds are one of the leading imported tree nuts. In this sense, countries like Spain, Germany, and Italy offer opportunities for exporters. In general, the European market for almond ingredients (whole almonds, almond pieces, almond flour, etc.) is expected to witness sturdy growth by 2029. This scenario is also attributed to the promotional activities carried out by US suppliers [9,10]. Likewise, North America is expected to witness robust growth in the market due to the increasing demand for almond ingredients from various segments such as confectionery, bakery, and snacks. The United States is a major producer and exporter of almonds, being the leading supplier of this product to Europe, with an emphasis on California, which produces about 80% of the world’s almonds and 100% of the U.S. commercial supply. On the other hand, the rising demand for almond-based cosmetics in the Asia Pacific is driving the growth of the market in the region [9].

2.1. Composition and Health Benefits

Almonds are abundant in macronutrients (for example, high-quality protein) and micronutrients such as calcium, copper, iron, magnesium, manganese,

phosphorus, potassium, and sodium (Table 1). The main vitamin E isomer in all almond types studied is α -tocopherol; β -, γ -, and δ -tocopherols are minor components. Phenolics and flavonoids are also present in high amounts [7,10]. Such characteristics make this food associated with a variety of health advantages, including cholesterol-lowering properties, diabetic prevention, and possible prebiotic qualities. In addition, almonds are useful for cardiovascular diseases because they contain a high level of unsaturated fatty acids as well as a high level of bioactive molecules (fiber, phytosterols, vitamins, other minerals, and antioxidants) [11].

In recent decades, almond by-products such as seed extract, skin shell, and hull have been shown to contain phenolic chemicals. Javaid *et al.* [11] discussed that polyphenols are a common micronutrient in human diets, and they play an important role in the prevention of degenerative illnesses including cancer and cardiovascular disease. Regarding cancer, the same authors reported that a person who consumes more almonds decreases the risk of developing breast cancer by 2 to 3 times. This is due to the antioxidant characteristics of the different phenolic compounds found in the almond and its by-products. Thus, when using these foods as natural dietary antioxidants, oxidative stress (which contributes to inflammation, aging, and cancer) could be prevented. However, polyphenols' health effects are determined by the amount ingested as well as their bioavailability. It was also notified that the amount of lipids and cholesterol in the blood is improved by eating almonds regularly, given this abundant concentration of antioxidants (mainly in the brown coating) [12]. That is, these compounds help to lower blood pressure and enhance circulation. As a result, cardiovascular problems are reduced [13].

Concerning the prebiotic qualities, some studies have highlighted this characteristic [14,15]. They suggest that almonds can support colonic microbiota health by stimulating its richness and diversity. This implies an increase in the proportion of symbiotic microorganisms against pathogens. Particularly, the study by Liu *et al.* [15] showed significant increases in the populations of *Bifidobacterium* spp. and *Lactobacillus* spp. after almond or almond skin supplementation. In contrast, the growth of the pathogen *Clostridium perfringens* was significantly suppressed. This prebiotic effect is strongly correlated to the fibers and polyphenols contents present in the almond.

Despite all these benefits and recognition as healthy food, almond is also a potent source of allergenic proteins. In turn, these proteins can trigger several mild to life-threatening immunoreactions, causing millions of people to suffer. In a simplified way, the allergy-causing proteins in plant seeds are the seed-storage proteins, for which no biological function is known except that they save nutrients for the growth of future young plants. A larger percentage of the total protein mass of a plant seed is compounded by seed-storage proteins [16]. However, techniques capable of reducing the allergenicity of these foods are studied, as shown in the work by De Angelis *et al.* [17], who were successful in applying heat and pressure treatments on almond protein, since no epitopes associated with known allergens survived after the procedures, evidencing the potential of the treatment to reduce almond allergenicity.

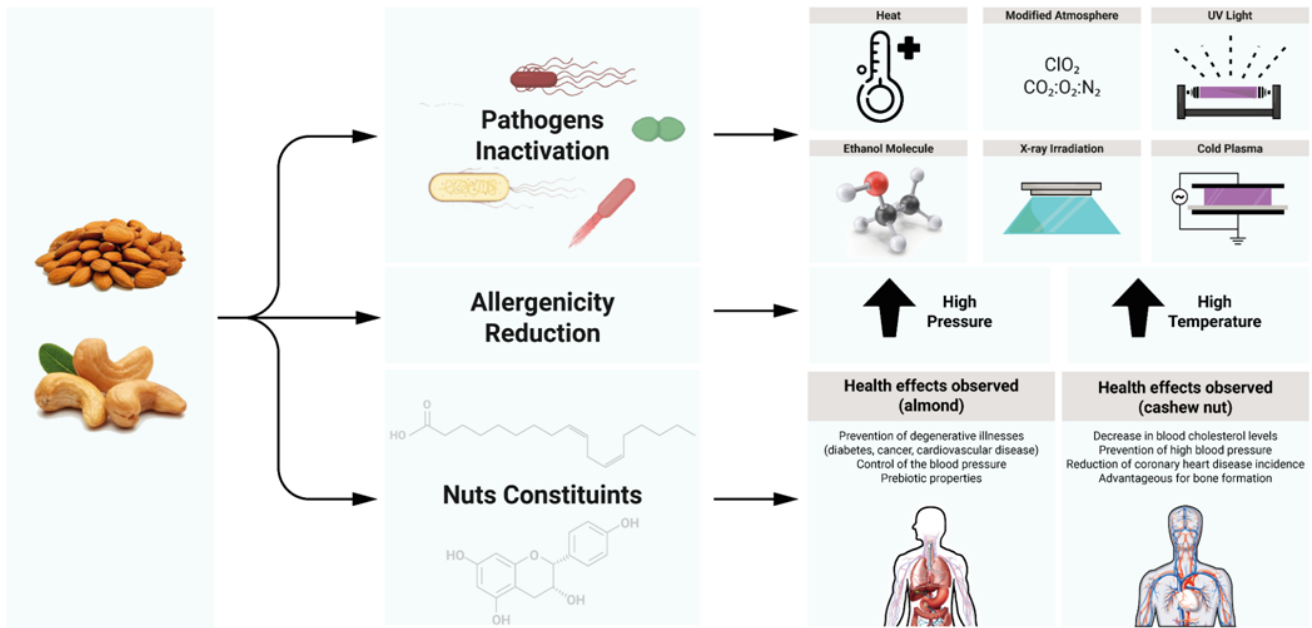


Figure 1. Schematic diagram of the current field state about almonds and cashew nuts

Table 1. Nutritional Composition of Almond and Cashew Nut

	Macronutrients (Value per 100 g)	Micronutrients	Bio-active compound	References
Almond (<i>Prunus dulcis</i>)	Carbohydrates = 2.6–7.4 Protein = 14–26 Lipids = 48–59 Fiber, total dietary = 11–14	Calcium Copper Iron Phosphorus Vitamin E isoforms	Phenolics (mg GAE/g FW) = 0.1 Flavonoids (mg CE/g FW) = 1.8	[7,33]
Cashew nut (<i>Anacardium occidentale</i>)	Carbohydrate = 18.1–30 Protein = 21.01–23 Lipids = 41.66–44.70 Fiber, total dietary = 3.2–3.9	Iron Zinc Sodium Vitamin B12 Vitamin B8 Vitamin B9 Vitamin K1	Phenolics (mg/100 g) = 107.00 Flavonoids (mg/100 g) = 63.7	[34,35,36]

2.2. Processing Effect

From a microbiological point of view, depending on the conditions during the production chain, the safety of almonds can be questionable. Between 2014 and 2020, 32 foodborne outbreaks in the United States and Vietnam were linked to almond-based products, resulting in salmonellosis or intoxication by *Clostridium botulinum* type B [18]. In addition, during the same period, several U.S. companies had to recall their products because of contamination by *Listeria monocytogenes* or *Salmonella*, with illness manifestations in some cases [19]. Despite this discouraging situation, a vast literature is currently available and reports the inactivation of these microorganisms through different chemical, thermal and non-thermal processes, or even their combinations [20-32].

Soaking almonds before eating them is common in commercial and domestic settings. Feng *et al.* [37] investigated the food safety implications of soaking almonds, since recipes on the internet detailed soaking conditions that would facilitate pathogen development. Data collected showed that better digestion and nutrient uptake were the most prevalent reasons for soaking almonds (94.1%). In trials by Feng *et al.* [37], it was found that the counts of *E. coli* O157:H7, *Salmonella*

enterica, and *L. monocytogenes* increased by 3.48, 3.94, and 3.22 log CFU, respectively, after 24 h of almond soaking at 23°C. Likewise, in almonds soaked at ≥ 18°C for more than 8 hours, pathogen populations increased significantly. In contrast, foodborne pathogens did not grow in almonds that had been soaked for 24 hours at 15 °C. The authors also related that salmonella viability was not reduced by drying soaked almonds at 66 °C for 14 hours.

2.3. Food Application

As already discussed, almonds are often consumed raw, sliced, or roasted, but they may also be processed into marzipan, butter, milk, oil, spreads, bread, pastry, chocolates, and confectionery goods. Aside from direct consumption, almonds are used to enhance the appearance and texture of a variety of sweet and savory meals and food products [11,38].

3. Cashew Nut (*Anacardium occidentale*)

The cashew (*Anacardium occidentale* Linn.) tree, which belongs to the Anacardiaceae family, is a resilient

tree that thrives in a variety of climates. It is a Brazilian native that is widely grown in India, East Africa, and Vietnam [39]. Cashew is one of the most significant plantation crops, with India being the world's top cashew nut exporter, followed by Brazil. With increasing production capacity in different nations, global raw cashew nut production has increased from 0.29 million tonnes in 1961 to 4.9 million tonnes in 2016. During the same period, cashew production in Africa increased by more than fourfold, from 400,000 MT to an estimated 1,800,000 MT [40]. Portuguese traders introduced the cashew tree to India and Africa in the 16th century to prevent soil erosion. Despite this actual purpose, the cashew tree is now widely cultivated for its nuts in many places throughout the world, mostly in Asia, Africa, and South America [40].

3.1. Composition and Health Benefits

The fruit (kernel) and the pseudofruit of the cashew are both edible. The cashew kernel, in turn, is the main commercial product of the cashew tree [40]. Cashew kernels are rich in macronutrients, with a high percentage of fat, followed by carbohydrates, protein, and total dietary fiber [34]. Micronutrients like phosphorus, magnesium, potassium, and E and K vitamins are available in abundant quantities [41]. Bioactive compounds such as phenolics and flavonoids are also present [35]. All the values of nutritional composition are mentioned in Table 1.

Many researchers found that practically all portions of the plant and its constituents are used to treat a variety of human disorders, including toothaches, ringworm, coughs, colds, syphilis, stomach problems, fevers, cholera, renal problems, diarrhea, asthma, leprosy, elephantiasis, psoriasis, warts, corns, new wounds, and cuts [42,43,44]. Specifically, cashew nuts can positively act on lowering blood cholesterol levels, controlling diabetes, and reducing the incidence of coronary heart disease [40,45]. The high magnesium content can be advantageous for bone formation and the prevention of high blood pressure [46]. Thus, despite the lower quantities of unsaturated fatty acids than other tree nuts, cashew eating may minimize the risk of cardiovascular disease [41]. On the other hand, the biggest caveat for the abundant use of this food is the incidence of nut allergy mainly in children; however, Ros [47] affirmed that this is uncommon.

3.2. Processing Effect

Roasting and frying are two of the most popular ways to improve the sensory qualities of nuts through heat processing. So much so that various commercial food products incorporate roasted and fried nuts, such as nut bars or snacks. Aiming at knowing possible changes in the nuts resulting from these treatments, Ghazzawi and Al-Ismael [48] studied the effect of roasting and frying on the properties of cashew and other nuts. In general, they concluded that heat-treated nuts (roasted/fried) presented significant negative and positive changes in their characteristics, varying according to the analyzed property. Concerning the antioxidant activity of cashew nuts, they observed that roasted samples presented better

effectiveness when compared to raw nuts, due to the higher values found for phenolic and flavonoid contents. On the other hand, there were no differences recorded in cashew nuts' fatty acid profile when roasted or fried. This is interesting since the literature shows us how healthy nuts consumption can be due to their fatty acid composition. Approximately 62% of nuts energy is coming from fat. Therefore, heat treatments influence (or not) the bioactive constituents of cashew, which are linked to several health benefits.

Recent works [49,50,51,52] have evaluated the effect of processing (including thermal) on the profile of proteins that are considered allergens. Allergenic proteins from cashew nuts are reported as more resistant to technological processes when compared to other nuts. However, some studies showed promising results in this sense. For instance, Cuadrado *et al.* [50] found that high pressure combined with heating processing markedly reduces the cashew nuts' allergenic potential as the pressure and treatment time increases. Venkatachalam *et al.* [53], in turn, observed a slight reduction in Ana o 1 and Ana o 3 values, which are allergen proteins, after roasting cashew nuts; indicating that this simple process would already minimize its allergenic potential.

3.3. Food Application

Cashews can be eaten raw as snacks, roasted and salted nuts, alone or in combination with other nuts, or used in recipes. Foods such as nut bars, bread, bonbon, and chocolate are well known for serving as the basis for the incorporation of this nut. Likewise, they are used in confectionery and pastry items [46]. Finally, cashew nuts can be processed into products such as cashew hydrosoluble extract ("milk"), cashew cheese, or cashew butter.

4. Conclusions

Almond is proclaimed as a healthy food containing high-quality protein and a high level of unsaturated fatty acids, which contributes to the reduction of low-density lipoprotein (LDL) cholesterol, in addition to generating energy and participating in important metabolic pathways. Almond is also rich in phenolic extract, which is useful in preventing or slowing down the processes of various oxidative stress-related diseases. Additionally, studies indicate that the regular consumption of almonds may modulate the intestinal microbiota since this nut stimulates its richness and diversity. On the other hand, the excellent profile of macronutrients and micronutrients also favors microbial growth (in the food, i.e. before ingestion), including pathogenic microorganisms. Thus, with excellent results, several studies were developed to eliminate this risk. In any case, in a domestic context, it is not recommended to soak the almonds for several hours (for example, more than 8 h at temperatures $\geq 18^{\circ}\text{C}$). These precautions taken together make it possible to safely consume this rich food; except for those who have a diagnosed allergy, although there are also works in the literature that aim to reduce the allergenicity of almond proteins. In this sense, it is important to highlight that for

both nuts, a considerable decrease in allergenicity was verified after submitting the samples to high-pressure treatments at high temperatures. Cashew nut is also known as a food that promotes the reduction of LDL cholesterol. Improvement in the cardiovascular system and control of diabetes were either reported. Finally, we believe that the current scenario discussed in the Introduction section is a good opportunity for more research to be done aiming to reduce the allergenicity of almonds and cashew nuts, incorporate them into different foods, reduce the initial microbial load, produce them sustainably, among others. Thus, the consumption of these foods in the world could be consolidated, taking into account that in various regions of the globe, they are expensive foods and therefore not accessible to several populations.

Competing Interest

The authors have no competing interests.

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