

## ALMONDS AS A NUTRITIONAL SUPPLEMENT FOR BONE HEALTH AND OSTEOPOROSIS PREVENTION

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DOI: <https://www.doi.org/10.58257/IJPREMS36278>

### ABSTRACT

Almonds (*Prunus dulcis*) have been recognized for their rich nutritional profile and diverse health benefits. Recent research suggests that almonds can play a significant role in promoting bone health and potentially aiding in the prevention of osteoporosis. Osteoporosis, characterized by decreased bone density and an increased risk of fractures, is a prevalent condition, particularly in aging populations. Almonds are a valuable source of essential nutrients such as magnesium, calcium, phosphorus, and protein, which are critical for maintaining bone integrity. Additionally, almonds are rich in antioxidants like vitamin E, which help reduce oxidative stress, a factor implicated in bone degeneration.

Magnesium in almonds aids in the regulation of calcium transport and bone mineralization, while phosphorus contributes to the formation of the bone matrix. The presence of healthy fats and polyphenols in almonds further supports bone health by reducing inflammation and promoting overall metabolic functions. Regular almond consumption may not only improve bone mineral density but also contribute to better absorption of key minerals essential for skeletal health.

This review explores the bioactive components of almonds, their mechanistic effects on bone physiology, and their potential as a natural supplement for preventing osteoporosis. Given the increasing emphasis on non-pharmacological interventions for bone health, almonds offer a promising dietary strategy for mitigating the risk of osteoporosis, particularly in individuals at high risk of bone diseases. Further clinical research is recommended to establish optimal consumption patterns and fully elucidate the benefits of almonds in long-term bone health.

**Keywords:** Almonds, Bone health, Osteoporosis, Essential nutrients, Antioxidant, Metabolic Function, Bone Physiology.

### 1. INTRODUCTION

Osteoporosis is a progressive bone disease characterized by the weakening of bones, which leads to increased fragility and a higher risk of fractures. It primarily affects the elderly, especially postmenopausal women, but it is increasingly recognized as a health concern for people of all ages due to lifestyle and dietary changes. While calcium and vitamin D have traditionally been the focus of osteoporosis prevention strategies, emerging research highlights the importance of a broader range of nutrients and dietary components in maintaining bone health. One such food, almonds (*Prunus dulcis*), is gaining attention for its potential role as a natural supplement for bone health and osteoporosis prevention.

Almonds are a nutrient-dense food rich in essential vitamins and minerals that support bone health. They provide significant amounts of magnesium, calcium, phosphorus, and protein, all of which are crucial for the formation and maintenance of strong bones. Magnesium, in particular, is involved in the regulation of calcium balance and the activation of vitamin D, both of which are essential for bone mineralization. Phosphorus works synergistically with calcium to build and repair bone tissue, while the protein in almonds contributes to collagen formation, a critical component of the bone matrix.

In addition to these bone-boosting nutrients, almonds contain bioactive compounds such as vitamin E and polyphenols, which possess antioxidant and anti-inflammatory properties. These compounds help to reduce oxidative stress and inflammation, factors known to contribute to bone degradation and the development of osteoporosis. Given the shift towards non-pharmacological approaches to bone health, incorporating almonds into the diet may serve as an effective strategy for reducing the risk of osteoporosis. This introduction aims to explore the potential of almonds as a nutritional supplement for enhancing bone health and preventing osteoporosis, backed by scientific evidence and nutritional insights.

#### Aim of the Study:

The primary aim of this study is to investigate the potential role of almonds (*Prunus dulcis*) as a nutritional supplement in promoting bone health and preventing osteoporosis. Osteoporosis is a prevalent bone disorder characterized by reduced bone density and increased fracture risk, particularly in aging populations. While calcium and vitamin D are commonly emphasized in bone health management, this study aims to explore the broader impact of almonds, which are rich in essential nutrients such as magnesium, phosphorus, calcium, protein, and bioactive compounds like vitamin E and polyphenols.

The study seeks to achieve the following objectives:

1. To analyze the nutrient profile of almonds in the context of bone health, focusing on their magnesium, phosphorus, and calcium content.
2. To evaluate the effects of regular almond consumption on bone mineral density (BMD) and bone strength, particularly in individuals at risk of osteoporosis.
3. To assess the role of almonds in enhancing the absorption and metabolism of key bone-related nutrients.
4. To examine the potential antioxidant and anti-inflammatory effects of almonds in reducing oxidative stress and inflammation, factors that contribute to bone deterioration.
5. To explore optimal consumption levels of almonds for the prevention of osteoporosis.

Through these objectives, the study aims to provide scientific evidence supporting the inclusion of almonds as part of a holistic dietary approach for maintaining bone health and reducing the risk of osteoporosis, particularly in high-risk populations.

## 2. REVIEW OF LITERATURE

The role of almonds in bone health and osteoporosis prevention has been increasingly studied in recent years, particularly in the Indian population. Several studies have explored how almond consumption can positively influence bone mineral density, calcium metabolism, and overall skeletal health. This review synthesizes the findings from multiple studies to understand the impact of almonds as a nutritional supplement for bone health.

A randomized controlled trial by Agarwal et al. (2024) <sup>(1)</sup> demonstrated that almond consumption significantly improved calcium absorption and bone health in young Indian adults. This study provided strong evidence that regular almond intake enhances bone mineral density, particularly by improving the body's ability to retain calcium, a key mineral for maintaining bone strength. Similarly, Patel et al. (2024) <sup>(9)</sup> conducted a trial on postmenopausal women, showing that almond supplementation increased bone density and decreased bone turnover markers, both of which are crucial in preventing osteoporosis.

The effects of almonds on diabetic populations were explored by Chopra et al. (2023) <sup>(2)</sup> who found that almonds not only helped improve glycemic control but also promoted better bone health outcomes. The study emphasized the dual role of almonds as a functional food for managing diabetes and supporting bone density, particularly in individuals at higher risk of bone degeneration.

Gupta et al. (2022) <sup>(3)</sup> focused on adolescents, finding that almond consumption improved nutritional status and bone health in this younger population. This study highlighted the long-term benefits of early nutritional interventions with almonds, particularly in improving calcium and magnesium levels, which are essential for bone development.

Postmenopausal women, who are at high risk of osteoporosis, were the focus of studies by Joshi et al. (2023) <sup>(5)</sup> and Sharma et al. (2023) <sup>(10)</sup> Joshi et al. conducted a cross-sectional study showing that almond intake positively affected bone health markers, while Sharma et al.'s pilot study found that dietary almonds increased bone mineral density in women with osteopenia. Both studies reinforce the value of almonds in combating bone loss during postmenopausal years.

In elderly populations, Kumar et al. (2024) <sup>(6)</sup> and Kaur et al. (2022) <sup>(7)</sup> provided evidence through systematic reviews and longitudinal analyses that almond consumption reduced the risk of osteoporosis. These studies particularly highlighted the role of almonds in managing bone density and metabolic health among elderly individuals. Verma et al. (2022) <sup>(12)</sup> also assessed the impact of almond-based diets on both men and women, concluding that almonds were effective in improving bone density and mineral content in older adults.

Nair et al. (2023) <sup>(8)</sup> further investigated almond consumption among Indian women, conducting a longitudinal study that indicated a significant improvement in bone health biomarkers, such as higher levels of calcium and phosphorus, which are critical for maintaining bone strength. Additionally, Singh et al. (2022) <sup>(11)</sup> provided a comprehensive review that discussed the preventative role of almonds in osteoporosis, summarizing clinical evidence that almonds contribute to better bone health by supporting mineral absorption and reducing bone loss.

Overall, the existing body of literature consistently demonstrates that almonds, due to their rich nutritional profile—high in calcium, magnesium, phosphorus, and vitamin E—play a beneficial role in maintaining and improving bone health. These studies underscore the potential of almonds as a natural, nutritional intervention to prevent and manage osteoporosis, especially in populations at risk, such as postmenopausal women, the elderly, and those with chronic conditions like diabetes. The widespread evidence suggests that regular almond consumption can be a key dietary strategy in promoting skeletal health across different age groups.

## Classification and Morphology of Almonds

Kingdom: Plantae

Phylum: Angiosperms

Order: Rosales

Family: Rosaceae

Genus: Prunus

Species: Prunus dulcis

Varieties: Prunus dulcis var. dulcis (Sweet almond)

Prunus dulcis var. amara (Bitter almond)

The almond plant (*Prunus dulcis*) is a deciduous tree known for its nut-like seeds and characteristic morphology. Below is a detailed description of its morphological features:

<b>Root</b>	Almond trees have a deep, well-developed root system, which enables them to access water from deep soil layers, making them drought-tolerant. The roots are fibrous and help in stabilizing the plant in the soil.
<b>Stem</b>	The almond tree typically grows between 4 to 10 meters in height, with a trunk that becomes thick and gnarled with age. The bark is grayish-brown and becomes increasingly rough and furrowed as the tree matures.
<b>Branching</b>	The almond tree has a wide-spreading canopy with branches that extend outward. The branches are often long, slender, and flexible, giving the tree a somewhat rounded crown.
<b>Leaves</b>	The leaves of the almond tree are simple, alternate, and lanceolate (lance-shaped) with finely serrated margins. They are typically 7–12 cm long and 2.5–3.5 cm wide. The leaves have a glossy green appearance and are deciduous, shedding in autumn.
<b>Buds</b>	Almond trees have mixed buds, meaning they produce both flowers and leaves from the same buds. The buds are small, pointed, and covered with protective scales.
<b>Flower</b>	Almond flowers are showy and bloom in early spring, often before the leaves emerge. The flowers are solitary or in pairs and have five white to pale pink petals. The flowers are about 3-5 cm in diameter and are highly fragrant. Almond flowers are hermaphroditic (containing both male and female reproductive organs), and they rely on cross-pollination, primarily by bees.
<b>Fruit</b>	The almond fruit is a drupe, consisting of an outer green, leathery hull, a hard shell, and the edible seed inside. The hull splits open when the fruit ripens, revealing the inner shell. The seed, commonly referred to as the "almond," is oval, brown, and covered with a thin seed coat. Sweet almonds ( <i>Prunus dulcis</i> var. <i>dulcis</i> ) are commonly consumed, while bitter almonds ( <i>Prunus dulcis</i> var. <i>amara</i> ) contain amygdaline, a compound that can release cyanide.
<b>Seeds</b>	The almond seed is smooth and oval, measuring about 2–3 cm long. It has a brown seed coat, with the edible kernel inside. Almond seeds are rich in oils, proteins, and other essential nutrients, which contribute to their wide usage in human diets.
<b>Flower/Fruiting Timeline</b>	Flowering occurs in late winter to early spring, often before the leaves appear. Fruiting follows, with the almonds maturing by late summer or early autumn.



(Plant)



(Flower)



(Fruit/Seed)

## Bioactive compound found in Almond

Almonds (*Prunus dulcis*) are rich in several bioactive compounds that contribute to their health benefits. These compounds play a crucial role in their antioxidant, anti-inflammatory, and Cardioprotective properties. Below are the bioactive compounds found in almonds:

<b>Phenolic Compounds</b>	<p><b>Flavonoids:</b> Almonds contain flavonoids such as quercetin, kaempferol, and isorhamnetin, which exhibit strong antioxidant properties and help in reducing inflammation.</p> <p><b>Phenolic Acids:</b> Almond skins are particularly rich in phenolic acids like p-coumaric acid and vanillic acid, known for their antioxidant activities.</p>
<b>Vitamin E (<math>\alpha</math>-Tocopherols)</b>	Almonds are an excellent source of vitamin E, especially $\alpha$ -tocopherols, a potent fat-soluble antioxidant. Vitamin E protects cell membranes from oxidative damage and plays a role in skin health, cardiovascular health, and anti-aging processes.
<b>Phytosterol</b>	Phytosterol is a plant compound structurally similar to cholesterol and help lower blood cholesterol levels. Almonds contain beta-sitosterol, stigma sterol, and campesterol, which contribute to their Cardioprotective effects.
<b>Monounsaturated Fatty Acids (MUFA)</b>	Almonds are high in monounsaturated fats, particularly oleic acid. These healthy fats help reduce LDL cholesterol and maintain cardiovascular health.
<b>Dietary Fiber</b>	Almonds are a good source of dietary fiber, which aids in digestion, improves gut health, and contributes to the management of blood sugar levels.
<b>Proteins and Amino Acids</b>	Almonds contain high-quality protein and essential amino acids, particularly arginine, which is important for nitric oxide production and improving vascular health.
<b>Magnesium</b>	Almonds are rich in magnesium, which plays a key role in maintaining normal muscle and nerve function, supporting the immune system, and improving bone health.
<b>Tannins</b>	Almond skins contain tannins, which have antioxidant properties and help in protecting the body from oxidative stress.
<b>Polyphenols</b>	Polyphenols found in almond skins and kernels act as antioxidants, helping to neutralize free radicals and reduce the risk of chronic diseases.

These bioactive compounds collectively contribute to the nutritional and medicinal value of almonds, supporting cardiovascular health, bone strength, and anti-inflammatory functions.

#### Nutrient profile of almond

Almonds (*Prunus dulcis*) are a nutrient-dense food packed with essential vitamins, minerals, healthy fats, and bioactive compounds. Below is a comprehensive nutrient profile for **100 grams of almonds**:

<b>Macronutrients in Grams</b>	<b>(1)Protein</b>	<b>21.15 g</b>
	<b>(2)Total Fat</b>	<b>49.93 g</b>
	<b>(3)Monounsaturated Fat</b>	<b>31.55 g</b>
	<b>(4)Polyunsaturated Fat</b>	<b>12.33 g</b>
	<b>(5)Saturated Fat</b>	<b>3.73 g</b>
	<b>(6)Carbohydrates</b>	<b>21.55g</b>
	<b>(7)Dietary Fiber</b>	<b>12.5 g</b>
	<b>(8)Sugars</b>	<b>4.35 g</b>
	<b>(9)Water</b>	<b>4.41 g</b>
<b>Vitamins in mg</b>	<b>(1)Vitamin E (<math>\alpha</math>-tocopherols)</b>	<b>25.63 mg</b>
	<b>(2)Thiamine (Vitamin B1)</b>	<b>0.211 mg</b>
	<b>(3)Riboflavin (Vitamin B2)</b>	<b>1.014 mg</b>



	(4)Niacin (Vitamin B3)	3.385 mg
	(5)Vitamin B6	0.143 mg
	(6) Pantothenic Acid (Vit. B5)	0.469 mg
	(7)Choline	52.1 mg
Minerals in mg	(1)Calcium:	264 mg
	(2)Magnesium	270 mg
	(3)Phosphorus	484 mg
	(4)Potassium	705 mg
	(5)Iron	3.72 mg
	(6)Zinc	3.12 mg
	(7)Manganese	2.285 mg

#### Optimal consumption levels of almonds for the prevention of osteoporosis.

When considering the role of almonds in osteoporosis prevention, it's essential to focus on how much should be consumed to gain optimal benefits for bone health without exceeding recommended daily calorie or nutrient intakes. Here's an exploration of optimal consumption levels of almonds, based on scientific evidence and nutritional recommendations.

#### Recommended Almond Intake

- Most studies and dietary guidelines suggest consuming **20–30 grams** of almonds per day (approximately 1 ounce or a small handful). This amount provides around:
  - **Magnesium:** 76 mg (~19% of the daily recommended intake)
  - **Phosphorus:** 136 mg (~19% of the daily recommended intake)
  - **Calcium:** 76 mg (~7-8% of the daily recommended intake)
  - **Vitamin E:** 7.3 mg (~49% of the daily recommended intake)

This moderate consumption level helps incorporate essential nutrients needed for bone health while keeping calorie intake in check (about 160-180 kcal for 1 ounce).

#### Magnesium for Bone Health

- The recommended daily intake (RDI) of magnesium for adults is approximately **310–420 mg**, depending on age and gender. A 30-gram serving of almonds provides around 76 mg, covering about **19% of the RDI**. For individuals at risk of osteoporosis, ensuring sufficient magnesium intake is vital for proper calcium utilization and bone mineralization.
- **Optimal Consumption:** Consuming 20–30 grams of almonds daily can significantly contribute to magnesium intake, which is important for maintaining bone density.

#### Phosphorus and Bone Mineralization

- The daily recommended intake of phosphorus for adults is **700 mg**. A 30-gram serving of almonds provides about 136 mg, contributing nearly **19% of the RDI**. Phosphorus works with calcium to strengthen bones, and regular almond consumption can help meet daily phosphorus needs, which is important for maintaining bone structure.
- **Optimal Consumption:** 1 ounce of almonds per day helps maintain phosphorus levels crucial for bone health, especially in individuals with low phosphorus intake from other sources.

#### Calcium Contribution

- The RDI for calcium in adults is **1,000–1,200 mg**. Almonds are not as rich in calcium as dairy products, but a 30-gram serving still provides about 76 mg, which is around **7-8% of the RDI**.
- Although almonds alone cannot meet calcium requirements, they can complement other calcium-rich foods in a balanced diet. Pairing almonds with foods high in calcium, like leafy greens or fortified products, can enhance overall calcium intake.
- **Optimal Consumption:** Almonds can be part of a broader calcium-rich diet, offering complementary calcium along with other bone-supporting nutrients like magnesium and phosphorus.

### Almonds and Energy Balance

- While almonds offer crucial nutrients for bone health, they are also calorie-dense. Excessive almond consumption can lead to an increased calorie intake, potentially leading to weight gain. Given that being overweight can increase stress on bones, leading to bone loss over time, it is essential to balance almond consumption within daily caloric needs.
- **Optimal Consumption:** Stick to 20–30 grams per day to avoid excess caloric intake while reaping the nutritional benefits for bone health.

### Additional Considerations

- **Bioavailability of Nutrients:** The nutrient absorption from almonds may be influenced by factors such as the presence of other foods in the diet. Pairing almonds with sources of vitamin D, such as fortified milk or exposure to sunlight, can further enhance calcium absorption and utilization.
- **Consistency in Consumption:** To benefit from the bone-health-promoting properties of almonds, consistent daily consumption over the long term is more effective than sporadic intake.

### Almonds as Part of a Holistic Approach

- While almonds provide beneficial nutrients for bone health, they should be part of a **balanced diet** that includes a variety of other bone-supporting foods, such as:
  - **Dairy products or fortified plant-based alternatives** (for calcium and vitamin D)
  - **Leafy green vegetables** (for additional calcium)
  - **Legumes and seeds** (for magnesium and phosphorus)
  - **Sunlight or vitamin D supplements** (to aid calcium absorption)

The optimal consumption level of almonds for osteoporosis prevention is about **20–30 grams (1 ounce) per day**. This amount provides a significant contribution to daily magnesium, phosphorus, and calcium intake, all of which are crucial for bone health.

Almonds should be consumed as part of a well-rounded diet that includes other sources of calcium and vitamin D to enhance their bone-protective effects. Regular consumption at these levels can help support bone density and prevent osteoporosis while maintaining a healthy balance of nutrients and calories.

## 3. CONCLUSION

Almonds (*Prunus dulcis*) are a highly nutritious and versatile food that offers numerous health benefits, making them a valuable addition to a balanced diet.

Their impressive nutrient profile includes essential macronutrients, vitamins, and minerals, all of which contribute to their role in supporting overall health and well-being.

The high content of monounsaturated fats and dietary fiber in almonds plays a crucial role in cardiovascular health by helping to reduce LDL cholesterol levels and supporting healthy digestion. The significant amount of vitamin E, a potent antioxidant, helps protect cells from oxidative damage, thereby supporting skin health and reducing the risk of chronic diseases such as cardiovascular disorders.

Moreover, almonds are particularly rich in magnesium, phosphorus, and calcium, which are vital for bone health. Magnesium and phosphorus contribute to bone mineralization and density, while calcium supports the formation and maintenance of bone structure.

Regular consumption of almonds can help prevent osteoporosis and promote overall skeletal strength, especially when combined with other bone-supporting nutrients in the diet.

Almonds also provide essential vitamins such as B vitamins and folate, which support energy metabolism and neurological function. The presence of bioactive compounds, including Phytosterols, polyphenols, and antioxidants, further enhances their health benefits by reducing inflammation and oxidative stress.

Incorporating almonds into a daily diet, typically in amounts of 20–30 grams per day, offers a balanced way to gain these nutritional benefits without excessive caloric intake.

This moderate consumption aligns with dietary guidelines and helps achieve the optimal intake of key nutrients for maintaining bone health, cardiovascular wellness, and overall vitality.

In summary, almonds are not only a delicious and convenient snack but also a nutrient-dense food that supports various aspects of health. Their role in preventing osteoporosis, enhancing cardiovascular health, and contributing to general well-being makes them a valuable component of a nutritious diet.

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