World Journal of Research in All Subject
www.multiworldjournal.com
Online ISSN: 3107-8664
Received: 04-07-2026, Accepted: 04-08-2026, Published: 19-08-2026
Volume 2, Issue 3, 2026, Page No. 29-33

Edamame (*Glycine max*): Nutritional composition, consumption forms and contribution to recommended dietary allowances—A review

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Abstract
Edamame, the immature green seed of soybean (*Glycine max*), has emerged as an important plant-based food because of its high-quality protein, dietary fiber, unsaturated fatty acids, vitamins, minerals and bioactive phytochemicals. Unlike mature soybean, which is predominantly processed into tofu, soy milk, oil and protein ingredients, edamame is generally consumed as a vegetable, snack or minimally processed whole food. This review summarizes the nutritional composition of edamame, its major consumption forms, processing considerations and contribution to recommended dietary allowances (RDA), with particular reference to Indian dietary requirements. Based on USDA nutrient composition data, 100 g of cooked green soybean provides approximately 141 kcal, 12.4 g protein, 6.4 g fat, 11.0 g carbohydrate and 4.2 g dietary fiber. It also supplies calcium, iron, magnesium, phosphorus, potassium, zinc, folate, vitamin C and B-group vitamins. When compared with the ICMR–NIN 2020 recommendations, 100 g cooked edamame provides approximately 27% of the protein RDA, 17% of the dietary-fiber recommendation, 16% of magnesium, 9% of iron, 7% of zinc, 15% of calcium and 26% of vitamin C requirements for a sedentary adult Indian woman. Edamame is consumed fresh, boiled, steamed, frozen, shelled, roasted and dried and can be incorporated into salads, soups, bakery products, protein-rich snacks, spreads and extruded foods. Processing influences nutrient and phytochemical retention; in particular, boiling, freezing and freeze-drying can alter isoflavone and carotenoid concentrations. The nutritional density and versatility of edamame support its potential as a whole-food source of plant protein and micronutrients and as a raw material for value-added food products. Further research is required on cultivar-specific nutrient composition, bioavailability, optimized processing, consumer acceptance and development of edamame-based foods suited to Indian dietary patterns.

Keywords: Edamame, immature soybean, *Glycine max*, plant protein, dietary fiber, nutritional composition, RDA, ICMR–NIN, food processing, functional food

Introduction

The increasing demand for nutritious, sustainable and plant-based foods has stimulated Soybean (*Glycine max*) is particularly important because of its high protein content, favorable amino-acid composition and versatility as a food ingredient. Edamame refers to soybean harvested at the immature green stage, when the seeds are fully developed but remain tender and green. It is consumed differently from mature soybean and is commonly treated as a vegetable or snack.

Edamame has traditionally been consumed in East Asian countries, particularly Japan and China, and has gained popularity in other regions through the expansion of frozen-food markets, plant-based diets and interest in high-protein snacks. Its nutritional profile is distinctive because it combines the protein density of a legume with the culinary characteristics of a vegetable.

The nutritional value of edamame is attributable to its protein, dietary fiber, unsaturated fatty acids, minerals, vitamins and soybean-specific phytochemicals such as isoflavones. The immature seed also contains carotenoids and phytosterols. Nutrient concentrations vary according to genotype, maturity, agronomic conditions and processing. Studies have demonstrated substantial genotype-related variation in isoflavones and carotenoids in immature soybean.

For India, assessment of the nutritional contribution of edamame against the recommended dietary allowances established by the Indian Council of Medical Research–National Institute of Nutrition (ICMR–NIN) is particularly relevant. The ICMR–NIN 2020 recommendations provide nutrient requirements for different population groups and are used as a reference for dietary planning and nutritional assessment in India.

The present review therefore focuses on three major aspects of edamame: nutritional composition, consumption and processing forms, and contribution to recommended nutrient intakes.

Edamame: Botanical and Food Characteristics

Edamame is the immature seed of *Glycine max* (L.) Merr. and is harvested before the soybean reaches physiological maturity. The crop is generally harvested when the pods and seeds are green, tender and physiologically suitable for vegetable consumption.

Edamame cultivars are generally selected for:

- large seed size;
- attractive green color;
- tender texture;
- desirable sweetness and flavor;
- low beany flavor;
- high seed yield; and
- favorable nutritional characteristics.

The immature seeds contain considerably more moisture than mature dry soybean. Consequently, fresh edamame is highly perishable and requires appropriate post-harvest handling, refrigeration or preservation.

Unlike mature soybean, edamame can be consumed after relatively simple cooking. This characteristic provides opportunities for its use as a whole food as well as a raw material for food-product development.

Nutritional Composition of Edamame

Nutritional composition varies with cultivar, maturity, growing environment and processing. For comparative purposes, cooked green soybean is used in this review because cooking is the most common preparation method. USDA-derived composition data for cooked green soybean indicate approximately 141 kcal, 12.4 g protein, 6.4 g fat, 11.0 g carbohydrate and 4.2 g dietary fiber per 100 g edible portion.

Table 1: Nutritional composition of cooked edamame per 100 g edible portion

Nutrient	Amount/100 g
Energy	141 kcal
Protein	12.4 g
Total fat	6.4 g
Saturated fat	0.74 g
Carbohydrate	11.0 g
Dietary fiber	4.2 g
Calcium	145 mg
Iron	2.5 mg
Magnesium	60 mg
Phosphorus	158 mg
Potassium	539 mg
Zinc	0.91 mg
Vitamin C	17 mg
Folate	111 µg
Thiamin	0.26 mg
Riboflavin	0.155 mg
Niacin	1.25 mg
Vitamin B6	0.06 mg

Source: USDA-derived nutrient composition data for cooked green soybean, boiled and drained without salt. Values may vary among cultivars and processing conditions

1. Protein

Protein is one of the principal nutritional attributes of edamame. Approximately 12.4 g protein is supplied by 100 g cooked edible seed. Soybean protein contains all essential amino acids and is generally regarded as a high-quality plant protein.

The amino-acid profile of cooked green soybean includes appreciable amounts of leucine, lysine, isoleucine and other essential amino acids.

This makes edamame particularly relevant to vegetarian and plant-based diets. However, dietary adequacy should be evaluated at the level of the total diet rather than on the basis of a single food.

2. Dietary Fiber

Approximately 4.2 g dietary fiber is present in 100 g cooked edamame. Dietary fiber contributes to normal gastrointestinal function and is an important component of a healthy dietary pattern. The combination of protein and fiber also makes edamame suitable for development of nutrient-dense snack foods.

3. Lipids

Edamame contains approximately 6.4 g total fat per 100 g, of which approximately 0.74 g is saturated fat, 1.21 g is monounsaturated fatty acids and 3.01 g is polyunsaturated fatty acids. Linoleic acid and α-linolenic acid are among the polyunsaturated fatty acids present in soybean. Thus, edamame provides a lipid profile dominated by unsaturated rather than saturated fatty acids.

4. Minerals

Edamame provides several nutritionally important minerals. Per 100 g cooked portion, approximately 145 mg calcium, 2.5 mg iron, 60 mg magnesium, 158 mg phosphorus, 539 mg potassium and 0.91 mg zinc are reported. The mineral contribution is particularly relevant because plant-based diets may require careful selection of foods to ensure adequate intake of iron, zinc, calcium and magnesium.

Nevertheless, nutrient concentration does not necessarily represent bioavailability. Phytate and other components of legumes may influence the absorption of minerals, and therefore bioavailability should be considered when assessing nutritional adequacy.

5. Vitamins

Edamame contains folate, vitamin C and several B-group vitamins. Approximately 111 µg folate, 17 mg vitamin C, 0.26 mg thiamin, 0.155 mg riboflavin and 1.25 mg niacin are present per 100 g cooked portion. The presence of vitamin C is notable because many mature soybean products contain substantially different vitamin profiles following processing.

Bioactive Components

1. Isoflavones

Soybean is particularly recognized for its isoflavone content. Major soybean isoflavones include genistein, daidzein and glycitein and their respective conjugated forms.

Edamame isoflavone concentration varies substantially with genotype and maturity. Simonne et al. reported total isoflavone concentrations ranging from 472 to 2280 µg/g among immature soybean genotypes. Processing also affected isoflavone retention.

Isoflavones have attracted considerable research interest because of their estrogen-receptor activity and potential biological effects. However, the presence of these compounds should not be interpreted as evidence that edamame functions as a therapeutic agent.

2. Carotenoids

Lutein and β-carotene are among the carotenoids identified in immature soybean. Simonne et al. reported substantial variation among genotypes and demonstrated that processing affected carotenoid retention. Carotenoids contribute to the characteristic green/yellow coloration and increase the functional-food interest of edamame.

3. Phytosterols

Phytosterols are also present in soybean. USDA-derived data report approximately 50 mg phytosterols per 100 g cooked green soybean. These compounds are of nutritional interest because of their interaction with intestinal cholesterol absorption, although the physiological significance of the amount obtained from ordinary edamame consumption depends on the overall diet.

Contribution of Edamame to Indian Recommended Dietary Allowances

The ICMR–NIN 2020 recommendations specify nutrient requirements according to age, sex, body weight and activity level. For a sedentary adult woman with a reference body weight of 55 kg, the recommendations include 46 g protein, 25 g dietary fiber, 1000 mg calcium, 370 mg magnesium, 29 mg iron, 13.2 mg zinc, 220 µg folate and 65 mg vitamin C per day.

For a sedentary adult man with a reference body weight of 65 kg, the corresponding values include 54 g protein, 40 g dietary fiber, 1000 mg calcium, 440 mg magnesium, 19 mg iron, 17 mg zinc, 300 µg folate and 80 mg vitamin C.

Table 2: Contribution of 100 g cooked edamame to ICMR–NIN 2020 RDA

Nutrient	Edamame/100 g	RDA: Adult woman, sedentary	Contribution (%)	RDA: Adult man, sedentary	Contribution (%)
Protein	12.4 g	46 g	27.0	54 g	23.0
Dietary fiber	4.2 g	25 g	16.8	40 g	10.5
Calcium	145 mg	1000 mg	14.5	1000 mg	14.5
Magnesium	60 mg	370 mg	16.2	440 mg	13.6
Iron	2.5 mg	29 mg	8.6	19 mg	13.2
Zinc	0.91 mg	13.2 mg	6.9	17 mg	5.4
Folate	111 µg	220 µg	50.5	300 µg	37.0
Vitamin C	17 mg	65 mg	26.2	80 mg	21.3
Thiamin	0.26 mg	1.4 mg	18.6	1.8 mg	14.4
Riboflavin	0.155 mg	1.9 mg	8.2	2.5 mg	6.2
Niacin	1.25 mg	11 mg	11.4	18 mg	6.9
Vitamin B6	0.06 mg	1.9 mg	3.2	2.4 mg	2.5

*Edamame composition: USDA-derived data for cooked green soybean. RDA values: ICMR–NIN 2020. Percentages calculated from the values above. *

The comparison demonstrates that edamame is particularly relevant as a source of protein, folate, vitamin C, magnesium and dietary fiber. A 100 g portion supplies approximately 27% of the protein requirement of a sedentary adult Indian woman and approximately 23% for a sedentary adult man. The contribution to folate is also substantial, with approximately half of the adult female RDA and more than one-third of the adult male RDA supplied by 100 g.

It is important to emphasize that these calculations represent nutrient contribution and not nutritional adequacy. A balanced diet containing diverse cereals, pulses, vegetables, fruits, nuts, seeds and other foods remains necessary to meet total nutrient requirements.

Consumption Forms of Edamame

Edamame can be consumed in several forms, ranging from minimally processed preparations to value-added food ingredients.

1. Fresh edamame

Fresh pods are generally cooked soon after harvest. The high moisture content provides desirable tenderness but also results in high perishability.

2. Boiled edamame

Boiling is a traditional and widely used preparation method. Pods or shelled seeds are cooked in water and may be consumed with salt or other seasonings.

3. Steamed edamame

Steaming provides a convenient alternative to boiling and minimizes direct contact between the edible portion and cooking water. It is commonly used for snack and appetizer preparation.

4. Frozen edamame

Frozen edamame is commercially important because freezing extends shelf life and allows year-round availability. It is marketed both as whole pods and shelled beans.

5. Shelled edamame

Shelled edamame is convenient for incorporation into:

- Salads;
- Soups;
- Rice and grain dishes;
- Noodles;
- Pasta;
- Stir-fries;
- Wraps; and
- Mixed vegetable preparations.

6. Roasted and dried edamame

Roasting and drying produce shelf-stable, crunchy products suitable for snacking. These forms have potential as alternatives to conventional high-energy snack products, although added salt, oil and flavoring ingredients must be considered during nutritional evaluation.

7. Edamame flour and powder

Dehydrated edamame can be milled into flour or powder and incorporated into bakery foods, protein bars, extruded snacks and instant food formulations.

Processing and Nutritional Retention

Processing is a major determinant of the nutritional quality of edamame. Simonne et al. investigated the effect of boiling, freezing and freeze-drying on isoflavone and carotenoid retention in immature soybean. Mean total isoflavone retention in immature Hutcheson soybean was approximately 46% following boiling, 53% following freezing and 40% following freeze-drying. Lutein and β-carotene showed different retention patterns depending on processing method.

These findings demonstrate that processing should not be considered nutritionally neutral.

1. **Boiling**

Boiling can improve texture and reduce heat-sensitive antinutritional factors, but water-soluble nutrients and phytochemicals may be lost through leaching.

2. **Steaming**

Steaming may reduce leaching because the food is not immersed in cooking water. It may therefore be advantageous for retaining some water-soluble components.

3. **Freezing**

Freezing is effective for maintaining the quality of edamame during storage. Blanching before freezing is generally used to control enzymatic deterioration.

4. **Drying**

Drying substantially reduces moisture and improves shelf stability. However, drying conditions can influence color, texture, vitamins and phytochemicals.

5. **Roasting**

Roasting improves texture and flavor but may induce changes in proteins, lipids and thermolabile compounds. Excessive temperatures may also promote lipid oxidation.

6. **Extrusion**

Extrusion provides an opportunity to convert edamame into ready-to-eat, high-protein products. Optimization of temperature, moisture, screw speed and residence time is necessary to achieve desirable expansion, texture, digestibility and nutrient retention.

Edamame as a Raw Material for Value-Added Foods

The nutritional profile of edamame makes it attractive for food-product development.

1. **High-protein snacks**

Roasted, baked and extruded edamame can be developed as protein-rich snack products.

2. **Bakery products**

Edamame flour can be incorporated into biscuits, crackers, breads and muffins to increase protein and fiber content. However, increasing legume flour may alter color, flavor, texture and consumer acceptability.

3. **Protein bars**

Edamame powder can be combined with cereals, nuts, seeds and fruit ingredients to develop nutrient-dense snack bars.

4. **Extruded products**

Edamame can be combined with cereals such as rice, maize, wheat or millets for development of protein-enriched extruded snacks. Such cereal–legume combinations may improve overall nutritional quality and product diversity.

5. **Plant-based foods**

Soy proteins have established technological applications because of their water-binding, emulsification and texturization properties. Edamame-based ingredients could therefore be investigated for plant-based meat analogues and other protein-rich foods.

6. **Spreads and dips**

Cooked shelled edamame can be blended into hummus-like spreads and dips, providing an alternative application for whole immature soybean.

Nutritional and Functional Significance

The nutritional value of edamame should primarily be considered in terms of its contribution to dietary nutrient density.

Its most significant characteristics include:

1. **High-quality plant protein:** Approximately 12.4 g/100 g cooked portion.
2. **Dietary fiber:** Approximately 4.2 g/100 g.
3. **Unsaturated fatty acids:** The majority of its lipid fraction consists of unsaturated fatty acids.
4. **Micronutrient contribution:** Particularly folate, magnesium, calcium, iron, potassium and vitamin C.
5. **Bioactive compounds:** Isoflavones, carotenoids and phytosterols.
6. **Food versatility:** Suitable for fresh, frozen, dried and processed applications.

Rather than attributing specific disease-preventive effects to edamame, it is more appropriate to consider these characteristics within the context of a balanced dietary pattern.

Safety and Nutritional Limitations

Despite its nutritional advantages, several factors require consideration.

1. **Soy allergy**

Soybean is a recognized food allergen. Individuals with soy allergy should avoid edamame and foods containing soybean ingredients.

2. **Antinutritional factors**

Soybeans contain trypsin inhibitors, phytate and other compounds that can affect nutrient utilization. Appropriate heat processing reduces the activity of several heat-sensitive antinutritional factors.

3. **Bioavailability**

The presence of a nutrient in food does not necessarily indicate complete absorption. In particular, phytate can affect mineral bioavailability. Therefore, RDA contribution calculations should not be interpreted as equivalent to absorbed nutrient quantities.

4. **Product formulation**

Plain boiled or steamed edamame should be distinguished from highly processed commercial products. Salt, oil, sugar and flavoring ingredients may substantially modify the nutritional profile.

5. **Perishability**

Fresh edamame has a relatively short shelf life because of its high moisture content. Appropriate refrigeration, blanching and freezing technologies are therefore important for commercial utilization.

Conclusion

Edamame represents a nutritionally valuable form of soybean with considerable potential for incorporation into contemporary diets and development of value-added foods. Its nutritional significance arises from the combination of high-quality plant protein, dietary fiber, unsaturated fatty acids, vitamins, minerals and bioactive phytochemicals.

Based on USDA-derived composition data, 100 g cooked edamame provides approximately 12.4 g protein, 4.2 g dietary fiber, 145 mg calcium, 2.5 mg iron, 60 mg magnesium, 539 mg potassium, 111 µg folate and 17 mg vitamin C. When these values are compared with ICMR–NIN 2020 recommendations, the same portion supplies approximately 27% of the protein RDA, 17% of the fiber recommendation, 16% of magnesium, 9% of iron, 7% of zinc, 15% of calcium and 26% of vitamin C requirements of a sedentary adult Indian woman.

Edamame can be consumed fresh, boiled, steamed, frozen, shelled, roasted or dried and can serve as a raw material for protein-rich snacks, bakery foods, extruded products, spreads and other plant-based foods. Processing conditions have an important influence on nutrient and phytochemical retention and should therefore be optimized according to the intended product. Overall, edamame should be regarded as a nutrient-dense whole food and versatile plant-protein ingredient rather than a single-food solution for meeting dietary requirements. Further research on Indian cultivars, nutrient bioavailability, processing optimization, product development and consumer acceptance could facilitate wider utilization of edamame in India and other emerging plant-based food markets.

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