

Production and Productivity of Vegetable Soybean

Subjects: **Agronomy**

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Vegetable soybean, popularly known as *edamame* in Japan and *mao dou* in China is a specialty soybean. Green pods with physiologically mature beans are harvested, and whole pods or shelled beans are used as a fresh or frozen vegetable. Vegetable soybeans are prepared in diverse ways, and they are highly nutritious, with excellent taste properties.

edamame

vegetable soybean

nutritional quality

1. Introduction

Vegetable soybean (*Glycine max* (L.) Merrill) is a highly nutritious leguminous vegetable crop rich in protein (13% at R6 stage), iron, and calcium ^[1], nutrients that are an essential part of the human diet to combat chronic malnutrition in the world. Vegetable soybeans are also known as ‘*edamame*’ (Japanese), ‘*mao dou*’ (Chinese), ‘*Poot kong*’ (Korean), beer beans, sweet beans, and green soybeans (in other parts of the world). Large seed size (>60–75 g/100 seeds fresh weight), sweeter in taste, and without beany flavor are the major traits of vegetable soybeans which distinguish them from grain soybeans. Pods harvested at the R6 growth stage (when the pods are still green, and the beans in the pods are 80% mature) can be sold in markets as fresh, frozen, and canned products ^[2] (**Figure 1**). Green beans can be served within pods as a snack or appetizer after boiling in salt water, or the shelled green beans can be sautéed with meats or other vegetables and used in soups, curries, and salads. Vegetable soybeans can be used instead of garden peas (*Pisum sativum*) ^[3] or lima beans (*Phaseolus lunatus*) in any recipe ^[4]. With its low input requirement, short duration (65–75 days to harvest), and soil nitrogen fixing ability, vegetable soybeans fit in a wide range of cropping systems ^[5]. After stripping the pods, green plant stalks with leaves can be fed to livestock ^[6] or incorporated into soil as green manure to enrich soil health ^[7].

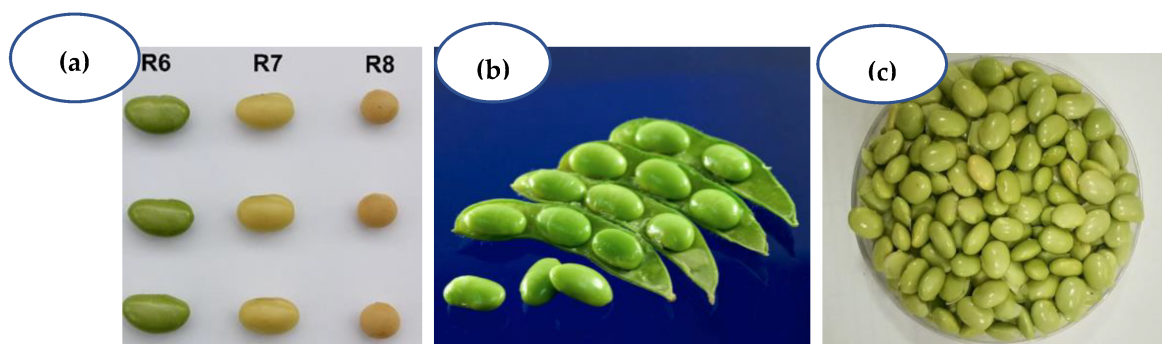


Figure 1. (a) Vegetable soybeans at the R6, R7, and R8 stages; (b) pods harvested at the ideal stage (R6); (c) beans in R6 ready for consumption.

While vegetable soybeans are not yet well known by people in Europe, Africa, and South and West Asia, it is popularly produced and consumed by East and Southeast Asian people and plays an important role in diets and agriculture in those regions. However, due to its high nutritional value and excellent taste properties, interest in the cultivation of this crop has increased significantly in several countries outside East and Southeast Asia during the last decade. Since vegetable soybeans can be produced in a short period of time, nearly all the parts of vegetable soybeans are utilizable, and the ability of the vegetable soybeans in association with *Rhizobia* to fix atmospheric nitrogen to the soil, this legume crop fits well with several cropping systems and can improve sustainability in agriculture. For example, in Thailand, farmers generally grow vegetable soybeans as a cash crop after major crops such as rice and maize, and after harvesting the pods, the plant parts are used to produce compost and to feed dairy animals. Although the production, uses, and export of vegetable soybeans in major producing countries appear to be promising, there are still several constraints and limitations in the production of this crop. For example, (i) most of the varieties grown for export to the major imported country, Japan, are closely genetically related and are susceptible to insects and diseases, resulting in extensive use of pesticides in production, (ii) the lack of germplasm limits developing varieties adapted to different regions or possessing eating qualities for domestic/local preferences, and (iii) the production of vegetable soybeans requires a high amount of water, limiting the expansion of the production to certain areas.

2. Nutritional Considerations

Vegetable soybeans are an excellent source of digestible proteins (13% in the R6 stage; **Figure 1**), carbohydrates (20–30%) lipids (19%), essential fatty acids, phosphorous, iron, calcium, zinc, thiamine, riboflavin, vitamin E (tocopherol), dietary fiber (16%), and sugar [8][9][10][11]. Both cysteine and methionine content in protein is slightly lower in vegetable soybeans than grain soybeans. Trypsin inhibitor activity is lower in vegetable soybeans than their grain counterpart. The major sugar content in beans is in the form of sucrose (74%), fructose (3%), and glucose (3%) [12]. Sucrose contributes 72% of total soluble sugars (6 g to 12 g/100 g on fresh weight basis) at the edible stage of vegetable soybeans [11][13][14]. A significant positive correlation has been reported between the eating quality score and sucrose content in 30 vegetable soybean varieties grown in China [15]. In general, vegetable soybeans are sweeter in taste at the R6 stage compared to grain soybeans which have an oily taste. Genetic differences in sucrose content have been observed among vegetable soybeans. Vegetable soybean lines AGS406 and AGS447 were found to be sweeter than the grain soybean variety (JS-335) in organoleptic tests conducted in Dharwad, India [16]. High levels of essential amino acids (glutamic acid, alanine, histidine, and asparagine) in the beans were also reported by Maruthi et al. [17] and Guo et al. [18], and these amino acids also play a vital role in flavor and sweetness of vegetable soybeans. Vegetable soybeans contain natural isoflavones (48.95 mg/100 g), which can lower the risk of cancer [19], cardiovascular diseases, and osteoporosis [20]. The isoflavones in vegetable soybeans are in the form of glycosides: genistin (β -glucosides), daidzin (acetyl- β -glucosides), glycitin (malonyl- β -glucosides) [21], and aglucones [9]. Poultry feed enriched with vegetable soybean

isoflavones (3 g/kg of feed) has enhanced the carcass quality of broiler chickens by reducing the fat percentage and level of cholesterol [22]. In addition, unmarketable pods and beans from the processing industry have been fermented to make vegetable soybean chips for use as poultry feed. Fermented vegetable soybean meal enhances immunity in black-boned chickens [23] and also improves muscle weight [24]. Fermented soymilk from vegetable soybeans was reported to be a good food matrix to deliver probiotic bacteria, as well as a soy product with a lower content of non-digestible oligosaccharides [25]. Fermentation reduces the contents of stachyose and raffinose in soymilk. The soy components that have stimulated the most research interest are isoflavones with estrogenic properties [26]. The low content of bioactive compounds in second generation soy foods and moderate amounts in traditional soy preparations offer modest health benefits with very limited risk for potential adverse health effects [27].

3. Global Area, Production, and Productivity

Awareness about the health and nutritional benefits of vegetable soybeans and demand from both domestic and international markets have caused an increase in acreage of the crop in countries in Asia (28–40% in the last fifteen years), the Americas, Europe [28], and sub-Saharan Africa [29]. Currently, the leading vegetable soybean producers are China, Japan, and Taiwan (**Table 1**), while the major consumers are China, Japan, Korea, the USA, Taiwan, Thailand, and Europe. China is the leading producer with 90% of the total area (about 400,000 ha) and production (2,000,000 tons per year) [7], followed by Japan (13,000 ha; 66,100 tons) and Taiwan (9180 ha; 84,490 tons) [28][30][31]. Zhejiang, Fujian Anhui, Shanxi, and Jiangsu provinces in the coastal area of Eastern China are major vegetable soybean producing and processing areas [28]. In Japan, major production regions include Hokkaido, Akita, Yamagata, Gunma, and Chiba, with about 1200–1570 ha planted in each region in 2019 [32]. In Thailand, total planting area is about 4000 ha with total yield of 25,000 t [33]. The major production areas for export are in the northern region include Chiang Rai, Chiang Mai, Payao, and Uthai Thani, while the main production areas for domestic use are in the lower central regions, including Kanchanaburi, Lopburi, Saraburi, Sing Buri, Ang Thong, and Ayutthaya. The production of vegetable soybeans is year-round, but the production for export can be made from two crops. In Indonesia, vegetable soybeans are produced primarily in Jember in East Java. Over a period of 20 years, the total harvested area of vegetable soybeans has increased from 30.5 ha (1994–1998) to 1417 ha (2017) in Indonesia due to its demand for export [34]. In the USA, vegetable soybeans have been grown commercially and processed in Arkansas, where a dedicated processing plant was built to process vegetable soybeans [35][36]. Other growers in the USA are SunRich in Minnesota and Cascadian Farms in Washington State [37]. Vegetable soybeans have become the second largest soyfood consumed in the USA at 25,000 to 30,000 t annually [38]. Canada continues to export food grade soybeans, including vegetable soybeans to the Asian market (<https://soycanada.ca/industry/industry-overview/> (accessed on 1 February 2022)). A study conducted in Latvia and Norway [39] showed the potential for successful cultivation of vegetable soybeans at higher latitudes, such as the Nordic–Baltic region in North Europe, with yield levels comparable to other regions of the world.

Table 1. Vegetable soybean area and production in selected countries (Updated from [1]).

Country	Area (ha)	Productions (t)	Year	References
China	400,000	2,000,000	2016	[7]
Japan	13,000	66,100	2019	[32]
Taiwan	9180	84,490	2018	[31]
Thailand	4000	25,000	2022	[33]
Indonesia	1417	11,202	2017	[34]

Japan is the largest vegetable soybean importer in the world and the demand was about 135,000 t during 2020 [32]. Taiwan, China, Thailand, and Indonesia are the four major vegetable soybean exporters to the Japan market that imported about 77,600 and 71,100 tons with a value of USD 161.0 and 199.2 million in 2019 and 2020, respectively [32]. The decline in imports in 2020 was possibly due to the outbreak of the COVID-19 pandemic. In fact, compared to 1987, current production in Japan is only slightly changed, while the imports increased nearly twofold. In Thailand, about 70% of vegetable soybeans are exported to Japan as frozen pods and frozen shelled beans. However, domestic consumption increased in recent years due to consumer perception of the health benefits of vegetable soybeans. Vegetable soybeans sold in markets across the USA are mainly imported from Canada, China, Guatemala, and Taiwan and are mostly marketed frozen either with or without the shell. At least 70% of the green vegetable soybeans consumed in the USA are imported, mainly from China and Taiwan. Increased demand has resulted in a steady increase in land acreage under vegetable soybeans in the USA [40][41]. An analysis of Indonesia's export market showed that the Japanese market was too competitive [33]. Indications of near saturation of the Japanese market meant that Indonesia needs to explore other countries, such as the US and Europe, where there is more demand. The need for improving the quality and the quantity of vegetable soybeans produced in Indonesia were highlighted for sustainable growth. In an analysis of the vegetable soybean supply chain in Indonesia, Marimin et al. [42] identified failures to comply with the order quantity and time delivery schedule as major factors that decrease the farmers' group efficiency.

In Thailand, while grain soybean production has hugely declined over the past 10 years, vegetable soybean production has increased. Although most of the production is for export, domestic consumption has increased significantly. The successful production for export in Thailand is due to a fair and strong contract farming system between companies and farmers. Vegetable soybeans were promoted for domestic consumption and production around the mid-1980s using local grain varieties. Then, vegetable soybean germplasm (mostly Japanese varieties) from WorldVeg was introduced and reselected for both domestic consumption and export. Such varieties are

KPS292 (AGS292), No. 75 (Ryokkho 75) and No. 2808. At present, the most popular variety used for production and export is 75A introduced from Taiwan. The variety can be grown year-round with the exception of March and April. A special variety, Chiang Mai 84-2, possessing a pleasant aroma (pandan-like aroma), high yield, and acceptable eating quality has been developed for export for a niche market in Japan [43]. A cultivar with unknown origin, Tharn Kasem, is popularly grown for domestic consumption for consumers who prefer intact pods (no splitting) after boiling, golden yellow pods, and crunchy seeds [44]. In addition, Thai consumers conventionally prefer vegetable soybeans with a creamy and beany taste/aroma. However, another trait that is mainly focused on selection by farmers is seed germination/storability. In general, soybean cultivars with large seeds/pods showed field emergence and short-period storability. Thus, the cultivars developed/selected by the farmers are medium seed/pod size.

The production of vegetable soybeans in other regions is still small, even in countries with significant production of grain soybeans such as Brazil and Argentina. Brazil currently is the largest producer of grain soybeans in the world [45], but cultivation and consumption of vegetable soybeans is not common. An evaluation study in Brazil found that JLM010 was the most recommended genotype for the region of Jaboticabal, owing to its better agronomic performance, producing 136.04 g of fresh weight of pods per plant, 92.52 g of fresh weight/100 seeds, and 11.12 t/ha of total immature seeds, with better functional properties. Although the consumption of vegetable soybeans is still small in these countries, since other soybean foods, such as soy sauce, tofu, soybean texturized protein, among others are well-known, accepted, and widely used, there is a great potential for vegetable soybeans.

Gradual progress has been made on vegetable soybean development in Africa. In 2020, two varieties (Chitedze vegetable soybean 1 and Chitedze vegetable soybean 2) were released in Malawi. In South Africa, since the crop was only introduced in 2009, the cropped area is still small [46]. There are plans to increase production and consumption through initiatives of the Edamame Development Programme and Fair Food Company.

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