Edamame: research, processing technology and functional food role

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Abstract. Edamame is a vegetable soybean that refers to soybean varieties having pods and seeds that can be harvested and consumed when they are still fresh and premature. The review paper documents the existing information on edamame and processing technology also analyzing the potentials of functional food. Edamame processing technologies have been widely used, including cold processing, heat processing, and structural modification. Various analytical data from various literature shows that edamame has potential as a functional food. The role of dietary fiber, antioxidants, and other physicochemical properties has shown beneficial health benefits Consumption of edamame with various processing methods has been shown to contribute to lowering cholesterol and blood glucose levels. The promotion of edamame requires numerous research activities, starting with the evaluation of food product development, determining consumer preferences, and determining functional properties.

1 Introduction

Edamame (Glycine max (L) Merr) is a legume plant highly favored by the public due to its high vegetable protein content. Edamame is also known as a green soybean vegetable because it is classified as a vegetable. Vegetable soybean is harvested at full-seed development stage with a larger, sweet, nutty, and mild flavour seed (Zhang et al., 2015).

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Edamame is highly demanded by the public, making it one of the most strategic commodities for consumption. This is because edamame provides a rich source of nutrients. Edamame can be an alternative to soybeans, which have a high national consumption rate. This is due to low and fluctuating soybean production (Lala & Fauzi, 2023).

The vegetable soybean is categorized as either large-seeded (3300–5500 seeds per kilogram) which is used for manufacturing soy food products. The vegetable soybean is superior to the grain soybean in flavor and texture, requires shorter cooking time, and is more tender. Other names for the vegetable soybean include beer bean, edible soybean, fresh green soybean, garden soybean, green soybean, green-mature soybean, green vegetable soybean, immature soybean, large-seeded soybean, and vegetable-type Soybean.

Edamame is rich in many nutrients, including dietary fiber (DF), protein, vitamin C and E, minerals (iron, calcium, zinc (islam, et al, 2019). Edamame is an important protein source for children and elderly people (Church et al., 2020),. It has 9 amino acids that cannot be synthesized in the human body. body (Kudełka et al., 2021). While edamame is an excellent source of plant-based protein, it is also a complete protein, containing all the essential amino acids and higher isoflavones as well as sucrose in the human diet (Velasquez and Bhathena, 2007)

The growing popularity of edamame as a healthy snack food has led to increased interest in edamame production from soybean producers, and begun to expand in recent decades due to increased awareness of nutritional properties, and the change in life styles towards healthier food as well, which created a market boom across many countries (Soyfoods, 2014)

This paper summarised the merits of food processing and the functional food of edamame, discussed the development of new products based on edamame related research, with an aim to fully exploit this profitable of edamame processing technology and the effect physiology for researchers, and food processors.

2 Materials and Methods

This review used keywords such as “origin and history of edamame”, “vegetable soybean production”,“conservation and consumption history of edamame”, “Vegetable soybean: characterization and evaluation”, “genetic diversity of vegetable soybean”, “physical, chemical and nutritional characteristics of vegetable soybean”,…, to search for literature in popular web search engines such as Google Scholar, Research Gate, PubMed Central, Science Direct, Food and Agriculture Organization (FAO), AsianVegetable Research and Development Center (AVRDC) and United States Department of Agriculture (USDA). Online resources were downloaded, organized into categories and summarized to draft the paper.

3 Results and discussion

3.1 Description And History Of Vegetable Soybean “Edamame”

Vegetable soybean [Glycine max (L.) Merr.] is native to China and domesticated from wild annual Glycine soja, similar to commodity soybean. Edamame (Mao dou) was first recorded around 200 BC as a medicine (Shurtleff & Aoyagi, 2021) and remains very popular (Jian, 1981).

Japan. Although the local names vary among Asian countries, the Japanese name “edamame” prevails and is used worldwide. It is pronounced “ay-dah-MAH-may” which can be translated to mean “bean on branch” in Japanese Edamame was first reported in 1275, when the Japanese Buddhist Saint Nichiren Shonin wrote a thanking note to a parishioner, as appreciation for his vegetable soybean gift (Shurtleff and Aoyagi, 2009). It was first introduced in America by Charles C. Georgeson and William J. Morse during the world wars when searching for an inexpensive source of protein (Shurtleff and Aoyagi, 2009).

Korea. Morse noted the availability of edamame (poot kong) in 1931 (Shurtleff & Aoyagi, 2021). Edamame is still cultivated throughout the country, and variety development is ongoing (Hong et al., 1982), along with research on crop management systems (Konovsky et al., 2020).

North America. Edamame is known by many names. However, the most common are vegetable soybeans, beer soybeans, edible soybeans, fresh green soybeans, garden soybeans, green soybeans, mature green soybeans, green vegetable soybeans, young soybeans, large-seeded soybeans, and the Japanese name edamame. Green soybeans come from mature soybean seeds with green cotyledons.

Other countries. Countries that commercially produce edamame include Argentina, Australia, Israel, Mongolia, New Zealand, and Thailand. Home-grown farmers produce edamame in Bhutan, Brazil, the United Kingdom, Chile, France, Germany, Indonesia, Malaysia, Nepal, the Philippines, Singapore, and Sri Lanka.

The surge in interest began with the emergence of organic farming in the 1970s. Currently, some home-grown farms grow edamame, but commercial production remains limited. Edamame offers a large export market opportunity. Export demand from Japan is 100,000 tons per year, and the States is 7,000 tons per year. Meanwhile, Indonesia can only meet 3% of Japan's market demand, with the remaining 97% supplied by China and Taiwan (Zulfaniah et al., 2020). Asian-Americans typically only find frozen edamame in specialty supermarkets

Soybean producers have conjectured that the desired qualities of cooked vegetable soybeans are appearance, aroma, flavor, and firm texture. The flavors most desired in beans are said to be sweetness and nuttiness and no beany taste. Texture is to be firm and nut-like, not mushy or hard. Shades of green are desirable The overall eating quality of the vegetable soybean was fairly good, having potential acceptability as a vegetable. Several sensory parameters were

intercorrelated. For example, the overall eating quality was correlated positively with sweetness and pleasantness, and negatively with beaniness and oiliness. Other motivational factors were cost, convenience, and having another vegetable to include in the diet. Using findings regarding consumers' food selection behavior may benefit food processors and manufacturers in producing and marketing vegetable soybeans. When making decisions in selecting genotypes for production, consideration should be given to the sensory attributes of the genotypes, because there was significant variability among the sensory characteristics of the green soybeans; several sensory characteristics together were associated with the overall acceptability of vegetable soybeans.

3.2 Processing vegetable soybeans

Freezing has long been established as an excellent method for preserving high quality in food products, including vegetables and fruits. Freezing decreases the rate of the most deteriorative reactions, such as senescence, enzymatic decay, and microbial growth. Generally, freezing preserves the taste, texture, and nutritional value of foods better than any other preservation method as a result, ever-increasing qualities of food are being frozen throughout the world.

A further effect of the thermal processing is degradation of chromophores such as chlorophyll, resulting in color change. Pigment degradation will continue to take place in frozen storage. The color of vegetable soybean pods is of paramount importance and genetically modified varieties in Asia have been created which have stayed green pod. The varieties are highly popular with growers, due to extending harvest period closer to soybean maturity without experiencing the yellowing associated with maturity. Vegetable soybean color has also been directly correlated with ascorbic acid and browning of vegetable soybean pods, during refrigerated storage.

Blanching can also lead to thermally induced degradation of nutrients, such as ascorbic. Ascorbic acid losses increase with extended storage improper frozen storage temperatures, low humidity, physical damage, chilling injury. The retention of ascorbic acid in frozen products is dependent on the product temperature history. Including harvesting conditions, processing parameters, and temperatures during frozen storage. Frozen edamame can be used as a weight-loss ingredient to lessen intake of food. The lower trypsin-inhibitor levels and lower cell density, making it more digestible than grain-type soybeans with only a shorter cooking time and cooking edamame has the benefit of doubling the iron bio-availability (Chadha and Oluoch, 2004)

3.3 Major Research On Edamame : Quality

Many research works have been carried out on edamame across the world, with a very limited range in Indonesia. These works tackled various aspects including evaluation for adaptation and diversity studies, consumers‟

preferences and sensorial qualities assessment, nutritional profiling, testing for yield and yield components, breeding and evaluation of production, harvest and post-harvest constraints. The protein and oil contents are the main quality traits of vegetable soybean and are valued by edamame breeders. The protein content of vegetable soybean was 56% higher than green peas (P. sativum) (Masuda, 1991). Rao et al. (2002) reported that protein and oil content of fresh seed vegetable soybean ranged from 33 to 39% and 13 to 16%, respectively. In developed countries, vegetable soybean varieties with lower oil percentage and relatively higher protein content are more popular among young people who seek healthy diets (Brar and Cater, 1993). Saldivar et al. (2011) stated that vegetable soybean seed with more than 45% protein and seed oil of less than 18% are acceptable Edamame quality can be affected by pod color, environmental factors, plant genetics, planting distance, and the application of organic compost. Edamame production is difficult to control, as it is susceptible to pests and diseases. According to Astuti et al, (2022) attacks by plant-disturbing organisms (OPT) reached 77.49%, especially pests and diseases that impact on plants. Carbohydrate is the predominant component ranging from 42.4 to 48.1%, followed by protein (34.2-35.4%), oil (13.1-17.5 %) and ash (4.21-4.88%) for three vegetable soybean varieties grown in Virginia. The major sugars in the beans are sucrose (5.94-12.2%) and fructose (1.61-2.31%) (Xu et al., 2015). The total soluble sugar content ranged from 6.0% to 7.4% in a four-year study in Taiwan (Tsou and Hong, 1991) and 7.5% to 12.5% during a three-year study in China (Zhang et al., 2006), while sucrose content constituted 71% of total soluble sugar (Li et al., 2012). The mean values in seed protein, oil, total soluble sugar (TSS) and sucrose of vegetable soybean varieties (lines) were 420, 186, 60 and 43 mg g–1, respectively (Li et al., 2012).

Decrease in crop production and quality. Control is carried out by administering chemical pesticides that can pollute the environment. Fresh edamame products go through a series of processes: (a) raw material receipt, (b) blower, (c) grading, (d) washing I, (e) sorting, (f) washing II, (g) blanching, (h) cooling I, (i) cooling II, (j) IQF, (k) packaging, (l) freezing, and (m) storage (Bakri et al., 2018). The washing process is crucial for product acceptance because it is related to contaminants (microbiology and pesticide residues). Pesticide residues can negatively impact human and animal health (Gazali et al., 2022). Edamame contains antioxidants and isoflavones. Consuming foods containing antioxidants can strengthen the immune system and reduce the risk of cancer. Isoflavones can also reduce the risk of prostate and breast cancer, prevent heart disease, lower blood pressure, and reduce menopausal disorders. (Fajrin et al, 2015). Edamame has a lower trypsin inhibitor content than soybeans, making it easier to digest. Trypsin inhibitors, found in edamame soybeans, function to break down proteins into peptides. Edamame contains 30.20 grams of protein per 100 grams (Larosta, Permana, & Sugitha, 2019). Edamame soybeans have a higher and more complete protein content, up to 36% more than other soybeans (Aditya, 2020).

Edamame has nutrients that are more easily digested by the body, as well as a sweeter taste, stronger aroma, softer texture, and larger seeds. Shanmugasundaram (1996) reported that the optimum time for harvesting green beans was when the pods are still green, immature, and tight with fully developed immature green seeds. This stage coincides with the R6 stage of soybean development (Fehr and Caviness, 1977). Thus, the R6 stage is very critical for ensuring bean yield and quality. Among physical characteristics, appearance as well as size of fresh pods and seeds is important.

The time of harvest plays an important role, since sucrose increases in the early stages of green soybean growth, peaking at or after around 35 days after flowering (Chiba, 1991; Zhang et al., 2015). There is a narrow window for optimal harvesting, usually around 35-39 days after flowering. After harvest, sugar levels drop swiftly, especially at high temperatures and, therefore, measures should be taken to preserve the high quality of beans by cooling and high humidity storage (Chiba, 1991). The time of harvesting is a critical factor in determining consumer acceptability and marketability of fresh vegetable soybeans (Mbuvi and Litchfield, 1995). Dietary Fiber (DF) content can vary depending on the variety and treatment method, it tends to be consistently higher than that found in other vegetables (USDA, 2019). DF is an intricate poly-saccharide prevalent in plants and typically consists of ten or more carbohydrate units (Bader Ul Ain et al., 2019). DF possesses crucial physical and chemical properties, specifically its encompassing water-holding, oil-holding, and water-swelling capacities (Xie et al., 2016; Xie et al., 2017), and promotes the elimination of bile acids and reduction of cholesterol in the body (Gunness & Gidley, 2010). Based on its water solubility, DF can be categorized as soluble DF (SDF) and insoluble DF (IDF) (Aleixandre & Miguel, 2008). SDF undergoes mi- microbial fermentation in the large intestine, leading to the production of short-chain fatty acids such as acetate, propionate, and butyrate (P′ erez-Lopez ′ et al., 2016; Bader Ul Ain et al., 2019) with probiotic properties. Short-chain fatty acids play a role in downregulating inflammatory factors and mucosal pro-inflammatory cytokines in the gut. Additionally, they contribute to enhancing the integrity of the intestinal barrier, consequently lowering the risk of intestinal diseases (He et al., 2022; Karra et al., 2009). IDF cannot be absorbed by the intestine and can pass through the gastrointestinal tract relatively intact the SDF, IDF, and TDF contents of edamame before and after HHP treatment. The TDF content of non-HHP-treated edamame was approximately 54.82 ± 1.69% dw (dry weight), with SDF and IDF constituting 7.94 ± 0.57% dw and 46.88 ± 1.61% dw, respectively. These findings suggest that HHP treatment at 600 MPa for 15 min altered the distribution of IDF and SDF in edamame. In previous studies, the SDF content also increased under different combinations of pressure and time. Xie et al. (2017) reported that a lower pressure value and long pressure-holding time (200 MPa 30 min) increased the SDF of purple-fleshed potatoes. Wennberg and Nyman (2004). Increasing the SDF content of dry, hydrated, and autoclaved okara samples by more than eight-fold. HHP primarily affects non-covalent interactions such as hydrogen bonds, electrovalent bonds, and hydrophobic bonds (Wang et al., 2016). Alterations in the fiber structure may

result from modifications to functional groups induced by the high pressure applied to cellulose and semi-fiber. This process may involve the cleavage of glucoside bonds or breakage between polysaccharides, potentially leading to the transformation of IDF into SDF (Tejada-Ortigoza et al., 2017; Benítez et al., 2011).

Table 1. Nutritional content of edamame compared to other vegetable and grain soybeans

Composition	Edamame (raw)	Hijau (Kacang Polong)	Kedelai (grain soybean)	Edamame (dry)	Kedelai (dry)
Energi (kkal)	**135**	**93**	**417**	**477**	**475,38**
Air (g)	71,7	76,5	12,5	0	0
Protein (g)	11,7	6,9	35,5	41,3	40,242
Lipid (g)	6,2	0,4	19	21,9	21,66
Karbohidrat (g)	8,8	15,3	28,2	31	32,148
Abu (g)	1,6	0,9	5	5,65	5,7
Mineral					
Na (mg)	1	1	1	3,53	1,14
K (mg)	590	340	1900	2083	2166
Ca (mg)	58	23	240	205	273,6
Mg (mg)	62	37	220	219	250,8
P (mg)	170	120	580	600	661,2
Fe (mg)	2,7	1,7	9,4	9,53	10,716
Zn (mg)	1,4	1,2	3,2	4,94	3,648
Cu (mg)	0,41	0,19	0,98	1,45	1,1172
Mn (mg)	0,71	0,48	1,9	2,51	2,166
Vitamin					
A (µg)*	22	35	1	77,7	1,14
E (mg)	0,8	0,1	1,8	2,82	2,052
K (µg)	30	27	18	106	20,52
B1 (mg)	0,31	0,39	0,83	1,09	0,9462
B2 (mg)	0,15	0,16	0,3	0,53	0,342
Niasin (mg)	1,6	2,7	2,2	5,65	2,508
B6 (mg)	0,15	0,15	0,53	0,53	0,6042
B12 (µg)	0	0	0	0	0
Asam folat, B9 (µg)	320	76	230	1130	262,2
Asam pantotenat (mg)	0,53	0,63	1,52	1,87	1,7328
C (mg)	27	19	Tr**	95,3	0

Consumers and distributors generally evaluate edamame quality based on appearance, aroma, taste, and texture after cooking. Edamame pods are young soybeans harvested before maturity, resulting in a green color. This distinguishes them from regular soybeans, which are light brown, yellowish-brown, or cream-colored. Edamame seeds are large, weighing over 300 grams per 100 seeds (Ichwan et al., 2021).

3.4 Variety Selection

Japan classifies edamame as either summer or autumn soybeans. Edamame varieties are quite sensitive to temperature and seasonality. Summer varieties are planted in spring and harvested before maturity after 75-100 days, while autumn varieties are planted in early summer and require 105 days or more. When selecting a

variety, factors such as harvest time, seed size and color, and adaptability to high-yielding environments should be considered.

There are hundreds of edamame varieties available, and most are determinate and can be separated into approximately 10 families with representative types. The summer varieties include Okuhara and Sapporo-midori, which fall into Maturity Group (MG) 0; Osodefuri and Shiroge, which fall into MG I; and Fukura, Mikawashima, and Yukimusume, which fall into MG II; and the autumn varieties, Kinshu, Tsurunoko, and Yuzuru, which fall into MG III. All have white pubescence. Unique characteristics include the sweet taste of Fukura, the dark pods of Kinshu, the numerous three-seeded pods of Mikawashima, the pleasant flavor of Osodefuri, the abundant branching of Shiroge, the large seeds of Tsurunoko, and the good color of Yukimusume pods after processing. The brittle pods of Fukura, the vining growth of Mikawashima, the short harvest period of Okuhara, the low germination of Sapporo-midori at low temperatures, and the tall growth of Tsurunoko are its negative characteristics. Among Chinese varieties, Sanyuewang, Wuyuewu, and Wuyueba are included in MG I-II, and Baishuiou, Liuyueba, and Baimaoliuyuewang are included in MG III-IV; Jiangyoudou and Daqingdou are autumn-type soybeans in MG V–VI. Sanyuewang, Liuyueba, and Baimaoliuyuewang are short-growing; Baishuiou, Baimaoliuyuewang, Jiangyoudou, and Daqingdou have superior qualities (Konovsky et al., 2020).

3.5 Implication for health

Research has implicated various elements in food that moderate or lessen the development potential for chronic diseases . Examples include the hypocholesterolemic effects of soy phytoestrogen cancer risk reducing properties of the isoflavonoids, the saponins and quercetin , and the xenobiotic effect of genistein , It appears that including soybeans as part of a diet is beneficial to one's health. Edamame being able to increase dietary fiber in a product affects its physicochemical properties. In mice, the physiological effects of defatted and deproteinized edamame flour were more potent than frozen and canned edamame flour in lowering serum lipids and blood glucose, while frozen and canned edamame flour had a more positive effect on maintaining colon health.

4 Conclusion

Edamame began to expand in recent decades due to increased awareness of nutritional properties, and the change in lifestyles towards healthier food as well. Edamame has potential to develop food processing technology and the functional food roles. The development of new products based on edamame related research, with an aim to fully exploit this profitable of edamame processing technology and the effect physiology for researchers, and food processors.

This research focused on the impact of dietary fiber, particularly soluble fiber, on cholesterol levels. Edamame, being a rich source of fiber, was highlighted as one of the plant-based foods that could aid in reducing cholesterol. The study confirmed that the fiber in soybeans can bind with cholesterol in the digestive system and reduce its absorption, leading to lower

blood cholesterol levels. The research showed that consumption of soy protein, including edamame, resulted in reduced LDL cholesterol and triglyceride levels.

Edamame has potential production as a food available dan has good nutrition. The Development Product of Edamame needs much research, mainly how the effect of functional food and mechanism be a legume substitute that is easier to cultivate and grow, and offers a better taste and more nutrition than regular soybeans. Edamame is a type of soybean that is easier to digest than regular soybeans and has a higher protein content. Edamame can be processed into a variety of snacks, vegetables, and jams.

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