EDAMAME: THE VEGETABLE SOYBEAN

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INTRODUCTION

Edamame is a specialty soybean (Glycine max (L.) Merr.) harvested as a vegetable when the seeds are immature (R6 stage) and have expanded to fill 80 to 90 percent of the pod width. Like field-dried soybeans, the seeds of edamame varieties are rich in protein and highly nutritious. Worldwide, it is a minor crop, but it is quite popular in East Asia. Edamame is consumed mainly as a snack, but also as a vegetable, an addition to soups, or processed into sweets. As a snack, the pods are lightly cooked in salted, boiling water and then the seeds are pushed Edamame is consumed mainly as a snack, but also as a vegetable, an addition to soups, or process into sweets. As a snack, the pods are lightly cooked in salted, boiling water and then the seeds are pushed directly from the pods into the mouth with the fingers. As a vegetable, the beans are mixed into salads, stir-fried, or combined with mixed vegetables. In soup, (gojiru in Japanese), the beans are ground into a paste with miso, which is used to form a thick broth. Confectionery edamame products, such as sticky rice topped with sweetened edamame paste (zunda mochi in Japanese), are occasionally prepared. For marketing, edamame pods are sold fresh on the stem with leaves and roots, or stripped from the stem and packaged fresh or frozen, as either pods or beans.

HISTORY

China. Edamame (mao dou) use was first recorded around 200 B.C. as a medicinal (Shurtleff & Aoyagi, unpublished) and is still very popular (Jian 1984). Major varieties (and their production areas) include: Sanyuewang in Zhejiang Province; Wuyuewu around Shanghai and Nanking; Wuyueba near Hangzhou; Baishuiou in the Chengdu area; Liuyueba around Hefei, Wuxi, and Hangzhou; Baimaoliuyuewang and Daqingdou near Nanking; and Jiangyoudou around Shanghai (Guan 1977). Numerous land races are still cultivated, particularly around Shanghai and Jiangsu.

Japan. Though soybeans were introduced from China at an early date, the first recorded use of edamame is the description of aomame in the Engishiki (927 A.D.), a guide to trade in agricultural commodities. It describes the offering of fresh, podded soybean stems at Buddhist temples (Igata 1977). Early interest in the edamame crop was seasonal, and it climaxed with the viewing of the full moon in September and October (Shurtleff and Aoyagi, unpublished). Historically, edamame was grown on the bunds between rice paddies, but with the current rice surplus and official pressure to convert paddy fields to other uses, field production is more common (Gotoh 1984). Japan is the largest commercial producer of edamame--turning out nearly 105,000 tons in 1988 (MAFF 1990)--and it is also the largest importer of the bean, bringing in over 33,000 tons in 1989 (JTA 1989). Taiwan supplies over 99 percent of those imports as frozen edamame. Almost all Japanese production is consumed as fresh product during the summer months (Kono 1986).

Korea. Morse noted edamame's (poot kong) availability in 1931 (Shurtleff and Aoyagi, unpublished). It is still cultivated throughout the country and variety development is underway (Hong et al. 1984), with research on crop management systems (Lee 1986a,b).

North America. Edamame is known by many names in North America (Shurtleff and Aoyagi, unpublished). The most common is vegetable soybean, but also beer bean, edible soybean, fresh green soybean, garden soybean, green soybean, green-mature soybean, green vegetable soybean, immature soybean, large-seeded soybean, vegetable-type soybean, and the Japanese name, edamame. Reference to green color is confusing because mature soybean seeds with a green seed coat (or cotyledon) are also called green soybeans.

Other Countries. Other countries that have produced commercial quantities of edamame include Argentina, Australia, Israel, Mongolia, New Zealand, and Thailand. Home gardeners are known to produce it in Bhutan, Brazil, Britain, Chile, France, Germany, Indonesia, Malaysia, Nepal, Philippines, Singapore, and Sri Lanka (Wang et al. 1979). USA Edamame Research. Research has been conducted for over 50 years. Dorsett and Morse collected extensive germplasm during 1929- 31, and Morse used it to develop 49 varieties of edamame (Hymowitz 1984). Research flourished during the 1930's and 1940's because of a protein shortage (Smith & Van Duyne 1951). The University of Illinois tested palatability (Woodruff & Klaas 1938) and regional adaptation (Lloyd 1940) of many soybean varieties, some of which were true edamame, and many companies experimented with canning fresh beans (Shurtleff & Aoyagi, unpublished).

A second surge of interest began with the rise of organic agriculture in the 1970's. The Rodale Research Center focused on adaptability and quality (Haas et al. 1982). Basic agronomic research was begun at Cornell (Kline 1980) and seed companies developed new varieties (e.g. butterbean). Today, some home gardeners grow edamame, but there is little commercial production. Asian-Americans seeking edamame are usually limited to frozen imports in specialty supermarkets.

QUALITY

At harvest, edamame has lower trypsin-inhibitor levels, fewer indigestible oligosaccharides, and more vitamins than field-dried soybeans (Rackis 1978). True edamame varieties are not easy to distinguish from immature, grain soybeans, except for a few unique characteristics (Rackis 1981). The larger seeds of edamame are considered superior to soybeans in flavor, texture, and ease of cooking, but significant differences in chemical composition have not been identified. Phytic acid levels are higher (Gupta et al. 1976) and may help explain why edamame is more tender and cooks faster. Large-seeded soybeans have nutritionally superior protein (Hymowitz et al. 1971), e.g., the gain-per-feed ratio was higher for edamame fed to rats than for soybeans (Yen et al. 1970). Edamame has a slightly sweet, mild flavor and nutty texture, with less objectionable beany taste. It has larger, easily shattered pods, seeds with a fragile seed coat (Smith & Van Duyne 1951), and stems that may have several podless nodes (Shanmugasundaram et al. 1989).

Edamame protein levels were thought to be slightly higher than soybeans (Liener 1978; Smith & Circle 1978), but recent research indicates larger seeds have a higher percentage of oil and less protein than smaller seeds (Reddy et al. 1989). Since protein and total sugars are negatively associated (Hymowitz et al. 1972), too much protein leads to a lack of sweetness, an important component of flavor. Conversely, oil content and total sugars are positively associated, but an excessively oily taste is unacceptable.

Edamame quality is evaluated by distributors and consumers for appearance, aroma, flavor, and firm texture after cooking. Morphologically, edamame pods should have white pubescence (Watanabe 1988), preferably sparse and soft (Sunada 1986); the hilum should be light brown or gray; the pods must have two or three seeds; most pods should be at least 5 cm long; 500 g should contain less than 175 pods; 100 seed weight should exceed 30 g (Shanmugasundaram et al. 1989); the pods should be completely green, with no hint of yellowing (IDA 1990); the mature seed coat can range from yellow or green to brown or black (Kiuchi et al. 1987); and the pods must be unblemished.

In Iwate Prefecture (IDA 1990), grade A edamame must have 90 percent or more pods with two or three seeds. The pods must be perfectly shaped, completely green, and show no injury or spotting. Grade B edamame must have 90 percent or more pods with two or three seeds, but can be lighter green, and a few pods can be slightly spotted, injured, malformed, short, or have small seeds. In both grades, pods cannot be overly mature, diseased, insect-damaged, one-seeded, malformed, yellowed, split, spotted, or unripe.

Pod color is the most visible quality of edamame. In addition to varietal influences, several management factors affect color. In general, exposure to sunlight has the greatest positive influence, followed by moisture level and supplemental fertilizer. When leaves were removed at two-thirds of mature height, the pods darkened considerably over the control by harvest due to increased exposure to sunlight (Chiba et al. 1989); however, researchers at the Asian Vegetable Research and Development Center (AVRDC) have suggested lower leaf area increases sunburn (Shin 1988). The pods seem to darken with the increased chlorophyll content caused by lower moisture levels (AVRDC 1988). Post-anthesis application of phosphorus darkened pods slightly, but the effects of nitrogen were mixed (Kobayashi et al. 1989). Ascorbic acid content deteriorates with pod color (Akimoto & Kuroda 1981) and can be used as an index of pod color and freshness.

Edamame releases a sweet aroma when cooked. At the peak of ripeness, aromatic concentrates have much higher levels of (Z)-3-hexenyl acetate, linalool, acetophenone, and cis-jasmone (Sugawara et al. 1988). Several components of beany odor were also identified: hexanal, 1- hexanol, (E)-2-hexenal, 1-octen-3-ol, and 2-pentylfuran. Cis-jasmone is found in edamame only at the peak of ripeness and may be the key component of aroma.

For edamame, the two most important components of flavor are sweet and savory. Its sweet taste is determined by sucrose content and its savory taste probably by amino acids like glutamic acid (Masuda et al. 1988). Beany flavor increases with maturity and can be divided into two components--beany and bitter (Rackis et al. 1972). The beany taste may come from linolenic acid oxidized by lipoxygenase and the bitter taste my be the lipoxygenase itself.

Many management choices influence flavor, such as: variety selection, fertilizer application, planting density, harvest procedures, and processing conditions (Masuda 1989). In Japan, basal fertilizer rates are generally around 50-80 kg nitrogen/ha, 70-100 kg phosphorus, and 100- 140 kg potassium. Excessive basal nitrogen will reduce pod set and increase the number of empty or one-seeded pods. Supplemental nitrogen after anthesis can increase amino acid levels but has an inconsistent effect on sugars. Kobayashi et al. (1989) found total sugars decreased from 3.18 percent to 2.63-2.94 percent depending on the rate and timing of nitrogen application. Abe et al. (1985) cites contrary data, but adds that pods given supplementary fertilizer may be damaged more easily during processing. Lower plant densities not only darken pods but produce consistently higher amino acid levels and sucrose during the maturation period (Chiba et al. 1989).

The date, timing, and method of harvesting are of crucial importance. Unfortunately, sugar and amino acid contents peak several days before beans have adequately filled the pods. When pod color and seed size appear the best, flavor has already begun to deteriorate. In addition, there is a daily cycle for amino acids. A peak occurs near sunset, and the more sunlight during the day, the higher the peak. For glutamic acid, a peak of 255 mg/g fresh weight was reported at sunset, with a decline to 160 mg by the next morning at sunrise (Masuda 1989). After harvest, sugar and amino acid deterioration can affect flavor within 3-10 hours unless the beans are cooled (Chiba & Yaegashi 1988), or unless whole plants are harvested. If whole plants are packaged and sealed in low density, polyethylene bags, they remain acceptable for one week at 20 oC (Iwata et al. 1982).

If the pods are adequately green, post-harvest handling is the major influence on quality and flavor. The need for rapid cooling cannot be overemphasized. Fresh product often sits at room temperature for 24 hours or more before sale and use. Masuda et al. (1988) found that frozen edamame from Taiwan often had more sucrose (e.g., 1.7 percent vs. 1.1 percent) and amino acids (e.g., alanine at 30 mg/100 g fresh weight vs. 16 mg) than fresh edamame in Japan. Both were significantly lower than harvest peaks (2.9 percent sucrose and 297 mg alanine). For frozen edamame, blanching is important to stop the oxidation of fatty acids into undesirable tastes.

Both blanching time and temperature must be controlled to reach a balance between the destruction of trypsin inhibitors and the maintenance of good texture. The length and temperature of storage is also significant. Ascorbic acid levels decrease 20 percent after six months at -20 oC, and 40 percent after one year. For post-harvest management, rapid cooling (or blanching and freezing) is essential to slow enzymatic activity and minimize deterioration.

Yield is influenced by planting density.. Higher densities intercept more light, which increases biomass (AVRDC 1988). Acceptable grade A and B pods/plant decrease with higher densities, while the total yield/area of the pods increases (Shin 1988). Inter-row spacing influences yield more than intra-row spacing (Kline 1980).

VARIETY SELECTION

Japanese classify soybeans as summer or fall types (Kono 1986). Most edamame varieties are temperature-sensitive, summer types; only a few are day-length sensitive, fall types. Summer types are planted in the spring and harvested immature after 75-100 days, while fall types are planted in early summer and take 105 days or more.

About 170 edamame varieties are listed by the Nihon Shubyo Kyokai (JSTA 1987), and several hundred others are available. Most are determinate (Gotoh 1984) and can be segregated into approximately ten families with representative types (IDA 1989; Kono 1986). Among summer types, Okuhara and Sapporo-midori are in Maturity Group (MG) 0, Osodefuri and Shiroge are in MG I; and Fukura, Mikawashima, and Yukimusume are in MG II. Among fall types, Kinshu, Tsurunoko, and Yuzuru are in MG III. All have white pubescence except Okuhara, Osodefuri, and Shiroge. Special qualities include Fukura's sweetness, Kinshu's dark pods, Mikawashima's numerous three-seeded pods, Osodefuri's good flavor, Shiroge's prolific branching, Tsurunoko's large seeds, and Yukimusume's good pod color after processing. Negative features include Fukura's fragile pods, Mikawashima's viney growth, Okuhara's short harvest period, Sapporo-midori's lack of vigor at low temperatures, and Tsurunoko's tall growth.

Among Chinese varieties (Guan 1977), Sanyuewang Wuyuewu, and Wuyueba are in MG's I-II, and Baishuiou, Liuyueba, and Baimaoliuyuewang are in MG's III-IV; Jiangyoudou and Daqingdou are fall-type soybeans in MG's V-VI. Sanyuewang, Liuyueba, and Baimaoliuyuewang are short plants. Baishuiou, Baimaoliuyuewang, Jiangyoudou, and Daqingdou are superior in quality, while Liuyueba, Jiangyoudou, and Daqingdou have high yields.

PRODUCTION

Edamame can be transplanted (teishoku) or direct-seeded (futsu roji). In Japan, transplants are used in forced (sokusei) and early (sojuku) production systems (Kono 1986). Planting under forced conditions in carbon dioxide-enriched, heated greenhouses starts in November and harvest ends by July. Early spring production starts with the planting of seedling nurseries in February; these seedlings are then transplanted to small plastic tunnels 25-30 days later, with harvest ending by July. Temperature management is achieved by placing dark covers over the tunnels during cold periods to increase temperature and by using ventilation during hot periods (Watanabe 1988). Field production begins in early March and ends by October. Occasionally, plant tops in seeded fields are cut after the primary leaf stage to increase plant branching and pod set (Gotoh 1984). Early summer demand pressures farmers to harvest as early as possible to obtain higher prices, so the onset of harvest is being continually advanced through crop management and variety development. Most edamame is harvested by hand. When edamame is sold on the stem, plants are hand-cut or pulled out with the roots intact; unacceptable pods and lower leaves are culled, and branches tied together in small, aesthetically pleasing bundles. For sale of harvested pods, plants are cut and pods stripped off, sorted, and packaged. In Japan, electrical-powered, stationary pod strippers are available, and in Taiwan, AVRDC has developed a manual pod stripper (AVRDC 1989). Initial studies on mechanical harvesting have been conducted in Tennessee (Collins & McCarty 1969) and at INTSOY (1987). For frozen product, standard methods for processing have been described (Liu & Shanmugasundaram 1982).

CURRENT RESEARCH

Quality aspects such as darker green, unblemished pods, earlier maturity (in Japan), higher pod set (for mechanical harvesting), lower temperature tolerance, longer harvest period, and a trypsin-inhibitor-free, sweet and savory flavor are major breeding objectives, with adequate seed size, seeds/pod, and pubescence already well established in the breeding lines. Pod shatter is a problem for seed production, but easily opened pods are important for vegetable production. Yield is a secondary consideration because of the high value of edamame, but disease resistance is important in some areas, particularly the tropics.

Active public research programs have been found at AVRDC for variety development (Shanmugasundaram et al. 1989), at INTSOY for mechanical harvesting (INTSOY 1987); and at Iwate Prefecture Agricultural and Horticultural Experiment Station for land race collection (Kiuchi et al. 1987), variety development (Kiuchi et al. 1989), crop management (Chiba et al. 1989; Kobayashi et al. 1989), and post-harvest management (Chiba & Yaegashi 1988). Other research programs include the Japanese National Food Research Institute at Tsukuba's study on quality (Masuda 1989) and Washington State University's evaluation of varieties and production systems. Many Japanese seed companies (Sakata and Yukijirushi, etc.) also have variety development programs underway. Other prefectures in Japan sponsor local research, and China, Korea, Sri Lanka, and Thailand all have active research programs.

SUMMARY

In the United States, edamame has potential as an easier-to-grow, better tasting, more nutritious substitute for lima beans. Served in the pods, it might appeal to consumers interested in natural foods, particularly if it were grown organically. In spite of drastic changes in the Japanese diet, demand is slowly rising and traditional foods like edamame continue to be very popular (Cook 1988). In a hungry world, with research and education, edamame could be a very nutritious, savory, and inexpensive addition to local diets, especially in calorie, protein, and vitamin deficient regions of the world.

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