Production of Vegetable Soybean

The case of Sweden

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Preface

After completing my bachelor's degree in Sri Lanka, I joined the government as an agricultural development officer, but deep down, I knew it was not my true calling. Sri Lanka has a rich agricultural heritage, with a history of agroecological practices that once allowed farmers to work in harmony with nature. However, times have changed. Today, farmers heavily rely on synthetic fertilizers and chemicals, leading to a disconnection from traditional, sustainable practices. When agricultural authorities attempted to reduce dependency on these synthetic chemicals, many farmers chose to abandon agriculture until the government reissued the chemicals. I realized that the problem was not just with farming techniques but also with the attitudes of the people. As someone from a developing country, I wanted to understand how these issues were addressed in more developed settings. That was when I discovered that the Swedish University of Agricultural Sciences (SLU) offered one of the best programs in agroecology, a field dedicated to sustainable agriculture. Fortunately, I was accepted into the program at SLU.

As I approach the final stage of my education, this thesis reflects the culmination of my learning, focusing on how to achieve sustainable development through farming and food systems. Animal agriculture, while a major source of protein, poses significant environmental challenges, including greenhouse gas emissions, deforestation, and resource depletion. With the global population growing, it is crucial to explore alternatives that balance nutritional needs with environmental sustainability. Reducing meat consumption is one such approach, offering benefits for both human health and the planet. Plant-based diets, particularly those incorporating protein-rich alternatives like soybeans, can play a pivotal role in this transition. By promoting the consumption of vegetables and plant-based proteins from an early age, we can shape future dietary habits that prioritize sustainability. Edamame, for instance, is increasingly recognized for its nutritional value and environmental benefits as a leguminous plant, making it a key component in achieving the United Nations' Sustainable Development Goals. Embracing these changes globally could significantly reduce the environmental impact of food production and contribute to a more sustainable future, including in Sri Lanka.

Thank you…….!

Abstract

Cultivation of vegetable soybean, also known as edamame, in the European region has shown significant growth in recent years. Northern Europe has also seen successful involvement, although Sweden has not yet started cultivation due to climatic conditions. To adopt successful edamame cultivation in Sweden with suitable high-yielding varieties and high-quality characteristics, an independent field trial was conducted in Skåne, southern Sweden, during 2020 to 2022. This study determined high-yielding varieties, assessed their quality, and analyzed their protein contents. The results demonstrated that true edamame cultivars gave very low yields, whereas standard soybean cultivars turned out to be a viable crop with high yield potential, similar to other European cultivations. The field trial showed that the standard soybean cultivars might potentially yield approx. 5 tons/ha. Sensory evaluation showed that 'Livius' performed best, although slightly lower than imported samples, whereas 'Abaca' had a higher protein content than the other cultivars. However, both taste and protein content were affected by harvest date, indicating the importance of determining the optimal harvest date. Consumer awareness and potential demand for edamame were assessed using a digital survey, which indicated that 90.9% of the participants were aware of edamame. Additionally, 49% of the participants found it important that the beans are locally grown, whereas 60% were highly concerned about the price of edamame. Finally, the study indicated that 60% of survey participants firmly believed that reducing meat consumption and increasing vegetarian intake is beneficial for the environment

Keywords: consumer awareness, high-yield edamame, protein content, quality edamame, sustainable agriculture

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1. Introduction

1.1 Significance of Edamame (Vegetable Soybean)

Edamame (vegetable soybean) is a special kind of soybean that was first cultivated over 2,000 years ago in China. The word "edamame" originates from Japanese. This vegetable has been referred to as "mao dou " in Chinese, which means "hairy bean" in English (Miles et al. 2018). Edamame cultivars are derived from the same species as standard soybean cultivars (*Glycine max* (L.) Merr.), and the cultivation takes into consideration the size, texture, and digestibility of the beans (Miles et al. 2018). Edamame comes in pods, but only the beans are edible. Pods with two or three beans are acceptable for sale (Carneiro et al. 2020). Edamame is commercially available in fresh, frozen, roasted, or freeze-dried forms, popularly consumed as a side dish (Ewan 2014; Zeipiņa et al. 2017). Its growing popularity worldwide can be attributed to its nutritional quality, purported health benefits, and appealing flavour profile (Xu et al. 2016).

Globally, 77% of the soybean production is used for animal feed, while merely 19.2% is directed towards human consumption (Ngarboui 2022). Notably, 100% of edamame is designated for human consumption, serving as a significant protein supplement. 100g of edamame, containing 38% of protein on a dry weight basis, offers a nutritional profile comparable to 113.4g of roasted chicken breast or four slices of whole wheat bread in terms of protein and dietary fiber content (Carson et al. 2011; Sharma 2013). Japanese analyses of edamame indicate that a 100g serving provides an energy value of 2,435kJ, along with 11g of protein, 7g of lipids, and 7g of carbohydrates. Furthermore, it boosts nutritional elements such as 2g of total fiber, 16g of dietary fiber, and 2g of ash. Additionally, edamame is rich in calcium (70mg), potassium (140mg), phosphorus (140mg), as well as vitamins A and C, and phytoestrogens (Zeipiņa et al. 2017).

1.2 Edamame Farming: Techniques, Challenges, and Future Prospects

Cultivation of edamame is similar to the cultivation of soybean intended for mature harvest, however, crucial differences lie in the harvesting period (Ngarboui 2022). Edamame, as a vegetable soybean, is harvested 90 to 120 days after sowing and is consumed while still green and premature (Mahoussi et al. 2020). Edamame, as well as soybean intended for mature harvest, is a photosensitive short-day plant (Miles et al. 2018), which means that flowering and maturity are regulated by the photoperiod (Ngarboui 2022). The length of day changes with latitude and at higher latitudes (further north), photoperiods are longer between the first day of spring and the first day of autumn (Weibold 2014). Considering this sensitivity, soybean varieties have been categorized into 13 maturity groups from 000 to X. Group 000 contains cultivars with early maturity, and can be grown in regions with long days (Miles et al. 2018).

1.3 Crop Management

Successful edamame cultivation requires meticulous management to ensure the quality of the beans. Key factors determining quality include sweetness, flavour, and size of the beans (Sharma 2013). High yield and quality of pods and beans depend on maintaining ideal environmental conditions such as soil temperature (at least 12°C), soil pH (6-6.5), soil moisture, fertility, and proper irrigation practices (Ciampitti, 2016; Miles *et al.*, 2018). Inoculating edamame seeds with the nitrogen-fixing bacteria *Bradyrhizobium japonicum* promotes growth and yield (Hymowitz 1990). The timing of harvest is crucial as it directly impacts bean quality. It is time to harvest the beans when the pods are plump and the beans touch the pods. Any yellowing of the edamame pods indicates that the optimal harvesting date has passed, and the beans have lost their sweetness, while their nutty flavour has increased (Carneiro et al., 2020). Mechanical harvesting is preferred due to the compact growth habit of edamame plants, with pods maturing simultaneously and concentrated around the stem. Therefore, a green pea harvester with minimal adjustments can effectively harvest edamame pods (Carson et al. 2011). For optimal food quality, it is recommended to grow 150,000 to 180,000 plants per hectare, with a standard yield ranging from 5 to 8 tons of pods per hectare, though actual yields may vary depending on various environmental factors such as temperature, water availability and soil type (Sharma 2013; Beesten 2023).

1.4 Market Trends and Consumer Preferences in the Edamame Industry

The global demand for edamame is on the rise, particularly in East Asian countries like Japan, China, Korea, and Taiwan, which were prominent in production and consumption already ten years ago (Williams et al. 2022). In 2017, edamame was considered to be the single most valuable crop in East Asia (Wang 2018). The popularity of edamame is now increasing in other parts of the world. Until 2012, China, as a traditional grower, was the largest edamame producer globally. However, the United States and Brazil have surpassed China as the world's top producers (Ewan 2014). Global statistics indicate that the frozen edamame market is expected to expand by 34.53% between 2023 and 2029 (Frost 2023). In USA, consumers prefer domestically grown fresh edamame over imported frozen ones (Carneiro et al. 2022). As a result, the food industry in the USA has focused on expanding edamame production to provide fresh, healthful, plant-based protein substitutes in response to the rising customer demand (Neill & Morgan 2021).

1.5 The Rise of Edamame Cultivation in European Agriculture

Recently, edamame has gained popularity also in European nations due to its numerous health benefits and nutritional advantages, leading to increased importation of frozen edamame to Europe. Due to the limiting factor of day length for flowering, soybean is suitable for cultivation in the south and east of Europe (Zeipiņa et al. 2022). Areas at higher latitudes have not been as involved in soybean cultivation. Nevertheless, it has been found that certain high latitude regions are appropriate for the cultivation of soybeans (Karges et al. 2022) and, as mentioned earlier, cultivars suitable for cultivation in areas with longer days have been developed. Soybean cultivation has been popular in both East and West Europe since the 18th century, with the first soy plant reported to have been planted in the Netherlands in 1737, and the cultivation expanded to France, the UK, and Czechoslovakia (Hymowitz 1990). Annually, on average, the European Union imports 14 million tons of dry and vegetable soybeans, with only 2 million tons grown within the EU and 8.4 million tons produced by non-EU European countries including Ukraine and Moldova (Karges et al. 2022).

Generally, edamame production in Europe is quite low, with high latitudes being a major barrier for cultivation. However, Germany has recently successfully developed edamame cultivation. Standard yields range from 5 to 8 tons per hectare, but with ideal soil and climate conditions, yields exceeding 12 tons per hectare have been achieved (Beesten 2023). Initiatives like the "Growing Green Protein" project in the Netherlands aim to boost vegetable soybean (edamame) production for human consumption, with significant progress noted in recent years (Dutch Edamame 2020). Companies such as Ardo and Edamax in Austria have developed agrotechnology for edamame cultivation, while southeastern Romania, guided by Edamax, is set to commence vegetable soybean cultivation due to favorable soil and climate conditions (Ardo 2023; Edamax 2023). Europe is embracing these small green powerhouses, with Dutch farmers experimenting with soybean varieties and Austrian and German producers perfecting the art of growing edamame.

1.6 Edamame: Exploring its Potential as a Profitable Crop in the Swedish Market

Dr. Sven A. Holmberg, a prominent soybean breeder in Europe, dedicated much of his time in the mid-1930s to breeding soybeans. His focus was on finding a variety suitable for the extreme conditions of northern Europe, including cold temperatures, maritime climate, and long summer days. He introduced ‘Fiskeby’ and after many experiments and field trials, ‘Fiskeby 111’ showed the highest yield of 2,266 kg/ha in 1953. Then, in 1970, ‘Fiskeby IV’, an important bred variety, became well-known in Europe. In Sweden, it was discovered that soybeans thrived most in the driest area of the country, specifically in the Kalmar Öland region (Shurtleff & Akiko Aoyagi 2007). Unfortunately, soybean cultivation never succeeded in Sweden, and due to low yields and lack of interest, breeding activities were closed (Fogelberg 2021). However, if beans were harvested green, soybean cultivation could be successful in Sweden.

Canada shares similar latitudes with Sweden, leading to comparable climate conditions, and has achieved successful edamame cultivation since 2010, led by MacKellar (Levy 2014). Southern Ontario's cooler temperatures have proven to be better suited when it comes to taste and insect control, making it a favourable location for edamame cultivation (Levy 2014). Considering these factors, it is plausible that edamame can be successfully cultivated under Sweden's climate conditions. Field trials on edamame cultivars (the 000-maturity group) conducted between 2010 and 2012 showed yields ranging from 1,500 to 2,500 kg/ha, making it suitable for commercial cultivation in Sweden. This indicates that soybean varieties from the 000-maturity group can indeed be successfully cultivated in Sweden. Another option is to grow cultivars intended for mature harvest, and harvest the beans green (Fogelberg & Mårtensson 2021).

1.7 The Significance of Recognizing Consumer Awareness in Assessing the Potential Demand for Edamame in Sweden

Understanding consumer demand and preferences is vital for both marketers and growers to effectively plan production. Including customers in the process of developing a product will significantly increase the probability of being successful in the marketplace (Kelley and Sánchez, 2005). Consumer data, such as understanding the current needs, preferences, and motivations of local consumers regarding edamame consumption, is invaluable for tailoring communications to stakeholders across the food value chain. This understanding is crucial for efforts ranging from developing new edamame cultivars to providing guidance to all stakeholders at every stage (Carneiro et al., 2022).

For instance, in Sweden, collection and analysis of consumer data can support the growth of a sustainable edamame agribusiness by accurately assessing existing and future demands. It is important to note that consumer preferences can vary by region. For instance, American consumers can choose a buttery flavour and texture, but Japanese consumers would favour a more floral and beany flavour profile (Kelley & Sánchez 2005).

1.8 Sweden's Edamame Cultivation: Value and Opportunities for Sustainable Agriculture

The Swedish diet significantly affects the environment in many ways, it greatly impacts climate change, biodiversity, land use, and the use of nitrogen and phosphorus. These effects are far beyond what can be considered sustainable (Röös et al. 2021). When changing diet by eating fewer animal products, it can greatly help reduce the environmental impact of food, especially its effect on the climate (Röös et al. 2017). Studies have shown that eating habits develop early in life (Dudley et al. 2015). Therefore, serving school meals with more vegetables and less meat can encourage healthier and sustainable eating habits among the Swedish community (Röös et al. 2021).

Edamame, due to its high protein content, could become a significant crop in Sweden. However, transporting crops over long distances increases energy consumption and climate impact, especially when processing and packaging are distant (Tidåker et al. 2021). Shifting to locally grown edamame can reduce the carbon footprint. Local cultivation reduces the need for long-distance transportation, cutting emissions associated with transport and logistics (Avetisyan et al. 2014). Global trends indicate an increase in sustainable behaviours, such as purchasing locally produced goods, and strengthening and defining the local production chain may assist to minimise dependency on foreign markets (Bimbo et al. 2021).

Growing local markets and demand could result from farmers and customers becoming more conscious of the origins of their food (Glowacki-Dudka et al. 2013). Minimizing food transport distances and favouring plant-based diets over animal-based ones can lower CO_2 emissions and reduce water, soil, and energy consumption in Sweden (Lacour et al. 2018). Edamame, like other legumes, is able to fix nitrogen from the air, minimizing fertilizer usage, and potentially providing residual nitrogen for subsequent crops, thus enhancing the sustainability and economy of cropping systems (Miles et al. 2018).

1.9 Problem Statement

As vegetable soybean (edamame) becomes more popular in Europe, many European countries are starting commercial cultivation to meet consumer demand and reduce imports. Growing edamame domestically can significantly decrease food miles, thereby reducing transportation-related CO_2 emissions and reliance on foreign markets. Promoting plant-based protein, like edamame, over animal meat products contributes to lower greenhouse gas emissions as the production requires less water, soil, and energy.

Starting vegetable soybean cultivation in Sweden impacts the entire food chain, from seed to plate, enabling consumers and farmers to know the source of their food. Edamame, as a leguminous crop that requires minimal amounts of fertilizer, offers several significant benefits—economically, environmentally, and socially. Its cultivation can enhance soil health, reduce the need for chemical inputs, support biodiversity, and provide valuable nutritional benefits. Additionally, promoting edamame can open up new market opportunities and contribute to sustainable agricultural practices, all while improving food security and public health (Sharma 2013; Wang 2018; Tidåker et al. 2021).

While many European countries have identified the best cultivars for their regions, these may not be suitable for Sweden due to different climate conditions and soil types. To be able to start a domestic production of edamame, it is essential to identify the best cultivars for Swedish conditions that also meets consumer taste preferences.

1.10 Objective

This study has two main objectives. Firstly, it aims to identify soybean cultivars with high yield and superior quality characteristics through protein analyses and statistical analysis of previously collected data from field trials and sensory evaluations. This involves assessment of yield potential and optimal harvest date, and evaluation of parameters such as pod size and seed quality to determine the most desirable traits for commercial cultivation.

Secondly, the research seeks to evaluate consumer awareness and potential demand for edamame products. A survey has been conducted to gather information about customer preferences, attitudes, and edamame-related purchase patterns. By gaining insights into consumer attitudes and market trends, the study aims to suggest strategies for promoting edamame consumption and expanding market opportunities for this nutritious legume.

2. Material & Methods

2.1 Field Trials

The field trials were carried out at Välingetorps Gård, close to Ängelholm in the Northwestern part of Skåne (56°11'36.2"N 12°49'10.0"E) during three years 2020, 2021 and 2022.

2.1.1 Selection of Cultivars for Cultivation

In 2020, the first field trial was conducted. A total of 11 cultivars were employed to determine the optimal cultivar for vegetable soybean production (Table 1). 'Fiskeby V' (Impecta, Sweden) was used as a reference cultivar due to its development for northern conditions. The other cultivars were either edamame cultivars (number 4-10, Table 1) or standard soybean cultivars developed for colder climates (number 1-3 and 12, Table 1). The field trial the second year (2021) was carried out based on the previous year's (2020) field data. Three varieties ('Livius,' ' GL Melanie,' 'Obelix') were selected, and a promising fourth variety, 'Abaca', was chosen for cultivation in the same field. The same four cultivars were cultivated also the third year (2022).

Table 1. List of soybean varieties included in field trials

	Cultivar	**Source of seeds**
1	Livius	Saatbau, Austria
2	GL Melanie	Saatzucht Gleisdorf GmbH, Austria
3	Obelix	Delley seeds and plants Ltd, Switzerland
4	Soy White	Not known
5	Chiba Green	L B Wannamaker Seed Co, SC, USA

6	Midori Giant	L B Wannamaker Seed Co, SC, USA
7	Natsukono Hitomi	Vilmorin-Mikado, France
8	Gokuwase Osaya	Vilmorin-Mikado, France
9	Wase Kaorihime	Vilmorin-Mikado, France
10	Dame Hanae	Sakata, France
11	Fiskeby	Sweden
12	Abaca	GmbH, Austria

2.1.2 Cultivation and Harvest of Soybeans

All three years, the experiment followed a randomized complete block design, with soybeans grown in three blocks. Within each block, there were plots, each 10 x 10m in size (2020) or 10 x 15m (in 2021 and 2022), and in each plot a specific cultivar was sown. However, in the 2020 trial, due to a limited supply of seeds for three cultivars one plot was subdivided into three parts, each 10 x 3.3m in size.

Väderstad´s planter 'Tempo'was used for sowing. Seedbeds were prepared before sowing (ploughed and harrowed). In 2020, the sowing took place on May 28, and in 2021, on June 4. The last year, 2022, the seeds were sown on May 3. The sowing date was determined by soil temperature and access to the planter.

The sowing depth for all cultivars was 3 cm, with a row spacing of 50 cm. In 2020, two different sowing densities were used, 60 seeds/m^2 (standard soybean cultivars and 'Soy White') or 20 seeds/m^2 (edamame cultivars; Table 2). The germination rate of the different cultivars can be seen in Table 2. In 2021, two different sowing densities were used, 30 seeds/m^2 or 60 seeds/m^2, and in 2022 60 seeds/m^2 were sown. After sowing 2020 and 2021, the seedbeds were covered with nonwovens for protection against birds, and the cover was removed approximately three weeks later. Weed control measures included the application of the herbicide Cleravo (BASF) and mechanical weeding. Seeds were inoculated with *Bradyrhizobium japonicum*. Different types of fertilization were applied to study the effect on yield and quality. Fertilization at sowing included the application of 30 kg N/ha, provided as NPK (2020, 2021, 2022) or N27 (2021). In 2022 also PK was applied.

Table 2 Seed germination rates of different cultivars in the 2020 field trial

Plot No	Cultivar	Seed/m^2	No of plants/m^2	No of plants/m^2	No of plants/m^2
			Block I	Block II	Block III
1	GL Melanie	60	55	50.5	54.5
2	Livius	60	44.5	56	53.5
3	Fiskeby V	60	5	2.5	9
4	Soy White	60	18.5	21.5	23
5	Obelix	60	19.5	26.5	28
6	Chiba Green	20	6	2	1.5
7	Midori Giant	20	4	2,5	1.5
8a	Natsukono Hitomi	20	21	21	19.5
8b	Gokuwase Osaya	20	22	18	23
8c	Wase Kaorihime	20	22.5	20.5	19
9	Dame Hanae	20	14	8.5	10.5

During the summer, the growth of the soybean plants was evaluated multiple times. In 2020, the soybean was harvested twice, on September 15 and September 24, using Foodhill's pea harvester (Ploeger). Half of the plot was harvested each time. Following the harvest, the beans were transported to Foodhills AB in Bjuv for further sorting and handling, and the yield was noted. However, due to non-optimal setting of the thresher, a large amount of waste was generated, thus affecting the yield. In 2021, the soybean was harvested on September 29 using the same machinery. However, for calculation of yield, pods were harvested manually. In 2022, due to insufficient weed control, soybeans were only manually harvested, but at two dates. All harvested beans samples were frozen for analysis of nitrogen (protein) levels. In the present thesis, previously collected data from the field trials were analysed statistically to identify superior cultivars.

2.2 Sensory Evaluation: Colour, Taste, and Texture of Vegetable Soybeans

A sensory evaluation was conducted at Foodhills on October 26 and December 3, 2020, for all cultivars grown 2020, except ‘Chiba Green’ which had a very low yield. In February 2022, a second sensory evaluation was conducted for the four cultivars grown 2021. Two imported edamame samples obtained from ICA and Coop supermarkets were used as reference samples. At harvest, the beans were transported to Foodhills, and after weighing and sorting, they were blanched, manually shelled and then frozen until the sensory evaluation.

For the sensory evaluation, the frozen edamame samples were kept at 4°C for 24 hours before boiling. On the evaluation day, the beans were boiled for 5-10 minutes and then placed in serving containers before being distributed to the survey participants.

The participants, six people both years, were not part of a trained panel, but were recruited from the project group and Foodhills . The evaluation was a blinded test, meaning that the participants were kept unaware of the samples’ identities. As the cultivars were grown in three different blocks, there were three replicates per cultivar. Each participant was asked to evaluate five characteristics of each sample such as colour, sweetness, chewiness, taste, and off-taste and then to score them on a 5-point rating system (1 - disliked, and 5 - highly liked). In the present thesis, previously collected data from the sensory evaluations were analysed to identify superior cultivars.

2.3 Analysis of Protein Content

2.3.1 Sample Collection and Storage

Altogether 81 soybean samples, representing the four cultivars Livius, GL Melanie, Obelix and Abaca, were analysed for nitrogen and carbon content. The samples were equally distributed as: 36 samples harvested on September 25, 2021, 24 harvested on September 9, 2022, and 21 harvested on September 15, 2022. Three imported soybean varieties were used as reference samples, obtained from ICA, Willys and Coop supermarkets. All samples were mixed and used in a single analysis of protein content. The harvested beans were frozen at temperatures ranging from -18°C to -20°C until the start of the test.

2.3.2 Milling, Drying and Weighing

Before starting the test, the frozen edamame samples were first thawed under normal cooling conditions. They were then freeze-dried for 2 to 3 hours to remove the condensation. To determine moisture content, a smaller amount of the samples was weighed and placed in an oven at 105°C overnight. After drying, the weight differences were measured to calculate the water content.

The rest of the seed samples were kept in whole form and then ground into powder using a ball miller (Oscillating Mill MM400, Retsch GmbH, Germany) at 3000 rpm for 2 minutes. After grinding, the powder samples were stored in labelled Eppendorf tubes and subjected to moisture removal by placing them in an oven at 60°C for 2 hours. They were then transferred to a desiccator to cool down.

To analyse the protein content, 3-5 mg of ground edamame samples were measured using a microscale (Mettler Toledo XP6 Micro Balance). The measured seed samples were placed in tin capsules, carefully sealed using tweezers, and weighed to obtain the final weight. This weight data was uploaded to LabX software. Two replicates were made for each sample.

Nitrogen and carbon quantification were made using the Elemental Particle Analyser (EPA, Flash 2000 Elemental Analyzer, Thermo Scientific) method. Acetanilide and alfalfa were used as reference samples. All measurement data were uploaded into the Eager Smart software, and a table was created following the specified format. The prepared samples were loaded into the Flash 2000 N/C detector after all checking processes were completed, and leakages were checked. All the samples were loaded, and the program was run to extract all data for nitrogen values upon completion. Total protein was calculated from measurements of nitrogen using a Nitrogen-to-Protein Conversion Factor (NPCF) 5.71. This conversion factor has been used in other studies to calculate the total protein content of the analysed soybean samples (Krul 2019).

2.4 Assessing and Understanding Consumer Preferences and Potential Demand for Edamame

A questionnaire was developed in order to understand consumer awareness of edamame and possible purchasing behaviour, as well as to establish market strategies based on consumer attitudes towards edamame consumption. The survey consisted of 12 exploratory questions, grouped as follows, demographics (1-2), current food consumption behaviour (3), purchase intentions for foods (4), edamame consumption behaviour and attitudes towards vegetable protein consumption (5-10). The questionnaire ended with two questions concerning conviction about climate change and diet change in relation to the climate change (11-12). All questions were closed-ended and multiple-choice (Appendix 1).

Before commencing the survey, I adhered to the Swedish University of Agricultural Sciences' policy on the Processing of Personal Data (Processing of personal data at SLU | Externwebben). For this survey, the non-probability convenience sampling method was chosen. Voluntary participation was encouraged, and a web-based survey platform was utilized to distribute the questionnaire, with the survey link directly emailed to SLU students in Alnarp. 323 people in all were chosen to get the survey; 17% of them responded. The survey was conducted from April 16 to April 30, 2024, with a reminder sent on April 28, 2024, to ensure participants had the opportunity to answer all questions.

2.4.1 Insights from Expert Interview on Soybean Cultivation

To gain insights into soybean cultivation practices in Sweden, an interview was conducted with a researcher specializing in soybean field trials. The purpose of the interview was to gather expert opinions and detailed information about current practices, challenges, and advancements in soybean cultivation.

A set of structured questions was used, focusing on various aspects of soybean cultivation, including techniques, challenges, and regional considerations (Appendix 2). The interview was conducted with Lotta Nordmark, a researcher at SLU (Biosystems and Technology), on April 25, 2024. During the interview, I asked the prepared questions to gather qualitative insights.

The information obtained from the interview was primarily used in the discussion section of the report to provide context and depth to the findings from the field trials. This interview provided essential insights into field trials and quality assessments, which were utilized in interpreting and discussing the results.

2.5 Statistical Analysis

All field data, sensory evaluations, and protein content measurements are reported as mean values. Field data and protein content were analyzed using analysis of variance (ANOVA). Soybean pod weight and bean weight were analyzed using Minitab one-way ANOVA with significance set at $p < 0.05$. Protein content data were analyzed using the General Linear Model (GLM).

3. Results

3.1 Field Trials

3.1.1 Analysis of Vegetable Soybean Yield

Statistically significant differences were observed in pod and bean weight among the cultivars, as indicated in Table 3. ‘Obelix’ showed the highest value for pod weight/ha for the harvest date September 15, 2020, followed by ‘GL Melanie’ and ‘Livius’ (Figure 1). The later harvest date, September 24, resulted in lower pod weight compared to the first harvest. For bean weight, the second harvest date resulted in higher bean weight kg/ha, with ‘GL Melanie’ having the highest values, followed by ‘Obelix’ and ‘Livius’ (Figure 2). The edamame cultivars ‘Soy White’, ‘Wase Kaorihime’, ‘Dame Hanae’, ‘Gokuwase Osaya’, and ‘Natsukono Hitomi’ consistently showed lower production. ‘Chiba Green’ and ‘Fiskeby’ exhibited very low pod and bean weight, whereas ‘Midori Giant’ did not produce a measurable yield (Figure 1, Figure 2).

Table 3. Main statistical parameters of the soybean harvest of the 2020 field trial with two harvesting dates. Cultivars analysed:, Livius, GL Melanie, Obelix, Fiskeby, Soy White, Midori Giant, Chiba Green, Natsukono Hitomi, Gokuwase Osaya, Wase Kaorihime, Dame Hanae.,

		2020.09.15				2020.09.24			
		Pod weight		Bean weight		Pod weight		Bean weight	
Source	DF	F value	P value	F value	P value	F value	P value	F value	P value
Cultivar	9	3.24	0.014	20.26	0.000	4.76	0.002	5.14	0.001
Error	20								
Total	29								

Significant at $p < 0.001$ according to the analysis of variance (ANOVA)

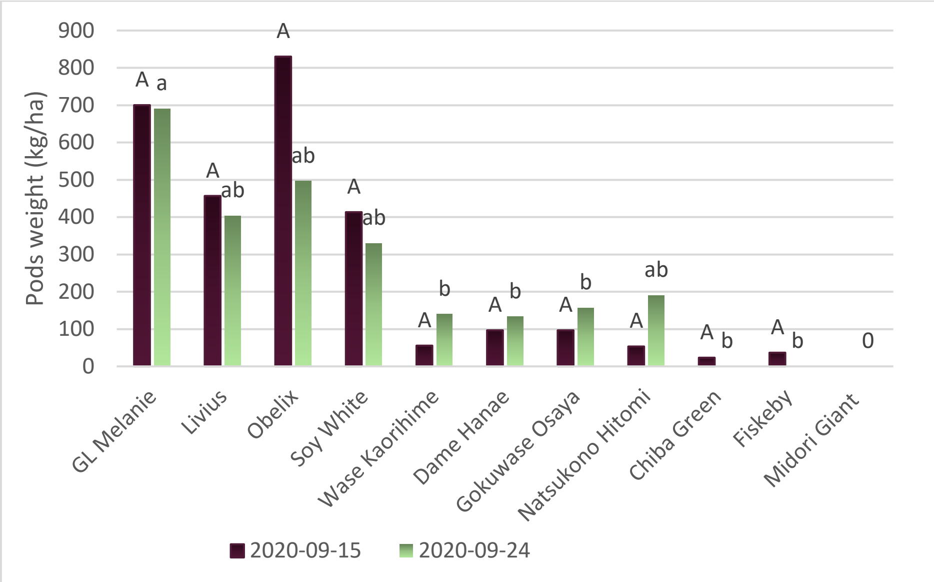

Figure 1. Mean vegetable soybean fresh pod weight in the 2020 field trial on two harvesting dates (2020.09.15 and 2020.09.24). Weights are given as kg/ha. Means for a specific harvest date marked with the same letter are not significantly different at p < 0.05 according to Tukey's HSD test

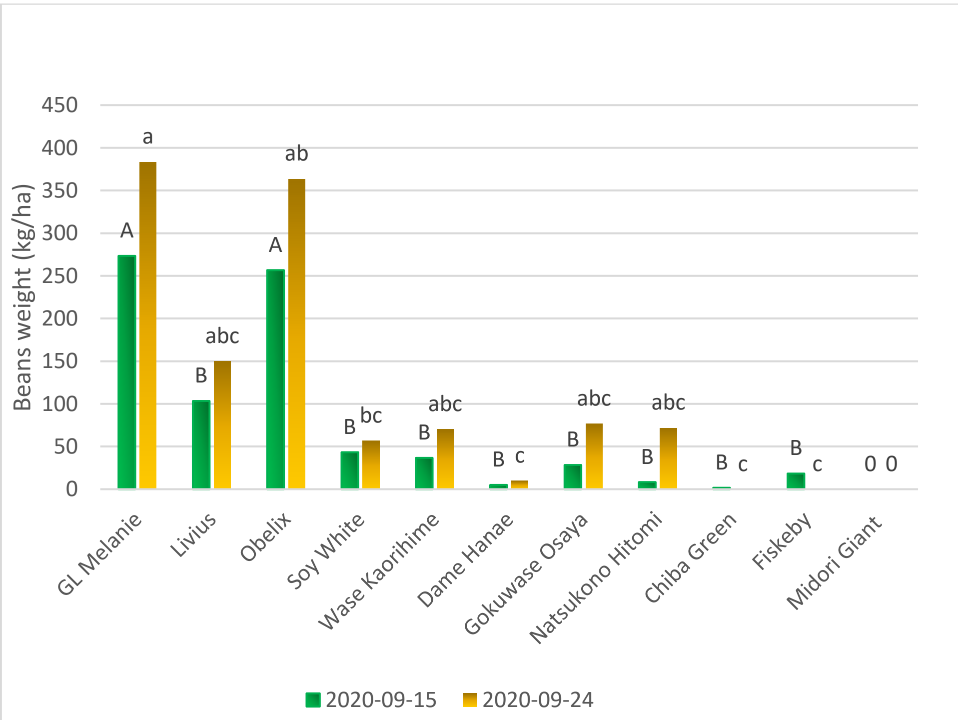

Figure 2. Mean vegetable soybean fresh bean weight in the field trial 2020 on two harvesting dates (2020.09.15 and 2020.09.24). Weights are given as kg/ha. Means for a specific harvest date marked with the same letter are not significantly different at p < 0.05 according to Tukey's HSD test

In 2021, pod and bean weight were examined for the four cultivars 'Obelix', 'Livius', 'GL Melanie', and 'Abaca'. The cultivars showed statistically significant differences in pod weight and bean weight, as shown in Table 4. The cultivar 'Obelix' showed the highest mean pod and bean weight, with 'Abaca' and 'Livius' following closely behind (Fig. 3). 'GL Melanie' showed somewhat lower pod and bean weights compared to the other three cultivars.

Table 4. Main statistical parameters of the soybean harvest of the 2021 field trial. Cultivars analysed: Livius, GL Melanie, Obelix, Abaca

		2021			
		Pod weight		Bean weight	
Source	DF	F value	P value	F value	P value
Cultivar	3	3.19	0.037	3.07	0.042
Error	32				
Total	35				

Significant at $p < 0.05$ according to the analysis of variance (ANOVA)

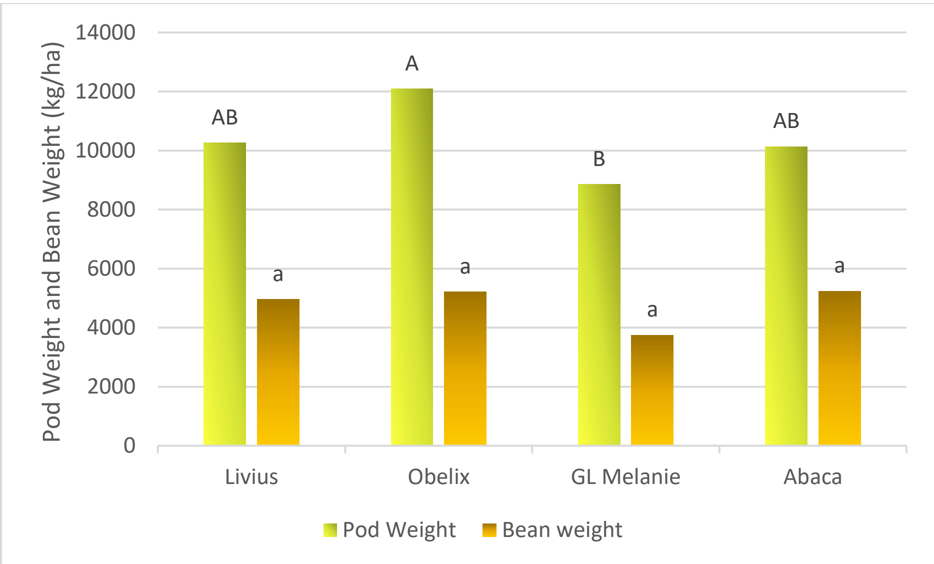

Figure 3. Mean vegetable soybean fresh bean and pod weights in the field trial 2021, harvested on 2021.09.29. Weights are given as kg/ha. Means for pod weight or bean weight marked with the same letter are not significantly different at p < 0.05 according to Tukey's HSD test.

3.1.2 Quality Analysis of Soybean Cultivars

Evaluation of colour, taste, texture, and off-flavours

For beans harvested 2020 and 2021, quality analyses were performed to identify the most preferred soybean cultivar. For comparison, reference samples bought in the store were included.

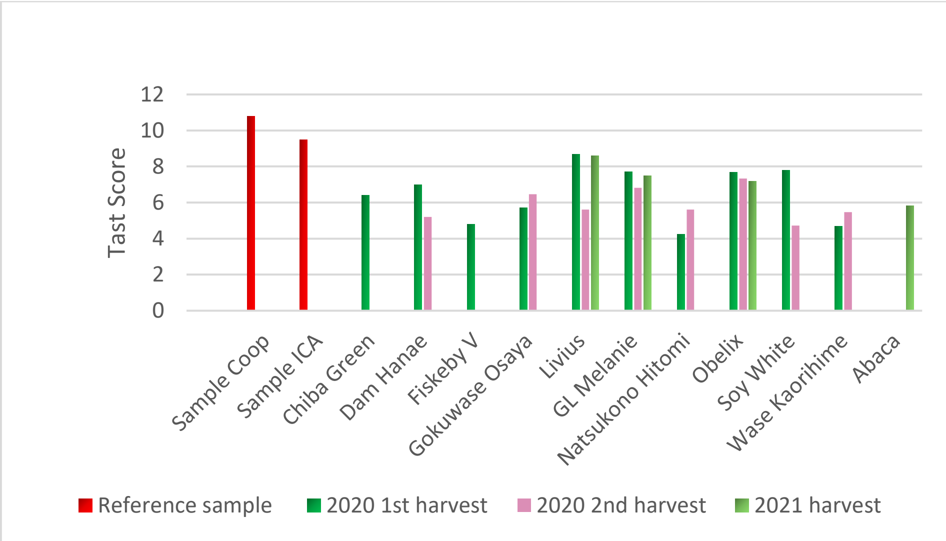

Figure 4. Mean preference scores for soybean cultivars cultivated 2020 and 2021, in comparison to reference samples. The score is a weighted average of colour, taste, texture and off-flavours.

Figure 4 shows taste scores for various soybean samples across different harvesting periods, with higher values indicating a more delicious taste, better colour and texture, and no/low level of off-flavours. The reference samples showed the highest score compared to all other cultivars, with the samples from Coop and ICA achieving scores of 10.8 and 9.5, respectively. ‘Livius’ demonstrated high scores across multiple harvests, scoring 8.68 in the 2020 first harvest and 8.60 in the 2021 harvest, indicating a high-quality profile. In the 2020 first harvest, ‘GL Melanie’, ‘Obelix’, and ‘Soy White’ showed good quality, though not as high as ‘Livius’. However, for the 2020 second harvest, there was a pronounced reduction in quality level for ‘Livius’ (5.62) and ‘'Soy White’ (4.73), clearly indicating the importance of an optimal harvest date. ‘Gokuwase Osaya’, ‘Natsukono Hitomi’ and ‘Wase Kaorihime ’ showed a somewhat higher quality score for the second harvest compared to the 2020 first harvest, indicating that these cultivars need a longer time in the field to develop a higher quality. Overall, ‘Livius’ stands out as the top performer due to its higher scores, but also 'GL Melanie', 'Obelix', and 'Soy White' seems to be good candidates. However, the harvest date is important for the quality.

3.1.3 Analysis of Protein Content

In the 2021 field trial data, there were no significant differences in protein content among the cultivars tested (P > 0.05) or between the different fertilizer applied (NPK or N27) (P > 0.05). However, there was a significant interaction between cultivar and fertilizer (P < 0.05). This indicates that the effect of fertilizer on protein content depended on the specific cultivar, highlighting the varying responses of different cultivars to the fertilizers used.

Table 5 Main statistical parameters of the protein analysis of the 2021 field trial and the 2022 field trial with two harvesting dates. Cultivars analysed: GL Melanie, Livius, Obelix and Abaca. Fertilizers used: NPK, PK, N27

	2021				2022 1st harvest				2022 2nd harvest			
Factor	Effect	DF	F value	P value	Effect	DF	F value	P value	Effect	DF	F value	P value
Cultivar (Cv)	NS	3	0.38	0.765	**	3	6.65	0.004	***	3	34.57	0.000
Fertilizer (Fer)	NS	1	0.07	0.790	*	1	4.87	0.042	NA	1	2.21	0.156
Cv * Fer	*	3	3.13	0.041	NA	3	0.39	0.764	NA	3	1.59	0.231

NS., not significant; *** significant at p < 0.001, ** significant at p < 0.01, and * significant at p < 0.05, according to the analysis of variance

In the 2022 field trial both the first and second harvest date showed that cultivar had a significant effect on protein content (P < 0.01). However, during the second harvest, the fertilizer type (NPK or PK) did not significantly affect protein content (P > 0.05). In contrast, the first harvest showed a significant difference in soybean protein content based on the fertilizer used (P < 0.05), with NPK fertilizer resulting in the lowest protein levels. There was no significant interaction between cultivar and fertilizer observed for either harvesting date (P > 0.05).

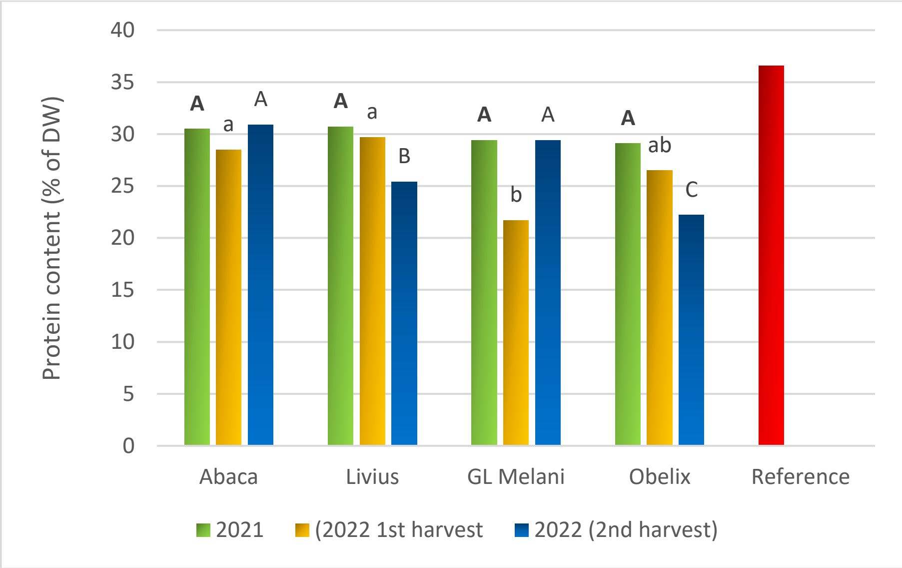

Figure 5. Average protein content of vegetable soybeans for the 2021 and 2022 harvests, including imported samples from ICA, Willys and Coop supermarkets. Protein values indicate the percentage of protein content (% of DW). Means for a specific harvest date marked with the same letter are not significantly different at p < 0.05 according to Tukey's HSD test.

In 2021, protein content ranged from 29.1% to 30.7% for the cultivars tested (Fig. 5). In 2022, there were two harvesting dates, with protein percentages ranging between of 21.7% and 30.9%. The reference, however, had the greatest value, 36.6%.

Among all cultivars, the highest protein content in 2022 was shown by 'Abaca' (30.9%, second harvest), closely followed by 'Livius' (30.7%, first harvest). 'Abaca' demonstrated consistent performance with high protein content in both 2021 and 2022 (second harvest). Also 'Livius' showed high levels both in 2021, and in 2022 (first harvest). For 'Abaca' and 'Livius', there was a considerably lower protein content for the first and second harvest, respectively, showing the importance of harvesting the beans on the optimal date. Also 'GL Melanie' exhibited significant variability, with a lower protein content in the first 2022 harvest (21.7%) compared to 29.4% in the second harvest, whereas 'Obelix' showed a lower protein content in second harvest (22.2%).

3.2 Consumer Awareness and Potential Demand for Edamame

3.2.1 Demographic Profile and Awareness of Edamame

The demographic characteristics of the respondents who completed the questionnaire during the survey period (N = 55) are presented in Table 6. The survey had a significantly higher response rate from females, comprising 80% of the participants, while males only made up 20%. The age range data showed that the majority of the participants were between 25 and 34 years old (63.6%). Most participants followed a balanced diet including both plant-based and animal-based foods (54.5%). A significant portion of the participants was vegetarians/vegans (41.8%), while only a small fraction adhered to a mostly meat-based diet (3.6%). There seemed to be a high level of awareness about edamame among the participants, with 90.9% indicating they know what edamame is. Only a small portion of the participants was either unaware or unsure about edamame, 7.3% and 1.8%, respectively (Table 6).

Table 6. Demographic description of the participants (N=55) in the survey about vegetable soybean sent out to SLU students on 2024.04.16.

Characteristic	Possible answers	Percentage of participants (%)	Count
Gender	Female	80	44
	Male	20	11
	Other		
Age range	Under 18 years old	0	0
	18 -24	18.2	10
	25 -34	63.6	35
	35- 44	12.7	7
	45 - 54	3.6	2
	55 -64	1.8	1
	Above 65	0	0
Meal description	Vegetarian/Vegan	41.8	23
	Balanced diet including both plant-based and animal-based foods	54.5	30
	Mostly meat-based diet	3.6	2
Awareness of edamame			

I am aware of edamame	90.9	50
Do not know about edamame	7.3	4
Not sure	1.8	1

3.2.2 Factors Influencing Customers When Purchasing Edamame

The survey results indicate that price was the most important factor for participants when buying edamame, with a total of 25 rating it as important and 12 as very important (Figure 6). Organic labelling also holds considerable importance, as 20 participants considered it important and 7 very important. Locally produced edamame showed a similar level of importance, with 16 participants rating it as important and 11 as very important. Appearance was somewhat lower valued, with 25 participants acknowledging its importance. The type of edamame (pod or beans) was the least prioritized factor, with 20 participants finding it important and only 4 very important (Figure 6). Overall, the data revealed that while price was the predominant concern, organic labelling and local production were also significant, whereas the specific type of edamame was less critical in the decision-making process.

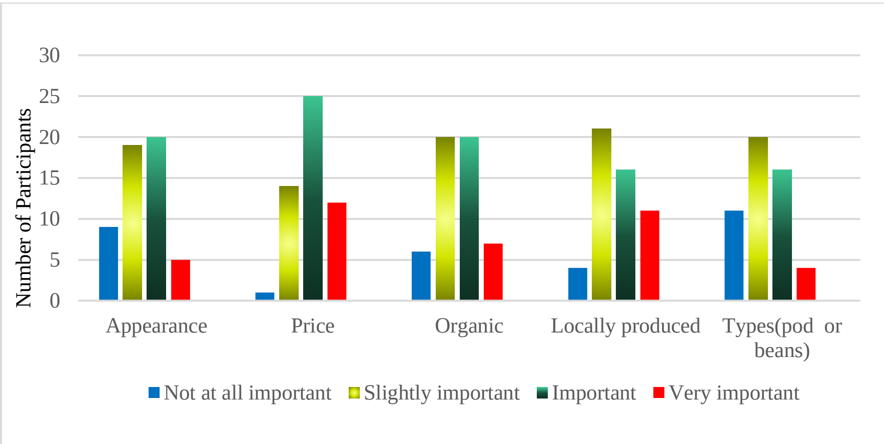

Figure 6. Key factors that influence customer decisions when purchasing edamame

To evaluate the participants' thoughts about ongoing climate change, two questions were included (Appendix 1). Most people, around 60%, firmly believed that reducing meat consumption is good for the environment (Figure 7). Another significant group, about 22%, felt moderately convinced of this idea, while 14.5% were somewhat convinced. However, a small minority, only 3.6%, remained unconvinced about the positive impact of reducing meat consumption on the climate.

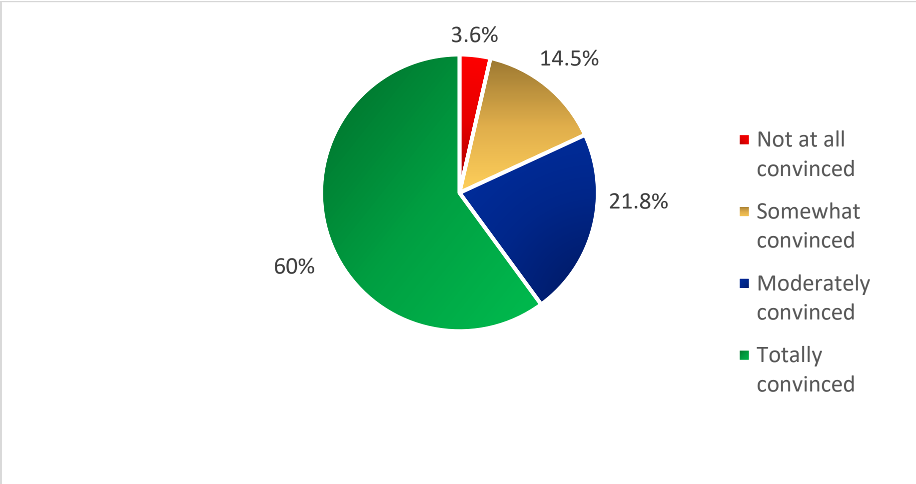

Figure 7. Level of conviction about the climate benefits of reducing meat consumption and increasing vegetarian food intake

4. Discussion

Although edamame is an East Asian crop, it is gaining popularity worldwide due to its high nutrient content and pleasant taste. Understanding this trend in Europe, total soy production, including the production of vegetable soybean, is projected to expand by up to 10%, reaching 5.6 million hectares. As a result, many European countries, including those in Northern Europe, are engaging in the cultivation of vegetable soybeans (Guttenberg, 2024).

Edamame consumption is increasing in the Swedish community. In our survey, which included only agricultural students, 90.9% of participants were aware of edamame. It is worth pointing out that awareness levels could be much lower in another demographic group. For instance, in the USA, during the early stages of cultivating edamame in 2002, 17% of survey participants were familiar with or had heard about edamame, and only 12% had tried it (Kelley & Sánchez 2005). Also, our survey results showed that 41.8% of respondents are vegan or vegetarian. In contrast, the latest survey statistics in Sweden indicate that around 10% of the population are either vegan or vegetarian (Ridder 2021). The survey results also indicate that 63.4% of participants are from the younger generation, belonging to the 24-34 age group. Research in Sweden indicates that there is a noticeable increase in vegetarianism and veganism among the younger generation (Ridder 2021). As a potential plant-based protein alternative, edamame has a great possibility of becoming popular in the Swedish society. After knowing about the nutrients and health benefits of edamame, 92% of the respondents in the American survey indicated they would like to buy edamame (Kelley & Sánchez 2005).

The complex interaction between climatic and agronomical elements is essential to the production of vegetable soybean. It is quite difficult to maintain the environmental conditions necessary for successful cultivation. Temperature is one of the most significant factors in seed germination, which directly affects the final yield. The ideal soil temperature for growing soybeans is found to be about 10^0C (Begum et al. 2022). In our study, laboratory trials showed a 70% germination rate, whereas the field trial germination rate was notably lower (Table 2). The seeds of 'Fiskeby V' were quite old, which could have affected the germination. Another possible cause of the poor germination rate in the field trial could be temperature, as edamame cultivars are somewhat sensitive to temperature at sowing. To overcome this problem in the future, transplanting experiments can be conducted in the field. A Latvian trial found that, under optimal hydrothermal conditions, growing vegetable soybeans using transplants instead of direct sowing could be a viable technology. This method helps address soil moisture deficiencies that are crucial for successful seed germination (Zeipiņa et al. 2022).

The germination rate was low, and in combination with birds probably feeding on soybeans despite initial covering with nonwovens, the plant density was significantly impacted in the 2020 field trial. Fogelberg & Mårtensson (2021) stated that the 2021 Skåne trial also had a high rate of bird feeding. In the present study, ‘GL Melanie’ and ‘Livius’ exhibited the highest germination rates in the field, which likely contributed to their higher yields in 2020. However, ‘Midori Giant’, ‘Chiba Green’, and ‘Fiskeby V’ exhibited a 12% lower germination rate, possibly contributing to very low yields in the first year of the field trial. Conversely, ‘Gokuwase Osaya’, ‘Natsukono Hitomi’, and ‘Wase Kaorihime’ also showed relatively high germination rates, but their overall yields were very low in the first field trial. Fogelberg & Mårtensson 2021 reported that in the Skåne trial of 2017, ‘Chiba Green’ and ‘Midori Giant’ showed pod weights of 2,300 kg/ha and 2,400 kg/ha, respectively, but suffered from high bird damage. Conversely, in the Öland trial of 2016, ‘Chiba Green’ and ‘Midori Giant’ produced the highest yields at 4,170 kg/ha and 4,330 kg/ha (Fogelberg & Mårtensson 2021). ‘Midori Giant’ and ‘Chiba Green’, also showed a high yield performance in field trials conducted in Latvia (Zeipiņa et al. 2022). These results indicate that there seems to be a yearly effect, but also that the location has an impact on the yield. Another possible explanation to these deviating results between studies might be the efficiency of weed control. It is possible that true edamame cultivars are more sensitive to competition from weeds, especially at their Northern cultivation limit. In the field study described in this thesis, the weed control was insufficient which might have affected the yield for the edamame cultivars. Considering the numerous shortcomings observed during the 2020 and 2021 field trials, it is imperative to conduct a subsequent field trial to validate the findings conclusively.

Based on the first year's (2020) field data, the varieties 'Livius', 'GL Melanie', and 'Obelix', along with the new variety 'Abaca', were selected for the second field trial in 2021. The results indicated that all cultivars are suitable for cultivation in Sweden under the current climatic conditions. According to the data, 'Obelix' yielded 5,213 kg beans/ha, while 'Abaca' yielded 5,238 kg/ha, and 'Livius' yielded 4,957 kg/ha. 'GL Melanie' had a somewhat lower yield of 3,749 g/ha. Therefore, the bean yield per hectare can be estimated to be around 5 tons. In Germany, commercially cultivated vegetable soy bean yields range from 3 to 4 tons per hectare (Beesten 2023). Consequently, cultivating vegetable soybean in Sweden is feasible under optimal conditions. These findings challenge previous assumptions about the difficulty of growing vegetable soybean in high-latitude regions due to daylight phenomena.

Another crucial point is the selection of true edamame cultivars alongside standard soybean cultivars. The cultivars in the present study that gave the highest yields are classified as standard soybean cultivars, whereas the true edamame cultivars all performed at a low level. This suggests that a successful cultivation of vegetable soybeans in Sweden should be based on standard soybean cultivars instead of true edamame varieties, provided that they show good product quality.

In the first field trial (2020), soybean yield was significantly lower, attributed to the use of a pea harvester for soybean harvest. Normal pea harvesters did not effectively remove the bottom layers of soybean pods due to their position close to the ground (Carson et al. 2011). Costa et al. (1980) suggest that narrower rows may sufficiently raise the lowest pod height. Alternatively, using snap bean harvesters could potentially enhance the efficiency of edamame harvesting (Carson et al. 2011). Also, the thresher used in the present study affected the bean yield, as a large number of beans and beans still in pods were sorted as waste. Possibly, because of the firm and tough texture of the pod, the equipment failed to open the pods.

When it comes to edamame, overall quality is crucial, and ‘Livius’, along with ‘GL Melanie’ and ‘Obelix’, showed better quality metrics than any other types. However, the quality panel was not trained, and the group size was small, which could affect the results. Therefore, in the future, edamame quality should be assessed with a trained panel. However, the harvesting date is a significant parameter that affects quality. For example, in our trials, ‘Livius’ showed high quality when harvested after 111 days, but the quality decreased considerably when harvested after 119 days.

Other field trials in Northern Europe, such as those in Latvia, showed that the vegetation period should be at least 123 to 127 days (Zeipiņa et al. 2022). This contrasts with our field trial results. Additionally, ‘Abaca’ showed the lowest performance in quality parameters. This variety exhibited a yellowish colour when evaluated, indicating over-maturity, which resulted in an unpleasant taste. Delayed harvesting can increase the lipid content in soybeans, and high lipid levels can result in an unpleasant taste in edamame (Costa et al. 1980; Wszelaki et al. 2005). This suggests that ‘Abaca’ should be harvested earlier than other varieties due to its early maturity. Considering these points, it can be concluded that each cultivar has its own optimal harvesting date. Additionally, the research indicates that harvest timing and production practices influence edamame quality (Wszelaki et al. 2005).

For the protein content, ‘Abaca’ demonstrated consistent performance with high protein content (30.9%) in both 2021 (30.5%) and 2022 (28.5% and 30.9%). However, this cultivar was as stated previously, somewhat more mature than the other cultivars. The protein level might have increased as the beans matured. Jaureguy et al. (2013) indicate that early planting or delayed harvesting can increase the protein content of soybean cultivars. According to Carson et al. (2011), standard soybean cultivars contain between 33.1% and 49.2% protein. In the present study, the cultivar and fertilizers caused significant differences in the protein content for some harvest dates, but not for others. Rotundo & Westgate (2009) have shown that water stress, temperature, and nitrogen supply can significantly affect the protein content of soybeans.

Despite the agronomic potential, practical and economic challenges remain. An interview with Lotta Nordmark, a lecturer responsible for vegetable soybean field trials at SLU (Biosystems and Technology), indicates that farmers and middlemen[1] show low enthusiasm for starting soybean cultivation in Sweden. Novel crops in the field frequently spread across farm areas, although occasionally the agricultural market can be challenging (Paarlberg et al. 2024). The involvement of middlemen significantly affects soybean cultivation because infrastructure facilities are crucial for successful cultivation (Marimin et al. 2010). For instance, the harvesting date as well as post-harvest treatments like an early blanching and freezing of the beans are critical (Xu 2017). This requires specific machinery, which individual farmers may not afford. Large-scale companies in Sweden already possess this machinery. Sweden is experiencing a growing interest in pea production, with many agricultural companies increasingly involved due to high demand and profitability. In 2022, Lantmännen[2] invested over 1 billion SEK in a new pea protein facility in Sweden to boost their lead in Northern Europe's plant-based protein market (Vegconomist 2022). Both peas and soybeans require cultivation during the summer, making it difficult to harvest at the right time using the same equipment. For proper storage, edamame samples require refrigeration, and an early blanching is also necessary. When harvesting peas and vegetable soybean simultaneously, their harvest periods can overlap. To mitigate this risk, strategic planning and support from agricultural extension services and middlemen are essential. Creating parallel farming lines for vegetable soybean could help integrate it into the existing agricultural calendar without disrupting established practices.

Another significant point is that imported edamame beans can be purchased for between 20 to 24 SEK per kilogram in supermarkets. A Swedish production of vegetable soybean would initially be somewhat expensive. Survey results indicate that 50% of consumers consider price an important factor, and 24% consider it a very important factor. Therefore, if the price is crucial to the customer, it could be difficult to introduce a Swedish produced edamame to the market.

1, Middlemen are intermediaries who facilitate the distribution of products and value addition from farmers to consumers

2, Lantmännen, the largest agricultural competitor in Northern Europe, is an agricultural cooperative.

Research has indicated that in the US, nearly 30% percent of consumers prioritise price when making edamame purchases (Kelley & Sánchez 2005). Also, they have shown a preference for purchasing fresh, locally grown edamame over frozen varieties (Carneiro et al. 2022). Our survey indicates that 29% of participants are willing to purchase locally grown edamame, and 38% consider it slightly important. Considering these points, it is likely that in the future, customers will prefer to purchase locally produced edamame rather than imported varieties.

Performance metrics, including high yields, quality, and protein content, are quite high in imported varieties, with similar results observed in ‘Abaca’, ‘Obelix’ ‘GL Melanie’, and ‘Livius’. However, further research, such as plant breeding might be necessary to develop new desirable cultivars suitable for Sweden's climate conditions and with optimal performance (Bar-Zvi et al., 2017). Additionally, further field trials are essential, both regarding cultivar testing and cultivation practices.

According to the survey results, 60% of survey participants are highly convinced about the climate benefits of reducing meat consumption and increasing vegetarian food intake. Furthermore, Röös et al. (2022) indicated that the majority of consumers in Sweden are aware of the negative effects of meat on the environment and the positive health benefits of eating legumes. Therefore, further awareness programs and increased local crop production will help reduce Sweden's dependence on meat and imported products. Introducing plant-based protein sources like edamame can functionally replace animal products. Therefore, promoting edamame can be beneficial for promoting a sustainable diet in Sweden. Achieving a sustainable diet, as defined by the FAO, positively impacts the country's social, economic, and environmental sustainability, as well as animal welfare and food quality.

The sustainability benefits of cultivating vegetable soybean in Sweden are significant. As a leguminous crop, soybean enhances soil health through nitrogen fixation, reducing the need for synthetic fertilizers (Sharma 2013). Therefore, promoting vegetable soybean cultivation aligns with Sweden’s environmental goals and consumer trends towards a sustainable plant-based diet.

5. Conclusion

In conclusion, the study demonstrates that it seems possible to cultivate vegetable soybeans in Sweden. While the agronomic potential is evident, addressing the economic and practical challenges through strategic planning, farmer support, and market integration is crucial for establishing successful cultivation. The high level of consumer awareness and demand, coupled with the sustainability benefits, make this a strong case for the introduction of vegetable soybean as a viable crop in Sweden. Future research should focus on optimizing cultivation practices, evaluate yield and quality aspects of a wider collection of plant material, enhancing consumer education, and ensuring economic viability to fully realize the potential of vegetable soybean in the Swedish agricultural landscape.

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7. Popular Science Summary

Soybean harvested in its green and crunchy stages is known as vegetable soybean or edamame. Edamame originated in China, but due to its high nutrient content and delicious taste, it has become popular worldwide. The USA, now the world's leading producer of vegetable soybeans, has started edamame cultivation, surpassing China in production.

Cultivating edamame is similar to regular soybean farming, but the harvesting time is different. Edamame is harvested 90 to 120 days after sowing while still green. Both edamame and mature soybeans are photosensitive short-day plants, meaning their flowering and maturity are regulated by the photoperiod, which varies with latitude. At higher latitudes, days are longer from spring to autumn, affecting soybean growth. Due to this sensitivity, Europe has not been heavily involved in soybean cultivation. However, certain soybean varieties, known as 000 varieties, are suitable for Europe.

Many European countries are growing edamame, but Sweden has not yet started. Although Sweden has a history of soybean cultivation dating back to the 1930s, currently there is no soybean farming in the country. However, before starting sustainable vegetable soybean cultivation, understanding the consumer market is essential, as preferences can vary due to different textures and flavours.

To explore the potential for cultivating vegetable soybean in Sweden, a field trial was conducted in 2020 using 11 standard soybean cultivars and edamame cultivars at Välingetorps Gård, near Ängelholm in the Northwestern part of Skåne. Based on yield data, a second and third field trial was conducted in 2021 and 2022 with selected high-yielding varieties. Soybean samples were frozen for sensory evaluation and protein content analysis. In 2024, consumer demand and preferences were identified through a web-based survey targeting SLU students.

Field trial data from 2020 showed that among the soybean varieties, ‘Obelix’, ‘Livius’ and ‘GL Melanie’ had the highest yields. These cultivars, along with ‘Abaca’, were cultivated also in 2021 and 2002. In contrast, true edamame cultivars had a low germination rate and yield. The 2021 field trial showed that all four cultivars performed quite well and gave relatively high yields, approx. 5 tons/ha. Sensory evaluation showed that ‘Livius’ performed best, although slightly lower compared to imported samples, whereas ‘Abaca’ had a somewhat higher protein content than the other cultivars. However, both quality and protein content were affected by harvest date, indicating the importance of determining the optimal harvest date. The consumer survey indicated that 90% of participants are aware of edamame. Price seems to be the most important factor when buying edamame, followed by organic labelling and locally produced beans. The survey results indicate that most people, around 60%, firmly believe that reducing meat consumption is good for the environment.

In conclusion, standard soybean cultivars can be cultivated successfully as edamame in Sweden and will give high yield under proper cultivation management. However, a proper plan involving stakeholders is essential before beginning cultivation. Since pea cultivation is common in the summer, machines, and facilities used for pea harvesting could overlap with soybean harvesting. Ensuring the quality of edamame requires careful attention to the harvesting date. Therefore, a proper plan is crucial before starting cultivation of vegetable soybean in Sweden. As a legume, soybean offers environmental benefits, and sustainable cultivation in Sweden can help achieve the country’s environmental goals.

Swedish Edamame

Is Local Production of Vegetable Soybean Possible?

Soybeans harvested in their green and crunchy stage are known as **vegetable soybeans** or **edamame** [8].

.

BACKGROUND

Edamame, meaning "hairy bean" in Chinese (mao dou), is a special type of soybean first cultivated in China over 2,000 years ago. Edamame belongs to the same species as standard soybeans (*Glycine max* (L.) Merr.), but is cultivated for its size, texture, and digestibility. Only the beans are edible, with pods typically containing two or three beans [7]. Edamame is available in fresh, frozen, roasted, or freeze-dried forms and is commonly enjoyed as a side dish. The global popularity of edamame is growing due to its high nutritional value, potential health benefits, and appealing taste [12].

In Sweden, soybean cultivation is limited due to the plant's sensitivity to day length (photoperiod).. In high-latitude regions, the day lengths often do not match the plant's needs, causing delayed flowering and lower productivity [8] [7]

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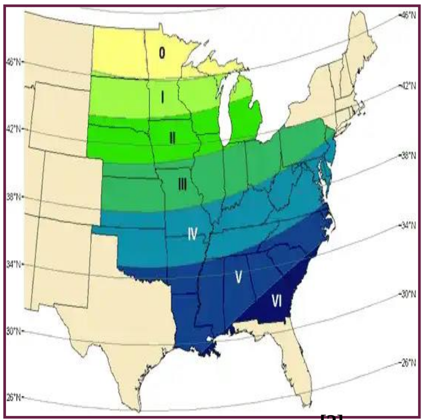

Figure 1. Soybean Maturity Groups [2]

- Soybean varieties are categorized into 13 maturity groups, from 000 to X.
- Group 000 contains cultivars that can be grown in regions with longer days.

Edamame in Europe

Recently, edamame has gained popularity in Europe due to its health benefits and nutritional value, leading to increased imports of frozen edamame. Despite generally low edamame production in Europe, Germany has recently developed successful cultivation, with yields ranging from 5 to 8 tons per hectare and up to 12 tons under ideal conditions [2]. Initiatives like the 'Growing Green Protein' project in the Netherlands, along with efforts by companies in Austria and Romania, are boosting edamame production [5]. Europe is increasingly embracing edamame, with advancements in cultivation by Dutch, Austrian, and German producers.

Importance of Understanding Consumers

Understanding consumer demand is crucial for successful product development and marketing [6].

Involving customers in product development enhances marketplace success [3].

Gathering data on local consumer needs, preferences, and motivations is essential [3].

This data helps tailor communications and guide stakeholders in the food value chain [l].

Why Edamame in Sweden?

- Eating fewer animal products and more plant-based foods, like vegetables, can greatly reduce the environmental impact, especially concerning climate change [9].
- Eating habits are formed early in life, so serving school meals with more vegetables and less meat can promote healthier and more sustainable eating habits in Sweden [9].
- Edamame, with its high protein content, could become an important crop in Sweden, contributing to a more sustainable food system [10].
- Locally growing edamame reduces the carbon footprint by cutting down on long-distance transportation, processing, and packaging, which are energy-intensive and contribute to climate impact [1].

Key Findings

- Standard soybean cultivars produce a viable crop yield of approximately 5 tons per hectare.
- Both the quality and protein content of vegetable soybeans are influenced by the harvest date.
- Survey participants are highly aware of edamame.
- Most survey participants consider 'locally grown' as an important factor for purchase.
- Survey participants are highly concerned about the price of edamame when making a purchase.
- A majority of survey participants believe that a vegetarian diet benefits the environment.

Conclusions

- It seems possible to cultivate vegetable soybeans in Sweden.
- Developing a strategic plan with stakeholders is crucial to establishing successful cultivation in Sweden.
- Consumer awareness and demand, along with sustainability benefits, make edamame a viable crop in Sweden.
- Promoting vegetable soybean cultivation aligns with Sweden's environmental goals and the shift towards a sustainable plant-based diet.

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10. Appendix

10.1 A Swedish Production of Edamame Beans

Introduction

My name is Dilshani, and I am a student at the Agroecology Master's program at SLU Alnarp. For my final year thesis, I am investigating the awareness of and attitudes towards vegetable soybeans (edamame) and whether it is possible to start a Swedish production. Therefore, I kindly request your participation by filling in the following questionnaire. Please note that the final data from this research will be published in my thesis.

Edamame, also known as vegetable soybeans, is tasty and packed with nutrients. These vibrant green pods are not just any ordinary beans, they're young soybeans harvested at the peak of their ripeness, bursting with wholesome goodness and a unique taste that's both familiar and exotic. This legume can be an addition to any diet, whether enjoyed as a snack, in salads, soups, or noodle dishes. Low in carbs and high in protein, edamame is gaining popularity all around the world. Edamame originates from Asian cuisines and has gained popularity in the USA due to its numerous health benefits. Furthermore, edamame is increasingly gaining popularity in Europe, with many countries already cultivating it. Today, frozen edamame is imported to Sweden, mostly from China. Sweden's climate is suitable for edamame cultivation, and if it were cultivated locally, fresh edamame could be made available in the Swedish market.

The aim of this survey is to assess consumers' knowledge of edamame and to identify what factors influence consumers when purchasing food products. Join us as we explore the awareness and willingness of Swedes to embrace this nutritious delicacy. Whether you're a seasoned edamame enthusiast or someone who's yet to discover its wonders, your input is invaluable in shaping the future of culinary exploration in Sweden. Let's dive into the world of edamame together and uncover the delicious possibilities that await us. Take a moment to share your thoughts, and let's make edamame a popular dish in Swedish households everywhere!

Questions

1. What is your gender?
   - Male
   - Female
   - Other

2. What is your age?
   - Under 18
   - 18 -24
   - 25 - 34
   - 35- 44
   - 45 - 54
   - 55 - 64
   - Above 65

3. Which of the following describes your meal / diet?
   - Vegetarian/vegan
   - Balanced diet including both plant-based and animal-based foods
   - Mostly meat-based
   - Specific diet (low calorie/ low sodium/ low cholesterol)
   - Other (please specify)…………..

4. How important are each of the following characteristics to you when purchasing foods?

	Not at all important	Slightly Important	Important	Very Important
• Low price				
• Good flavour				
• Healthy food				

- Nice packaging
- Origin
- Low price
- Good flavour
- Healthy food
- Nice packaging
- Origin

5. Do you know about edamame (vegetable soybean)?
    - Yes
    - No
    - Not sure

6. If yes, have you ever tasted edamame??
    - Yes
    - No

7. How often did you eat edamame in the past three months?
    - Never
    - 1 - 5 times
    - 6 - 10 times
    - 11 - 15 times
    - More than 15

8. How do you usually eat edamame?
    - I prepare it at home.
    - I eat it at the restaurant.
    - Other:……………

9. If you have never tried edamame before, how likely are you to purchase the vegetable named edamame, even if you have never eaten it before, given evidence that it has numerous health benefits?
    - Extremely likely
    - Somewhat likely
    - Neutral
    - Definitely not

10. If you were to buy edamame, which of the following factors would be important to you?

Not at all important   Slightly Important   Important Very Important

- Appearance
- Price
- Organic
- Locally produced
- Types (Pods or Bean)

11. How convinced are you that global warming (climate change) is taking place?
    - Not at all convinced
    - Somewhat convinced
    - Moderately convinced
    - Totally convinced

12. How convinced are you that it is better for the climate if you reduce your meat consumption and eat more vegetarian food?
    - Not at all convinced
    - Somewhat convincedModerately convinced
    - Totally convinced

10.2 Questionnaire for Interview with Researcher Lotta Nordmark

Barriers

1.What are the economic (Social/Environmental) barriers that demotivate Edamame cultivation in Sweden?

(High input costs, labor requirements, low facilities, low profit)

Would financial support help in addressing and mitigating these risks?

Collaborative Programs

1. Can any collaborative programs or partnerships be implemented with farmers for Edamame cultivation? (production plan, quality seeds, on time harvesters)
2. Is it possible to create a production plan by considering the monthly purchasing pattern of edamame
3. In the value chain of edamame which sector need to be target the to increase the Edamame production.

Farmers –Processors –Retailers- Consumers

Training and Assistance

1. Would you think offering training will improve your Edamame cultivation practices ?
2. Do you think it's possible to sell locally produced edamame at cheap prices? Will the price affect production?
3. Can customer demand increase production, or will it lead to more imports?
4. Which sector should be involved to increase production? Agricultural institutes, government, or processors?
5. Without growing, we can import edamame for cheap prices. Then why do we want to cultivate edamame in Sweden?
6. How can we achieve the sustainability through edamame cultivation ?
7. Without growing edamame varieties, do you think normal soybean varieties can be used as edamame? What do you think about it?

8. How do you see the future of edamame cultivation in Sweden, considering the identified challenges and potential solutions?
9. What role do research and development play in improving edamame cultivation techniques and overcoming production challenges?
10. How do other lupins and legumes cultivated in Sweden overcome environmental barriers?
11. After producing local edamame and releasing it to the markets, can we increase demand in both sectors (demand for production and demand for cultivation) through marketing?
12. Are there any regulatory or policy barriers that hinder the smooth flow of edamame through the value chain in Sweden?
13. What are the major challenges faced by farmers during the cultivation stage of edamame in Sweden?
14. How efficient is the transportation and logistics system for edamame from farms to markets in Sweden?
15. Are there any issues with storage facilities or infrastructure that affect the quality and availability of edamame in the market?

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