Sensory preference criteria and willingness to adopt vegetable soybean “Edamame” in Benin (West Africa)

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Abstract

Edamame, has many nutritional and human health benefits and is likely to overcome malnutrition, a common scourge among West African populations. This study aims to identify sensory preference criteria in order to select edamame varieties that meet the organoleptic needs of potential consumers in Benin. Ten soybean varieties were selected on the basis of their stability, adaptability and yield performance in Benin. These varieties were evaluated through hedonic test conducted with 200 untrained panelists, followed by a descriptive sensory evaluation conducted with 20 trained panelists. The hedonic test used sensory attributes such as appearance, flavor, taste, and texture. The study showed significant variation in sensory attributes for most genotypes ($P < 0.001$), expressing the variation in choices made by the panelists. The genotypes AGS 466, AGS 429, AGS 472, and Ashorowasse were the most preferred (more than 90%). Taking gender into account, AGS 466 and Ashorowasse were most preferred by women, who mainly based their choice on seed appearance and sweetness. In opposite, men were more interested in the taste and texture. Soybean varieties Maksoy 3N and Early hakucho were least preferred (less than 20%) by women and men, respectively. Respondents expressed a high willingness (90.11%) to adopt edamame. Preference criteria were large seed size, sweet taste, moderate chewiness, and starchy texture. The high-yielding grain-type soybean variety S1079/6/7 that showed moderate acceptability for edamame consumption among consumers in Benin may be considered by breeders for improvement in sensory attributes.

1. Introduction

Approaches to enhance food security in developing countries include the use of grain legumes, which provide quality proteins [1]. Fruits and vegetables are important dietary components that provide minerals and vitamins [2]. They are recommended as functional food elements that are necessary to enhance health and immune system [3]. Edamame, vegetable soybean (*Glycine max* L. Merr.), as a legume and vegetable, serve as a dual purpose crop, as it contains high protein, low fat [4; 5], high carbohydrates, high levels of essential minerals, vitamins and fiber [6], as well as many antioxidants and health promoting compounds [7; 8]. The crop is gaining interest in Africa because of its nutritional and health improvement attributes, which are greater than green peas [9]. As such, edamame is potential to fight against hunger, a plague affecting more than 45% of children under five years in Benin [10]. However, its utilization is very scarce in Sub-Saharan Africa, which carries 92.20% of the burden of undernourishment in Africa [11]. As endeavors to fight-off hidden hunger in Benin and beyond, the Legume Breeding Program at the University of Abomey-Calavi, has undertaken to introduce edamame production and consumption. The pleasure derived from consumption of a food product is an important key motivator in eating [12; 13]. Generally, the adoption of healthy diets by consumers proceeds through sensory experiences leading to general acceptability [14].

In the process of introducing a new crop into a food system, sensory evaluation is a necessary step [15]. Sensory evaluation pertains to assessing differences between products, reasons for preferences, overall acceptability and willingness to adopt and purchase [16]. Lawless & Heymann (2010) reported that, sensory and consumer studies help to identify the preferences for plants or varieties which determines the acceptability and willingness to consume the products. This is important as no instrumental method is able to fundamentally mimic human responses and perceive food products as humans do. Sensory evaluation is a multidisciplinary science that uses tasters and their senses of sight, smell, taste, touch and hearing to measure the sensory characteristics and acceptability of food products [18].

In edamame, many studies have been conducted to analyze the seed composition. Johnson et al (2000) who performed a proximal analysis of the nutritional composition of Japanese and Colorado vegetable soybeans; Mebrahtu (2008) identified genotypes with stable nutritional values over three years of study. Nutritional values such as fat, protein, fatty acid profile, and carbohydrates were compared on 31 genotypes grown at the Randolph Research Farm at Virginia State University, Petersburg, Virginia. Kaiser & Ernst (2013) ; Ntatsi et al (2018) ; KUNDGOL (2015); Masuda (1991) and many other authors have evaluated the nutritional composition of several vegetable soybean varieties. However, very few studies have specifically investigated the sensory characteristics of edamame Laxmibhai & Kulkarni (2016a) has examined seven varieties of vegetable soybeans for physical, chemical and sensory parameters. In the A. Wszelaki et al (2005) study, six vegetable soybean varieties were compared using consumer tests and descriptive analysis.

In general, acceptable immature soybeans possess favorable sensory characteristics such as large seeds, sweet, smooth texture, high digestibility and good taste [27]. Sweetness is one of the most important attributes for vegetable soybean, it remains the primary quality criterion for edamame [19]. According to Carneiro et al (2020), sweetness is a major sensory attribute that leads to greater acceptability by consumers. Nevertheless, preference criteria may vary from one region to another. For example, Japanese consumers prefer sweeter beans, with crisper texture while American consumers seem to prefer more mature beans, with “buttery” texture and flavor [19]. No study has investigated the sensory preference criteria for African consumers of edamame.

This study aims at assessing acceptability of edamame, identifying the preferred sensory characteristics, and relating consumer preferences to the sensory characteristics.

2. Material And Methods.

2.1 Cultivars

Ten varieties of vegetable soybean from various origins were used in this study; these include 8 true edamame varieties and 2 grain type soybeans that were proved suitable for edamame production in Benin. These varieties were selected based on their good agronomic and yield performance in Benin [29]. Specific emphasis was put on stability, adaptability, and earliness (Table 1).

Table 1.Cultivars used for sensory tests [29]

2.1. Tasting materials

Sensory evaluation was done with fresh pods harvested from the experiment farm of the Legume Breeding Program at the University of Abomey Calavi (UAC) in Benin. Ten varieties of edamame selected after multilocational trials [29] were grown organically, during the rainy season on a sandy-clay soil. Before planting, land was prepared using machete to slush fallows and hand hoes to harrow and demarcate seedbed for edamame planting. Direct sowing of plots was done with seeds treated with inoculum (*Bradyrhizobium japonicum*) obtained from the Laboratory of Soil Microbiology and Microbial Ecology (LMSEM/FSA/UAC). Inoculum was applied at the rate of 3.4 g inoculum/kg of seed, using application method recommended by [30].

Plots contained 6 rows of 10 m spaced 50 cm apart. Seeds were sown at a rate of 20 seeds/m. Plots were arranged in a randomized complete block design with four replications. Pods were harvested at R6 maturity from the middle 8 m of the 4 inner rows of each plot.

2.3. Physical characteristics of pods and seeds

At the laboratory, data were collected on pods. Thereafter, pods were shelled and seeds weighed to estimate the fresh seed yields. Hundred fresh seeds were randomly selected from each accession on which measurements of Fresh Seed Length (FSL), Seeds Width (SW), and Fresh Seed Thickness (FST), were taken as described by Wani et al (2013), using a Vernier calliper reading to 0.01 mm. The geometric mean diameter (*Dm*) of each accession was calculated using equation 1 described by Mohsenin (1970) reported by Sobukola and Abayomi (2011)

$$Dm = (LWT)^{1/3} \qquad (1)$$

with L= Length; W= Width and T=Thickness.

Three lots of hundred seeds were counted from each plot then weighed on precision electronic scale (Servo balans) with accuracy up to 0.001 mg and the average was recorded as 100-seed weight. Seed volume (*Vm*) was calculated using Mohsenin (1970) formula reported by Sobukola and Abayomi (2011).

$$Vm = \frac{\pi B^2 L^2}{6(2L-3)} \qquad (2)$$

Where $B = (WT)^{1/2}$ *with* width (W) and thickness (T)

2.3 Sensory tests

The protocol and questionnaire used were approved by the National Ethics Committee for Health Research (CNERS) in Benin. The panelists gave their consent by signing a consent form, confirming their willingness to participate in the study.

Participants

Based on the approach described by Watts et al (1991), 200 naïve, nonsmoking, normal-weight, non-soy allergic and volunteer panelists were selected for the hedonic and global acceptability tests. To test the hypothesis that social characteristics influence acceptability, panelists were selected taking into account ethnic groups, age, and gender. The number of panelists selected by ethnic group was based on the number of volunteers registered (Table 2).

Table 2. Number of panelists per ethnic, age and gender groups.

Tasting and evaluation

Prior to sensory evaluation, pods of each variety were boiled for 10 min on electrical cooking plate. After cooking, the pods were immersed water for two minutes, drained and served cold. Each panelist received one portion of 5 pods from each variety. Portions were served on a white, non-recyclable tray, with a bottle of drinking water for rinsing the mouth between tasting of two varieties. Sensory evaluation consisted in two types of tests, hedonic test and descriptive test. Hedonic test involved 200 participants and used a nine-point hedonic scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely.

Two tasting sessions were carried out on different days with 5 accessions per session with the same panelists replicated two times.

Samples were scored for Appearance, Flavor, Texture, and Taste using the nine-point hedonic scale. Panelists also indicated their willingness to adopt edamame consumption using a nine-point hedonic scale: 1=Extremely reluctant, 2=Very reluctant, 3=Moderately reluctant, 4=Slightly reluctant, 5=Neither wanting nor reluctant, 6= Slightly willing, 7=Moderately willing, 8=Very willing and 9=Extremely willing. In addition, panelists ranked eight meals that can potentially be missed with or made out of edamame.

The ten green soybean varieties were subjected to descriptive analysis to characterize the sensory properties of edamame that underlie potential consumer preferences. To this end, twenty panelists with prior experience in sensory evaluations were identified and selected to participate in three evaluation training sessions. In the first preliminary session, the evaluators tasted sweet, salty and bitter products of various concentrations. The second session was devoted to chewability tests with food products and the third session covered the ability to identify aroma and flavor. In each session the evaluators had to number randomly, taking into account the intensity of the perception felt. Descriptors and their intensity scales are defined in table 3. The seed size scores given by the panelists were used in combination with the geometric diameter (Dm) and seed volume (Vm) computed for each variety, in order to define classes of seed size.

Table 3. Descriptors associated with sensory parameters and intensity scale

2.4 Statistical Analysis

R software version 3.6.1 [36] was used for all statistical analyses. ANOVA was performed to show the variations observed in each analysis. Physical characteristics of varieties were expressed as mean ± standard deviation. Means separation was done using the least significant difference (LSD) test computed with the lmer function in the lmerTest package.

A linear mixed model was used for studying the effects of gender on the trend of overall acceptability. A preference map was drawn based on the coordinates of the varieties on the first two principal components and acceptability test scores.

T-test was used to compare the mean value of the descriptive sensorial parameters of each variety with the overall mean for all varieties. The most descriptive variables of the varieties were those whose associated t-value were greater in absolute value than 2. For a given variety, a sensory variable is considered as of high value if its t-value is positive. On the contrary, if the t-value is negative, the variety has a low value for that parameter.

To establish variety-related differences on the descriptors, principal component analysis (PCA) was performed in R, assuming a quadratic relationship between acceptability and sensory variables. The packages FactoMine R and SensoMine R were used for these purposes.

A factorial correspondence analysis (FCA) was performed in order to describe relationship between perceptions of ethnic groups and their willingness to adopt edamame consumption and potential types of use.

3. Results

3.1 Physical characteristics of seed

Analysis of variance (tableau 4) showed significant variation among varieties for seed characteristics including seed length ($p<0.001$), width ($p<0.01$), thickness ($p<0.05$), geometric mean diameter ($p<0.01$) and seed volume ($p<0.01$). Seed length varied between 9.3±0.48 mm and 13.51±2.52 mm, seed width varied between 6.19±0.38 and 9.4±1.71mm, thickness varied between 4.04±0.45mm and

4.65±0.32 mm, geometric mean diameter varied between 6.15±0.4 mm and 8.87±1.56 mm, seed volume ranged from 73.36±15.83 mm^3 to 220.90±119.9 mm^3. Variety ***AGS429*** scored the highest values for most seed characteristics, while the variety ***Chinese Black*** exhibited the lowest values for most seed characteristics, except thickness where the variety ***Black Jet*** had the lowest (Table 5).

Table 4:ANOVA table of morphological of seeds

Table 5:Mean values of seed' physical characteristics

3.2. Hedonic test

Analysis of variance of the hedonic scores showed highly significant variation among varieties for all tasting parameters (P<0.001) (table 6). There was also variation in gender perceptions (P<0.05, P<0.001) for all parameters except flavor (P>0.05) (table 6).

Table 6: ANOVA table for sensory parameters

The hedonic test showed differing perceptions among parameters for the varieties. Indeed, for men, variety Ashorowase had the best score for seed appearance (7.48), flavor (5.76), taste (8.25) and texture (8.2) (Fig.1a-d) while, for women variety AGS 466 had the best score for seed appearance (7.72) and taste (8.26), Ashorowase had the best score for seed flavor (5.96), and and texture (8.6) (Fig.1a-d).

For men, variety Early hakucho had the lowest score for seed appearance (3.8), Kuromame had the lowest score for flavor (4.92) and Maksoy 3N had the lowest score for the seed texture (5.68) and for taste (5.2), while for women variety Maksoy 3N had the lowest score for seed appearance (6.36), flavor (4.52), lowest texture (4.76) and taste (5.4) (Fig.1a-d).

Figure 1: Sex-disaggregated scores for seed appearance and flavor.

The sensory map (Figure 2) revealed that the genotypes ***AGS 466***, ***Ashorowasse***, ***AGS 472***, AGS ***429 and Black Jet*** were appreciated by more than 90% of the panelists. Genotypes ***Kuromame*** and ***Chinese Black*** were moderately appreciated by 55% and 50% respectively. The least preferred varieties were ***Early Hakucho*** and ***Maksoy 3N*** (less than 20%) (Figure 2).

Figure 2:Preference mapping for edamame varieties in Benin

As for the overall acceptability, variety ***AGS 466*** received the best score among women, while ***Maksoy 3N*** was the most disliked. Among men, ***Ashorowase*** was the most appreciated while ***Early hakucho*** was the least accepted (Fig.3). Figure 4 showed the sensory characteristics determining the overall acceptability for a given gender group. It appeared that for women, seed appearance, taste and texture contributed equally to the general acceptability, while men based their choice only on taste and texture.

Figure 3:Radar graph showing a comparison of the overall acceptability scores of edamame varieties by gender**.**

Figure 4:Radar graph showing a comparison of the scores of sensory criteria determining the overall acceptability of edamame varieties by gender**.**

3.3. Descriptive analysis of sensory parameters of edamame

There was significant difference in scores received by descriptors among edamame varieties and panelists (table7). Highly significant difference (P < 0.001) was observed among varieties and panelists for all descriptors excepted beaniness. This implies that the panelists effectively distinguish the varieties based on the descriptors, however perceptions differ among panelists. The non-significance of repetition and repetition*variety across parameters, suggested that the panelists effectively evaluate the varieties in the same way regardless the day the seesion took place.

Table 7:AVOVA of sensory descriptors and of interactions

The test showed no significant difference among varieties for beaniness (fig. 5.a), which in average had low nuttiness(fig. 5.b). AGS 466, AGS 472, AGS 429, and Ashorowase were highly starchy, while Maksoy 3N and Early Hakucho were not starchy (Figure 5.c). The varieties Early Hakucho, Maksoy 3N, Black Jet and Chenese Black were characterized by high chewiness (test-value ≥ 2, p < 5%), whereas AGS 466, AGS 472, AGS 429, Ashorowase and Kuromame exhibited a very low chewiness (test-value < 2 , p < 0.05) (Figure 5.d). Ashorowase, Kuromame, AGS 466, AGS 429 and AGS 472 were the most sweet varieties, while Maksoy 3N and Early Hakucho were not

sweet (Figure 4.e). Varieties Maksoy 3N and Early Hakucho had strong Aftertaste, while AGS 466, AGS 472, AGS 429, Ashorowase and Black Jet had no aftertaste (Figure 4.f).

Figure 5: Sensory profile of 10 edamame varieties: Beaniness; Chewiness; Nuttiness; Aftertaste; Sweetness; Starchy and Buttery. On the Y axis, V-computed from the V-test in comparison of the mean value of the sensorial parameter for a genotype to the overall mean.

Results of PCA revealed that 71% of the total variance was explained by the first two components. There was a strong relationship between varieties and sensory descriptors. Indeed, Early-hakucho and Maksoy 3N were located on the same side of the PCA axes as the sensory descriptors Chewiness, Olive green, small caliber and Aftertaste, which means that these three varieties were particularly discriminated by their chewiness, Olive green color, small seed caliber and Aftertaste characteristics. On the contrary, Ashorowase, AGS 466, AGS 472 and AGS 429 were mainly characterized by their sweet taste, butteriness, starchiness and their large size. In the same way, Chinese Black, Black Jet and Kuromame were characterized by Bottle green and Beaniness. Variety S1079-6-7 was mainly distinguished by medium caliber.

Figure 6:Principal component analysis (PCA) showing relationship between genotypes and sensory descriptor. Legend: Black texts indicate the genotypes while the blue texts indicate the sensory description

Correlation coefficients and significance between sensory descriptors and overall acceptability of edamame varieties were presented in table 8. Chewy texture of seed was positively and significantly correlated with small seed ($p < 0.01$) and negatively related to Sweetness ($p < 0.05$), Starchiness ($p < 0.05$) and Large seed ($p < 0.05$). This means that the Chewy varieties were varieties with non-large seeds, they were not sweet, and had less starch.

Sweet taste was significantly positively correlated with starchiness ($p < 0.01$) and large seed ($p < 0.05$), and negatively correlated to small seed ($p < 0.001$), olive green color ($p < 0.05$). The level of starch was significantly positively correlated with large seed ($p < 0.05$). It was negatively related to nutty flavor ($p < 0.05$), Aftertaste ($p < 0.01$), small seed ($p < 0.01$), and olive green ($p < 0.01$). Nutty flavor was significantly positively correlated with Aftertaste ($p < 0.01$), olive green ($p < 0.01$). It was negatively correlated with Bright green color ($p < 0.05$). Aftertaste was positively significantly correlated with small caliber ($p < 0.05$) and olive green ($p < 0.001$) (Table 8).

Overall acceptability of varieties was positively correlated with Sweetness ($p < 0.01$), level starchy ($p < 0.001$), large seed ($p < 0.001$) and Bright green color, and was negatively related to chewy texture ($p < 0.05$), nuttiness ($p < 0.05$), Aftertaste ($p < 0.05$), small seed ($p < 0.01$) and olive green color. This means that the varieties that possess chewy texture, nutty flavor, small seed and olive green color were not generally accepted (Table 8).

Table 8:Correlation between sensory descriptors for Overall acceptability

3.4. Willingness to adopt edamame consumption

Willingness to adopt edamame consumption varied among ethnic groups (X-squared = 205.94, df = 54, $p < 0.000$). On the contrary, there was no link between willingness to consume edamame and gender (X-squared = 14.405, df = 8, p-value = 0.072) or age groups (X-squared = 6.888, df = 4, p-value = 0.142).

The results of the FCA conducted to assess the willingness to adopt edamame consumption in relation to the ethnic groups showed that the first two axes explain 72.9% of the variations observed (Fig.7). The willingness to adopt edamame consumption varied among ethnic groups. In Fig. 7, Djerma ethnic group was located on the same side of the "reluctant" FCA axes, meaning that Djerma people were not yet ready to adopt edamame consumption. Aizo was on the same side as “Slightly willing”, which means that the Aizo people were willing but still had doubts. Goun ethnic group was closer to “Moderately willing”, Fon, Mahi and Adja were on the same side as “Very willing”, Dendi , Bariba and other ethnic groups were on the same side as “Extremely willing” which means Bariba, Dendi, Fon, Mahi and Adja were immediately ready to consume edamame.

Figure 7: Correspondence analysis (CA) showing the link between ethnic groups and their willingness to adopt edamame consumption. Blue text indicates the ethnic groups while the red text shows their willingness.

Overall, 90.11% of the respondents were willing to consume vegetable soybean and 4.94% were undecided while 4.95% were reluctant (Fig.8.)

Figure 8: Willingness to consume vegetable soybean

Several potential ways to process and consume edamame were proposed by the respondents (Fig.9). To this end, around 98% of the informants chose to consume edamame as an appetizer, 97% think consuming stir-fries edamame with rice is the best, while 95% prefer to consume edamame in salads, and 59.05% prefer to mix stir-fries edamame with spaghetti. Only few respondents choose edamame soups (25.64%), edamame mixe with maize (5.53%) and edamame mixed with peanuts 31%.

Figure 9:Possible forms of edamame processing and consumption

4. Discussion

4.1 Sensory preferences and overall acceptability of edamame varieties

The first variables of interest in this study were the morphological traits of seeds that translate into appearance criteria. Indeed, the physical characteristics of foodstuffs are the first elements that influence consumers' preference [37]. According to Hutchings (1977), the first impression of a food is usually visual, and a major part of our willingness to accept a food depends on its appearance.

Moreover, our study showed that the overall acceptability of the varieties was strongly correlated with physical characteristics such as bright green color and large seed size (7mm< Dm and Vm >130mm^3). These results were in agreement with those of Laxmibhai & Kulkarni (2016) who reported that varieties such as Karune followed by DSb 21 which were more accepted by consumers in India, received very good scores for color and size in contrast to the pale green and small seeded varieties. In addition, our results showed that the variety ***Early hakucho*** less desirable, due to its small seeds (Dm≤7mm and Vm≤110mm^3), this same variety was less desired in study conducted by Wszelaki et al., (2005) in USA.

The green color is under the influence of several factors. Laxmibhai & Kulkarni (2016) reported that, the chlorophyll content of seeds, presence of phenolic compounds at the time of harvest as well as the genetic differences cause variations in the color components. Physical characteristics of seeds would therefore be the first targets on which breeders should concentrate while developing improved edamame varieties, in order to enhance acceptability. It would also be appropriate to consider assessing, in future studies, the influence of physical characteristics of pods on overall acceptability.

Flavor is the second "anticipatory" attribute after appearance that influences the "participatory" phase [38]. According to Arikit et al (2011), 2-acetyl-1-pyrroline (2AP) represents the volatile aroma compound of edamame, characterized by a "popcorn-like" aroma. It's an important aroma discriminator for premium characteristics and higher price of edamame and influences its acceptability and consumer preference. Nuttiness is aroma and flavor associated with nuts and having legume-like character [33]. According to Young et al (2000), the nutty flavor is one of the most expected flavors in edamame. Surprisingly, in our study all varieties had low nuttiness. On the contrary, the beany flavor was strongly present in most of the varieties. This beany flavor could therefore strongly influence the overall flavor by the fact that it was not a very good smell [40, 41]. This could explain the low level of nutty flavor observed in our varieties and the low score fetched by flavor in the hedonic test. In our study, among all the sensory parameters tested, flavor was the least liked. This may be because the Beninese panelists were not yet accustomed to this aroma and will need time to get used to it, while the texture and taste of the different edamame varieties were similar to those of the peanuts they were already familiar with. Similar results were found where consumers in South Asia have expressed dislike for the 'beany' flavor of vegetable soybeans, indicating that there was a need to improve the taste before it can be successfully introduced on a large scale in India [42]. However, our findings were in contrast with those of Wszelaki et al (2005) who observed that beaniness and nuttiness could not be consistently differentiated among varieties. Although taste and aroma are different sensory parameters, their combination produces an impressive effect. Yin et al (2017) showed that the combination of the two parameters in a food at best reduces the feeling of hunger to a greater extent than independent of either of them. Flores et al (2019) reported that Sweetness is one of the most important sensory attributes to differentiate edamame genotypes. In our study, the intensity of sweet taste varied among varieties. Indeed, the global acceptability of the varieties, was highly correlated with the sweetness. Varieties that had a remarkable sweetness were AGS 466, AGS 472, and AGS 429 from AVRDC and Ashorowasse from Japan. Moreover, the varieties with low sugar taste had an aftertaste that was not well liked. According to Li et al (2012), sucrose, glutamic acid and alanine are the basic nutrient compounds that give vegetable soybeans their taste. Then the variation in sugar intensity obtained may be due to the quality and quantity of sugar contained in each edamame variety. These analyses are confirmed by the results of Han et al (2017) who stated that a combination of ascorbic acid, sucrose, glutamic acid, alanine and volatile components makes vegetable soybeans tasty. In addition, cooking and chewing have a transforming effect on the sugar. Masuda (2004) has shown that boiling turns sucrose into another sugar, maltose which was 40 % sweeter than sucrose and has a more refreshing aftertaste. It would therefore be important to evaluate the quality and quantity of carbohydrates contained in edamame varieties which were suitable

for consumption through a study on the nutritional value of these varieties. In addition, the low-sugar varieties had an aftertaste that was not well liked.

Our findings showed that varieties with a long chewing time were not well liked. According to Wszelaki et al (2005), moderate chewing was preferred for edamame. This is in agreement with our findings. Indeed, overall acceptability was positively correlated to starchy, which reduces chewiness. According to Stevenson et al (2006), the main carbohydrate in plant storage organs in general is starch, however it is not well studied in soybean or edamame because of its relatively low content and because soybean is generally considered a protein and oil crop [49].

In total, panelists expressed a clear preference for some varieties based on the quality of their appearance, flavor and texture. The results of this study, showed that the flavor criterion of the most varieties did not receive high scores compared to the other sensory criteria such as texture and taste. These results were similar to those of [50] who reveled that, AGS 447 and AGS 457 varieties recorded the highest average acceptability scores due to their appearance, texture and sweetness. On the other hand, the sensory evaluation of boiled vegetable soybeans with Laxmibhai & Kulkarni (2016) revealed that the varieties Karune and DSb 21 had higher acceptability scores because the panelists highly valued all sensory characteristics including flavor.

There was no expressed food neophobia in Benin for edamame. Such a phenomemon was reported by Wszelaki et al (2005) in the US. In addition, the results of it were shown that women tend to give higher scores than men in the hedonic tests for almost all the sensory criteria assessed. Also, there were gender differences in hedonic ratings and in the overall acceptability of the varieties. Similar findings have been reported in previous studies. Indeed, a survey of vegetable preferences conducted by Babicz-Zielinska (1999) among 100 Polish university students showed a significant influence of gender on the preference test performed. The results of this study showed that out of 25 varieties evaluated, women ranked 19 varieties higher than men considering their appearance.

Women chose ***AGS 466*** based mainly on its appearance and sweetness while ***Ashorowase*** was preferred by men due to its taste and texture. Overall, the two varieties retained were characterized by their large seed, sweet taste, moderate chewiness and their starchiness. In addition, ***AGS 466*** had a very good agronomic and yield performance, and was stable and adaptable in several agro ecological zones in Benin [29].

Women were more keen on appearance; this means that appearance was an important preference criteria for women. This attraction that women have developed for appearance of some varieties is very important for breeders to take seriously into consideration. The ***AGS 466*** variety had a very good performance, stable and adaptable in several agro ecological zones in Benin. Because women are the main links in the leguminous value chain [52]. Women are the main sellers and buyers of agricultural products in general and most food cooking activities are done by them.

4.4. Adoption of Edamame consumption

Understanding local perceptions for the adoption of edamame can be helpful in determining the level of willingness and supporting its particular promotion. Our results showed high link between ethnic groups and willingness level. Our findings showed that, 89 percent of ethnic groups were ready to introduce edamame consumption into their dietary habit. The majority of these ethnic groups were found in areas with high production of grain soybeans. They already know the product but never knew that there are varieties that can be used as vegetable like peas or snap bean.

Potential consumers in Benin were ready to introduce edamame into their diet. The information presented here is a first indication of the expectations of potential consumers regarding the physical-sensory characteristics of fresh edamame in Benin. It is important to track the evolutionary trend of such expectations as consumers get familiar with edamame products. Although sensory criteria are basic parameters that influence consumer preferences, the nutritional and health value of a food is also essential for its acceptability and adoption for consumption [53]. It would therefore be useful to evaluate the organic and chemical compositions of varieties that meet the criteria of both potential Beninese producers and consumers in order to examine their contribution to consumer welfare. Further important research should assess the influence of agricultural conditions and practices and environmental impacts on the sensory and nutritional characteristics of edamame in Benin.

5. Conclusions

Edamame varieties have organoleptic attributes that are well appreciated by potential consumers of Benin. Consumers have preference for bright green and large seeded edamame varieties, that are sweet, nutty and moderately chewy. There is high willingness to adopt

edamame among Benin's population, thus advocating for continued efforts to introduce cultivation, consumption and trading of edamame in Benin. There is gender implication in the consumers'preferences for edamame in Benin. While women have preference for the seed appearance and sweetness, men have greater preference for texture and taste. This is a very insightful information provided by this study, as it would guide the development of product profiles to fulfill the needs of various market segments for edamame secor in Benin. some grain type soybeans seem to be appropriate for edamame production. It is the case with *S1079/6/7* which was slightly sweet and well accepted by consumers in Benin. This variety could be used by breeders as parental lin, in order to improve yield and tolerance to various stresses in edamame.

Abbreviations

AVRDC
Asian Vegetable Research and Development Centre
CNERS
National Ethics Committe for Health Research
FAO
Food and Agriculture Organization
FCA
Factorial Correspondence Analysis
FSA
Faculty of Agronomic Sciences
LMSEM
Laboratory of Soil Microbiology and Microbial Ecology
PCA
principal component analysis
UAC
University of Abomey Calavi
USA
United States of America

Declarations

Authors' contributions

SEA and EEA conceived the study. SEA and EEA laid the tests, collected and encoded data. SEA, BEL, and CEA., processed and analyzed the data. SEA and EEA developed the manuscripts. EE Aprovided the funding. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of supporting data

The data generated and analyzed in this study are available to readers as in the manuscript.

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ETHICAL STATEMENT

Ethical Statement

Studies involving human participants were reviewed and approved by National Ethics Committe for Health Research (**CNERS**) in Benin. Participants gave written informed consent to participate in this study.

Consent for publication

Not applicable

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Tables

Table 1.Cultivars used for sensory tests (Ahomondji et al., 2022)

						SELECTION CRITERIA	
	Accessions	**Origin**	**Seed coat color**	**FPY (t/ha)**	**DM**	Stability	Adaptability
True Edamame	AGS 429	AVRDC	Light green	10.9	67	++	+++
	AGS 466	AVRDC	Light green	13.5	67	++	+++
	AGS 472	AVRDC	Black	12.7	66	+++	+++
	Ashorowase	Japan	Light green	12.6	66	++++	+++
	Kuromame	Japan	Black	13	68	++	+++
	Hakucho Early	USA	Green	9.5	66	++	++++
	Black Jet	USA	Black	7.9	74	++	++++
	Chinese Black	USA	Black	11.4	70	++	+++
Grain type	S1079-6-7	Zimbabwe	light yellow	13.3	84	++++	++++
	Maksoy 3N	Uganda	light yellow	15.9	84	++	++

+ Very low; ++ Low; +++ High ++++ Very high; FPY= Fresh pod yield, DM=Days to Maturity;

Table 2. Number of panelists per ethnic, age and gender groups.

	Number selected	Percentage (%)
Ethnic group:		
Fon	63	31,5
Mahi	27	13,5
Gun	25	12,5
Nago	23	11,5
Adja	17	8,5
Aïzo	11	5,5
Bariba	12	6
Dendi	10	5
Djerma	7	3,5
Others	5	2,5
Age group :		
Youth [15-24] ages	85	53.13
Adults [5-64] ages	75	46.83
Old people (65≥ages)	40	25
Gender :		
Male	105	54.16
Female	95	45.83

Table 3. Descriptors associated with sensory parameters and intensity scale

Sensory	Descriptors	Scale	Definition
Appearance	Size	1-small 2- medium 3- large	Refers to the dimensions length, width, thickness, diameter and volume of the seed.
	Color	1-bottle green 2-olive green 3-bright green	Green color scale of the seed.
Flavor	Nuttiness	1= “Not” to 5= “Extremely”	Aroma and flavor associated with nuts and having legume-like character (Krinsky et al., 2006a)
	Beaniness		Aroma associated with fresh green beans and freshly cut twigs, grass (N’Kouka et al., 2004 Krinsky et al., 2006a)
Texture	Chewiness		Food texture that requests long chewing time in order to obtain a satisfactory consistency for swallowing (Wang et al., 2017)
	Starchy		Starchy vegetables, as the name suggests, contain more starch, but are nevertheless rich in nutrients.
Taste	Sweetness		Basic taste on tongue associated with sugars and high potency sweeteners (Krinsky et al., 2006a).
	Aftertaste		Perception in the mouth of a flavor once swallowed: it is a or a "residual" aroma.

Tableau 4. ANOVA table of morphological of seeds

Sources		Fresh seed Length		Fresh seed Width		Fresh seed Tickness		Diameter		Volume	
	df	F	Prob	F	Prob	F	Prob	F	Prob	F	Prob
Varieties	1	10.24	***	5.76	**	3.81	*	5.876	**	5.421	**
Rep	9	3.45	0.09	0.28	0.60	0.83	0.38	1.12	0.31	0.70	0.41
Varieties*Rep	9	1.75	0.19	0.94	0.52	0.87	0.57	0.95	0.52	0.75	0.65

F = F value; Prob = probability, Rep= Replication,* statistically significant at $0.01 \leq p < 0.05$; ** statistically significant at $0.001 \leq p < 0.01$; *** statistically significant at $p < 0.001$.

Table 5. Mean values of seed' physical characteristics.

Varieties	Length (mm)	Width (mm)	Thickness (mm)	Diameter (mm)	Volume (mm^3)	*Rank
AGS429	13.51±2.52 a	9.4±1.71 a	5.99±1.74 a	8.87±1.56 a	220.90±119.9 a	I
AGS466	12.91±0.96 ab	8.68±0.39 ab	4.65±0.32 ab	8.05±0.46 ab	155.59±26.15 ab	II
ASHOROWASE	11.81±0.24 abc	8.05±0.34 abc	5.07±0.35 ab	7.84±0.26 ab	144.92±13.73 ab	III
AGS472	11.57±0.46 abc	8.03±0.66 abc	4.86±0.57 ab	7.67±0.6 ab	137.76±31.17 ab	IV
S1079-6-7	10.40±1.2 abc	6.81±0.37 bc	4.39±0.28 ab	7.46±1.45 ab	131.01±69.52 ab	V
Hakucho, Early	10.36±0.16 abc	7.43±0.09 abc	4.58±0.24 ab	7.06±0.14 ab	108.08±6.46 ab	VI
Maksoy 3N	10.61±0.33 abc	7.06±0.33 bc	4.5±0.27 ab	7±0.3 ab	105.21±13.11ab	VII
KUROMAME	10.93±1.83 abc	7.24±0.35 bc	4.29±0.27 ab	6.96±0.27 ab	102.76±10.13 ab	VIII
Black Jet	9.39±0.46 bc	6.96±0.42 bc	3.95±0.12 b	6.37±0.2 b	80.97±10.45 ab	IX
Chinese Black	9.3±0.48 c	6.19±0.38 c	4.04±0.45 ab	6.15±0.4 b	73.36±15.83 b	X
Mean	11.08±0.86	7.59±0.5	4.64±0.46	7.34±0.56	126.06±31.64	
CV (%)	10.27	8.7	13.79	10.27	36.99	
LSD (0.05)	3.53	2.05	1.98	2.34	144.87	

*LSD: Least significant difference according to Tukey's Post-Hoc test, Means followed by the same letter/s in a column do not differ significantly.*The varieties were ranked based on their volume.*

Table 6: ANOVA table for sensory parameters

Sources		Appearance		Flavor		Taste		Texture	
	df	F	Prob	F	Prob	F	Prob	F	Prob
Varieties	9	25.628	<0.001	4.089	<0.001	14.816	<0.001	24.43	<0.001
Sex	1	155.987	<0.001	10.607	0.1146	2.499	<0.001	3.937	<0.05
Varieties	9	25.628	<0.001	4.089	<0.001	14.816	<0.001	24.43	<0.001
Sex*Varieties	9	1.635	0.103	2.463	<0.001	2.173	0.0227	5.178	<0.001

Table 7:AVOVA of sensory descriptors and of interactions

	Edamame descriptors				
Sources	Beaniness	Chewiness	Sweetness	Nuttiness	Aftertaste
Varieties	NS	***	***	***	***
Repetition	NS	NS	NS	NS	NS
Panelists	NS	***	***	***	***
Repetition*Variety	NS	NS	NS	NS	NS
Panelists*Variety	NS	***	***	***	***
Means	2.13	3.28	2.34	1.2	2.4
CV (%)	36.2	31.15	39.27	40.95	37.95
LSD(0.05)	0.48	0.57	0.55	0.31	0.52

NS, **, *** = not significant or significant at P <0.01 or P < 0.001, respectively

Table 8.Correlation between sensory descriptors for Overall acceptability

	CHE	SWE	STA	NUT	AFT	BEA	CAS	CAM	CAL	OGR	BtGR	BrGR	OVA
CHE	1												
SWE	-0.72*	1											
STA	-0.67*	0.86**	1										
NUT	0.2	-0.33	-0.65*	1									
AFT	0.41	-0.61	-0.84**	0.77**	1								
BEA	-0.44	0.37	0.33	-0.24	-0.16	1							
CAS	0.86**	-0.89***	-0.84**	0.26	0.69*	-0.31	1						
CAM	-0.29	0.46	0.14	0.24	0.29	0.02	-0.22	1					
CAL	-0.79**	0.76*	0.76*	-0.27	-0.74	0.33	-0.95***	-0.07	1				
OGR	0.34	-0.69*	-0.81**	0.81**	0.91***	-0.21	0.61	0.02	-0.59	1			
BtGR	0.27	0.001	*0.25*	-0.64*	-0.49	-0.47	0.1	-0.23	-0.11	-0.49	1		
BrGR	-0.52	0.58	*0.5*	-0.53	-0.56	0.31	-0.55	0.11	0.54	-0.72*	0.04	1	
OVA	-0.67*	0.84**	0.92***	-0.65*	-0.79**	0.5	-0.79**	0.05	0.77***	-0.79	0.07**	0.63*	1

CHE= Chewiness, SWE= Sweetness, STA=Starchy, NUT= Nuttiness AFT=Aftertaste, BEA= Beaniness, CAS=Caliber small, CAM= Caliber medium, CAL= Caliber large, OGR= Olive Green, BtGR= Bottle Green, BrGR= Bright Gren, OVA= Overall Acceptability.* statistically significant at 0.01 ≤ p < 0.05; ** statistically significant at 0.001 ≤ p < 0.01; *** statistically significant at p < 0.001.

Figures

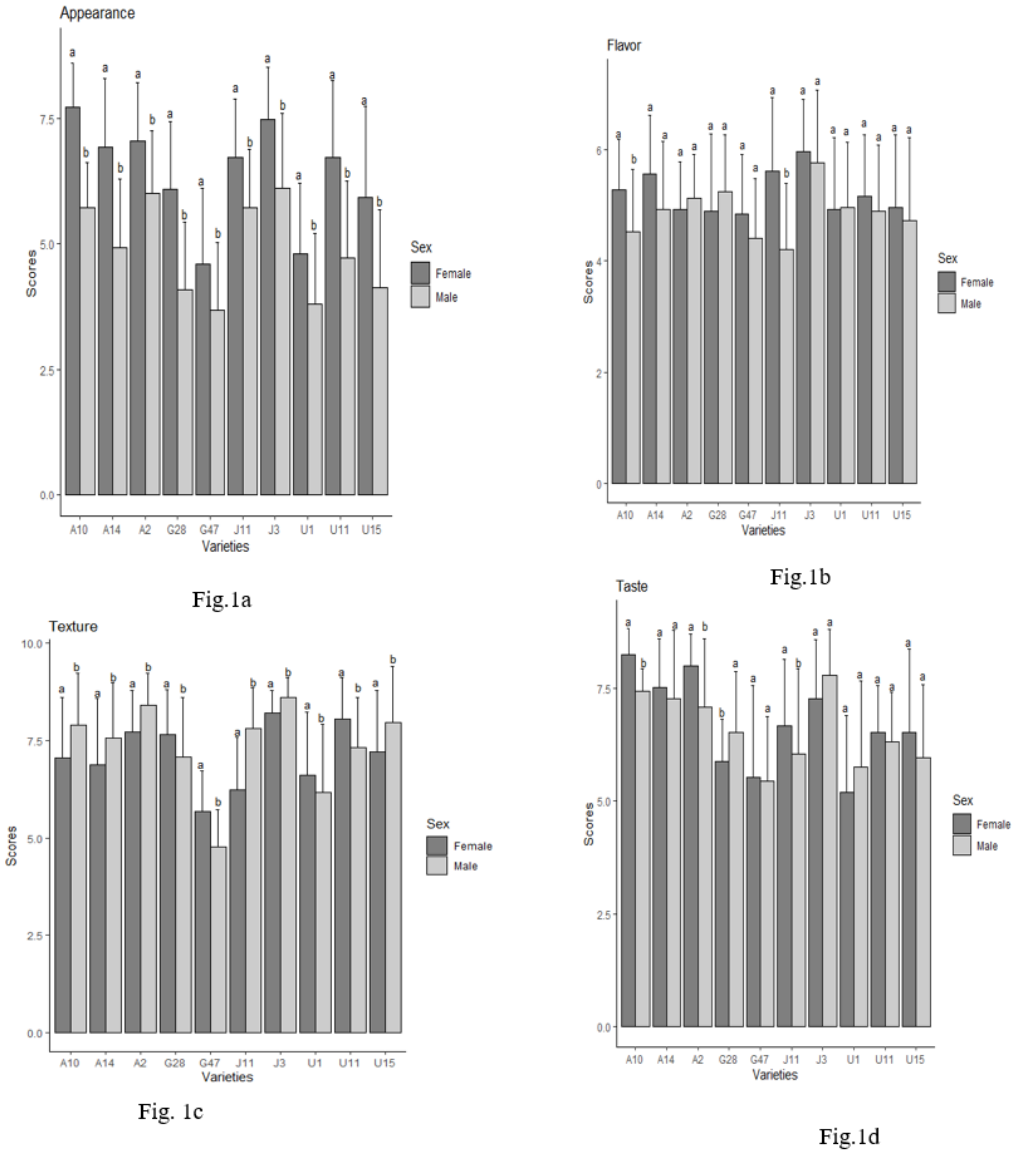

Figure 1

Sex-disaggregated scores for seed appearance and flavor.

Legend: *A2: AGS 429; A10: AGS 466; A14: AGS 472; G28: S1079-6-7; G47: Maksoy 3N; J3: Ashorowase; J11: Kuromame; U1: Early Hakucho; U11: Black Jet U15: Chinese Black*.

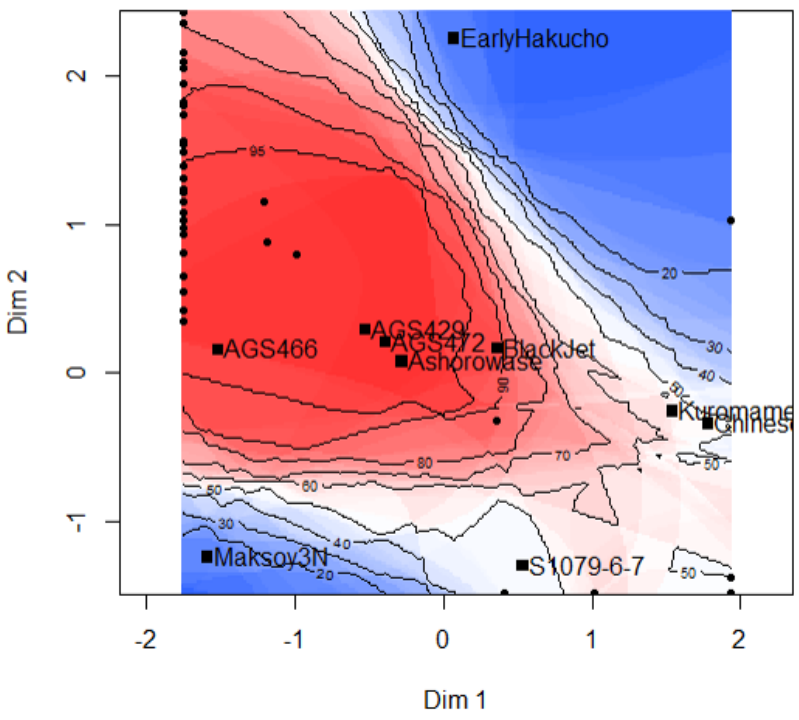

Figure 2

Preference mapping

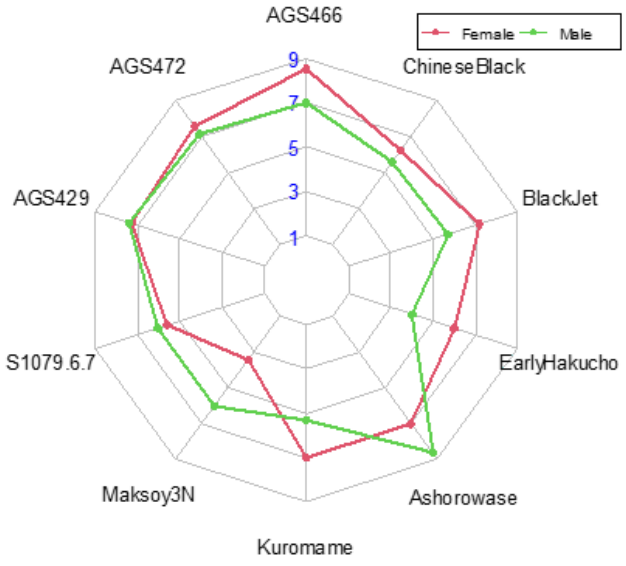

Figure 3

Radar graph showing a comparison of the overall acceptability scores of edamame varieties by gender.

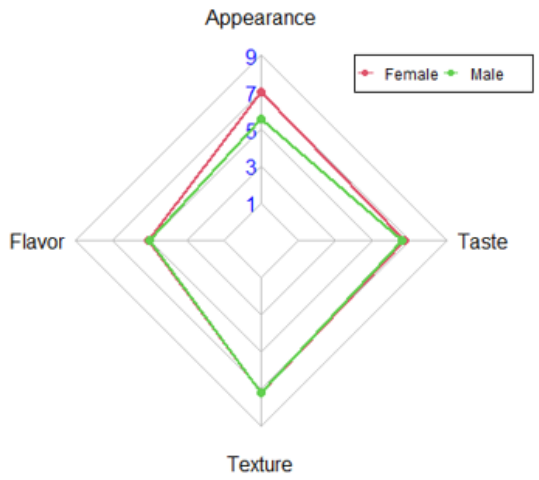

Figure 4

Radar graph showing a comparison of the scores of sensory criteria determining the overall acceptability of edamame varieties by gender.

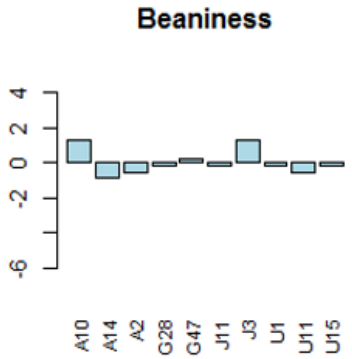

Fig.5.a

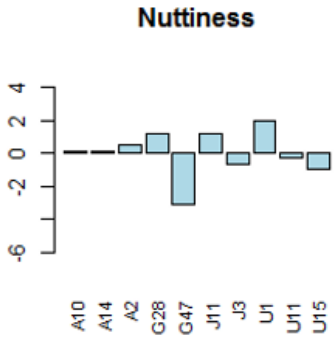

Fig.5.b

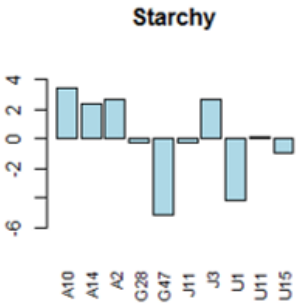

Fig.5.c

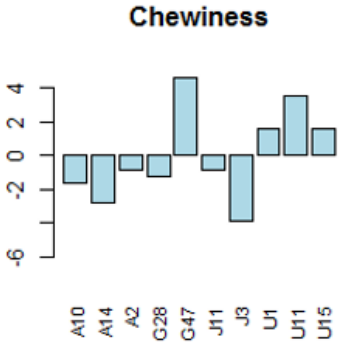

Fig.5.d

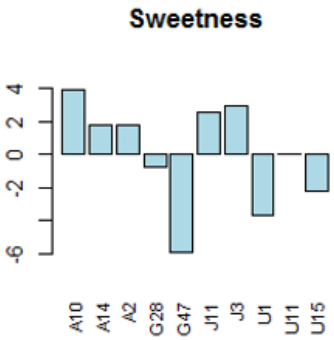

Fig.5.e

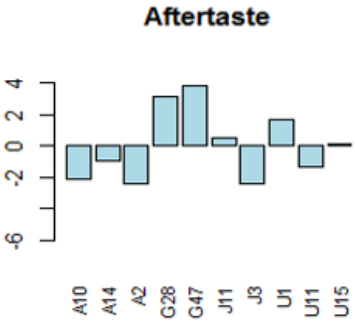

Fig.5.f

Figure 5

Sensory profile of 10 edamame varieties: Beaniness; Chewiness; Nuttiness; Aftertaste; Sweetness; Starchy and Buttery. On the Y axis, V-computed from the V-test in comparison of the mean value of the sensorial parameter for a genotype to the overall mean.

Legend: *A2: AGS 429; A10: AGS 466; A14: AGS 472; G28: S1079-6-7; G47: Maksoy 3N; J3: Ashorowase; J11: Kuromame; U1: Early Hakucho; U11: Black Jet U15: Chinese Black.*

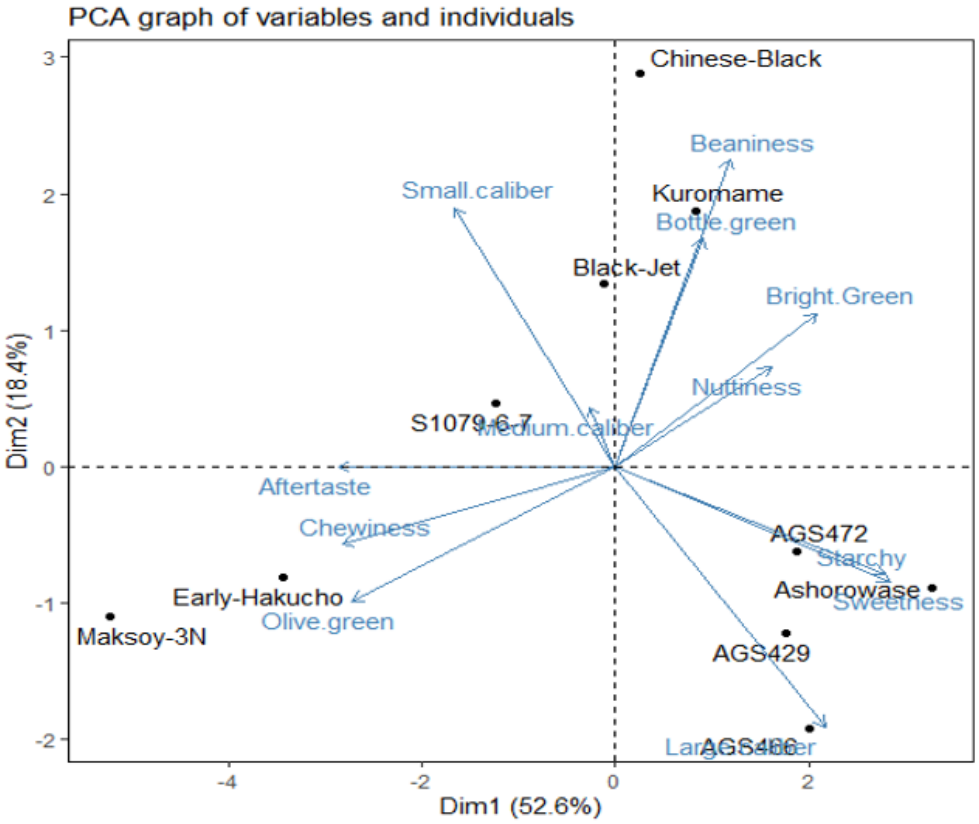

Figure 6

Principal component analysis (PCA) showing relationship between genotypes and sensory descriptor. Legend: Black texts indicate the genotypes while the blue texts indicate the sensory description

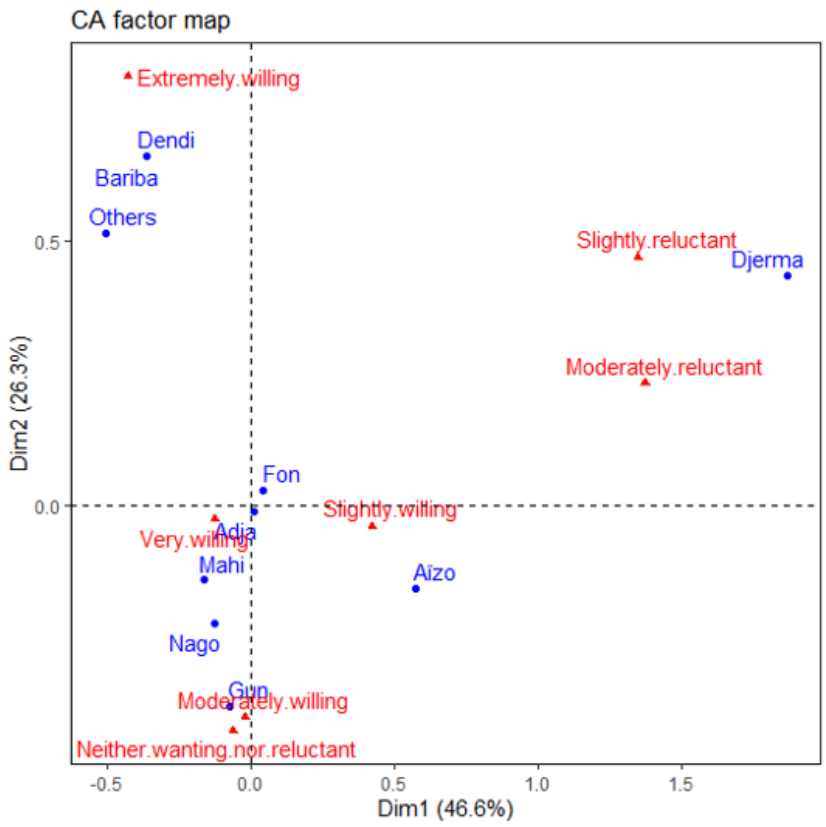

Figure 7

Correspondence analysis (CA) showing the link between ethnic groups and their willingness to adopt edamame consumption. Blue text indicates the ethnic groups while the red text shows their willingness.

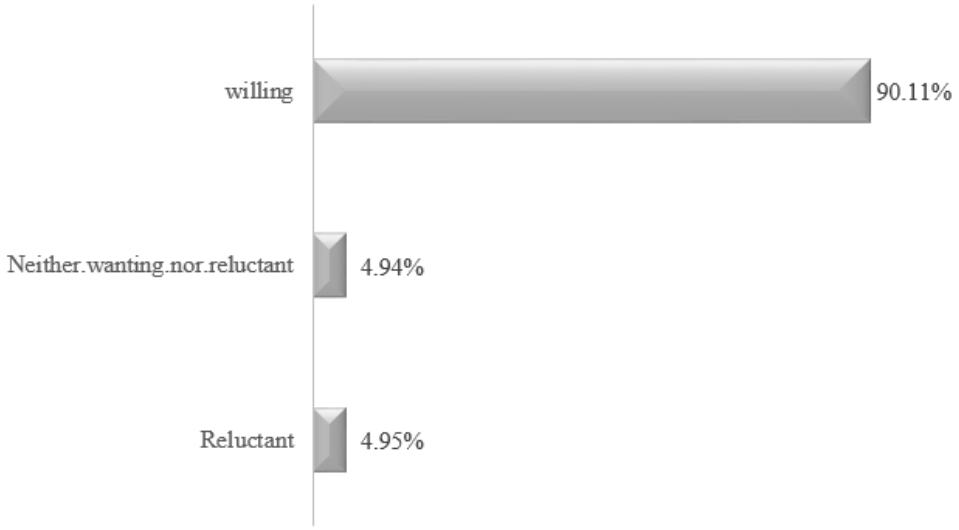

Figure 8

Willingness to consume vegetable soybean

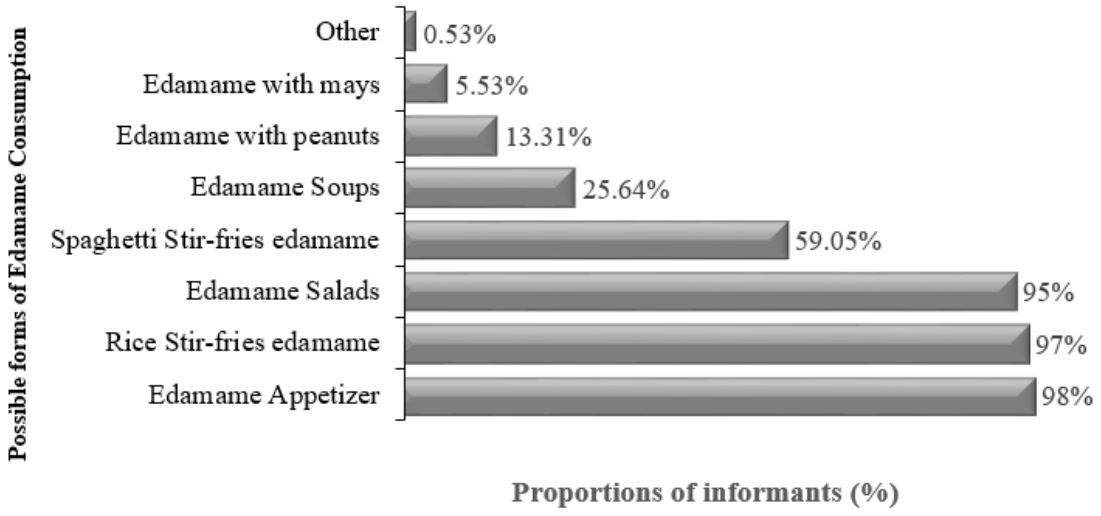

Figure 9

Possible forms of edamame processing and consumption