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Case Report

Influence of organic compost treatment on biometric patterns and sensory attributes of fresh green beans (*Phaseolus vulgaris* L.)

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ABSTRACT

Organic production is nowadays more important for the care of the environment. Therefore, fresh horticultural products such as green beans produced with organic compost are healthier and are influenced by their sensory characteristics. The objective of this research was to evaluate the effect of organic compost on the biometric characteristics of fruits and leaves, texture, and sensory attributes of fresh green beans (Phaseolus vulgaris L.), as assessed by consumers. A completely randomized design (CRD) with five experimental treatments with different levels of organic compost was used. The results show the direct influence of the level of organic compost concentration on foliar characteristics, as the concentration of compost increases, its chemical properties are increased. However, there is no direct influence on biometric, firmness, physical-chemical, and color characteristics. The Sorting Task test according to sensory attributes shown with descriptors allows the identification of four groups: the first one formed by T1, second by T2, third by T3, and fourth by T4 and T5; while the Flash Profile test shows the formation of three groups: the first one formed by samples T1 and T2, the second T3 and the third one formed by T4 and T5. The sensory tests allowed finding similarities and differences between the green beans by consensus according to the consumers' perception.

1. Introduction

The green bean is a vegetable, green, elongated, and tapered, immature fruit of the species *Phaseolus vulgaris* L., comprising fleshy and tender bracts that enclose the beans [1]. They come from the most important legumes worldwide [2]. After harvesting, no process is carried out that affects its natural state, maintaining its nutritional and sensory characteristics. It is a widely consumed food on the coast of Peru [3], it is part of (complements) various red or white meat dishes, as well as various types of previously blanched salads. In addition, it has a nutritional profile rich in protein, fiber, and amino acids that make this product a functional food due to its low caloric content and low cost compared to other protein sources [4].

The Peruvian Technical Standard – NTP, establishes a classification of fresh green beans in Extra, First, and Second Quality, all of them must be clean, fresh, whole, and healthy [5]; they must belong to the same cultivar, they must have a degree of commercial maturity that allows them to withstand handling, transport, and conservation in good conditions. This standard establishes the quality requirements of these, being their appearance, fibrousness, cracking, mechanical damage, chemical damage (burns), shape, color, size, minor diameter, weight, tolerance, length, health, pustules (produced by Roya), dry rot (Anthracnose), wet rot (Sclereotiniosis) and innocuousness. There are agronomic studies on yield parameters such as plant height, average number of pods per plant, average weight and length of pods per plant, and crop yield expressed in kg/ha [6,7].

The biometric study of fruit and vegetable fruits is an important strategy for distinguishing between varieties, even the study of the morphological aspects of the leaves can allow the characterization of the product, even when these do not present flowers and/or fruits [8,9], so

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the study of biometric parameters becomes relevant and is complemented by sensory evaluation.

On the nutritional aspect, green beans have a nutritional profile rich in protein, fiber, and amino acids that make this product nutritious, low calorie, and low cost compared to other protein sources with an average content (in 100 g sample) of moisture 86–90 %, protein 2. 4 %, fat 0.3 %, total carbohydrates 0.1 %, available carbohydrates 4.7 %, dietary fiber 1.3–3.4 %, ash 0.83–1.0 %, calcium 88 mg, phosphorus 49 mg, zinc 0.24 mg, iron 1.40 mg, vitamin A 0.07 mg, riboflavin 0.20 mg, niacin 0.71 mg, vitamin C 9.60 mg and energy 25 kcal [4,10,11].

Currently, due to the impact generated by the use of agrochemicals on the environment and taking into consideration the 13th Sustainable Development Goal - Climate Action, there is a worldwide trend to gradually use more organic residues to im-prove the fertility and physical properties of the soil [12], thus in organic agriculture, the presence of microorganisms that facilitate nutrient fixation and absorption by plants is achieved, and there are very interesting experiences of its application in vegetable production under greenhouse conditions [13–15].

Sensory analysis is an elemental aspect in the acceptability of fresh vegetables, their characteristics such as color, aroma, flavor, and texture, define their purchasing power. Currently, there is a marked tendency to use consumers to identify descriptors, and tests such as CATA (Check All That Apply), JAR (Just All Right), RATA (Rate All That Apply), Sorting, Napping, Pivot Profile, among others Pineau et al. [16], have been used in processed products; however, there is little information on sensory and instrumental analysis in ripe pods or beans. On the other hand, Galina et al. [17], found that breaking strength was significantly and negatively correlated with the sensory traits: free parchment layer, crispiness, and stringless, while in fresh products there are descriptive evaluation limitations.

The objective of this study was to evaluate the effect of organic compost made from waste from food markets on the biometric characteristics of fruits and leaves, texture, and sensory attributes of fresh green beans (*Phaseolus vulgaris* L.), as assessed by consumers.

2. Materials and methods

2.1. Location of production and agroclimatic conditions

The production of fresh green beans (Phaseolus vulgaris L.) was carried out in the district of Supe (45 m. a. s. l.), province of Barranca - Lima Region, located between UTM coordinates 18X:205313 Y:8803953 [18]. Production was carried out during the August–November 2022 production season.

The agrometeorological parameters of the production zone were: monthly temperature between 21.8 and 26.3 °C in summer, while in winter temperatures between 15.0 and 17.9 °C, monthly relative humidity 85 %. Rainfall is absent or scarce for most of the year, however, there are slight accumulations during the winter, with an average rainfall of 1.7 mm and wind speed of 10 km/h [18].

2.2. Green bean production

In the production of fresh pods, a completely randomized design was applied with 5 treatments of compost doses: T1 (0 t/ha), T2 (6 t/ha), T3 (8 t/ha), T4 (10 t/ha) and T5 (12 t/ha), which was made from organic waste. The compost doses were added at the bottom of the furrow. During production, all plots were cultivated under the same conditions, such as fertilization at the bottom of the furrow, weeding, irrigation, phytosanitary control, and harvesting.

2.3. Soil characterization

A complete analysis of inorganic elements present in the soil was carried out. The electrical conductivity of the soil was determined by the method of measuring electrical conductivity in soil suspension, pH by the potentiometric method, moisture was determined by the gravimetric method, the organic matter present was determined by the process of oxidation of organic carbon to CO_2, nitrogen was found by the Kjeldahl method, P by the Olsen method, K by the saline extraction method and measurement with a flame photometer, $CaCO_3$ was measured by the Collins calcimeter, Ca, Mg, Na and K cations were measured by atomic absorption and emission spectrophotometry. These analyses were developed with methodologies validated by the Water, Soil, and Foliar Laboratory (LABSAF) of the Donoso Kiyotada Miyagawa Agricultural Experiment Station of the National Institute for Agrarian Innovation (INIA).

2.4. Seeding process

The green beans plants were sown at a distance of 0.25 m between plants and 0.6 m between twin furrows, 2 seeds per stroke. After 20 days, the compost doses of the different treatments were applied to the plants.

2.5. Foliar analysis

To carry out the analysis, it was necessary to select mature leaves in good condition, crush and homogenize them, extract the nutrients using a solvent, and perform a chemical analysis of their concentration by atomic absorption spectroscopy, according to the methodologies validated by the Water, Soil, and Foliar Laboratory (LABSAF) of the Donoso Kiyotada Miyagawa Agricultural Experiment Station of the National Institute for Agrarian Innovation (INIA).

2.6. Biometric and physicochemical analysis of pods

The biometric measurements of major or equatorial diameter (mm) and minor diameter were made using a micrometer (Kamasa, SKU, Peru), with a scale of 0–25 mm; while the length (m) was measured with a digital electronic caliper vernier (Control Company Traceable, model SR44, Mexico). The weight was recorded using an analytical balance (Sartorius, model Entris 224-1S, Germany), according to the methodology reported by Rosales [19].

Horizontal and vertical firmness were measured with a penetrometer (Wagner, Force Dial FDK 30, USA) with a scale of 14 kgf x 100 gf. The horizontal strength was measured by placing the pods horizontally, while for the vertical strength, 1 cm cuts were prepared and then measured vertically [20].

The physicochemical analyses of the green beans were: moisture using an oven (Binder brand, model FD53, Germany) [21], dry matter by the difference between 100 % and % moisture, ash using a muffle furnace (Thermo Concept brand, model KL15/11, Germany) [22], acidity by gravimetry in titration equipment (Titronic brand, model 500, Spain) and pH with potentiometer (Hanna HI320 brand, USA) [23]. The physicochemical analyses applied to the pods were performed in triplicate.

2.7. Color parameters

The color parameters of the rind, mesocarp, and grain were quantified with the PCE Instruments Colorimeter (Model CSM 3, Spain), observation angle of 8°, Illuminant blue LED D65 with 8 mm aperture. The color coordinates L* (0 = black, 100 = white), a* (+red, -green) and b* (+yellow, -blue) were determined according to the CIELAB coordinate color space system [24,25]. In addition, the C*, h*, was determined, where C* is the chroma and h* denotes the hue or angle of a polar measurement. The chroma value C* = (a*2 + b*2)0.5 and the hue angle h* = arctangent (b*/a*) [26,27]. Color was determined by quadrupling at room temperature.

2.8. Leaf and fruit shape analysis

Porosity was determined by image analysis. Images were obtained with the Laser Jet Pro Scanner (Model: 400 MFP, M425 DN Series), using a black background cover (0.25 m × 0.30 m), natural illumination, and a 300x zoom. The brightness, contrast and threshold of the images were adjusted and converted to 8 bits for analysis using the ImageJ® Software particle analysis tool (https://imagej.nih.gov/ij/). The area of leaves and fruits were calculated as the total area of the image [28].

2.9. Sensorial analysis

2.9.1. Consumers

The sensory study was conducted with 53 consumers between 18 and 40 years of age. The participants were students, professors, and administrative staff of the Universidad Nacional de Barranca. The evaluators were regular consumers of vanitas. The participants performed the discriminative and descriptive tests of vanitas in 2 sessions (5 samples per session); they were given an induction and informed consent for their participation.

2.9.2. Discriminative test – free sorting task

The samples were given in groups of five samples, they were asked to taste the samples in the order they wanted, trying to remember the characteristics of each sample. They were asked to rinse their mouths between samples and to group the samples considering the similarities or differences they perceived between the samples, considering that very similar samples should remain in the same group and very different samples should remain in different groups. You can group the samples using any number of groups de-sired by the consumer. Values ranging from 1 (if all samples look the same) to 5 (if all samples are different) were used to group the samples. They were asked to write down the samples that remain in each of the identified groups and then to describe in 4 or 5 words the characteristics of each of the identified groups [29,30].

2.9.3. Descriptive test – flash profile

It was performed in individual booths with white light. Three sessions were held. In the first session, the evaluators were instructed to generate an individual list of attributes describing the sensory properties that they could perceive and that would allow them to differentiate the samples. In the second session, an individual interview was conducted with each consumer to reach a consensus and avoid duplication of terms in their list describing similarity to the list. The consumers were then informed of the descriptors proposed by the other team members, and each was in a position to update their final list before the analysis, to be sure not to forget or confuse any descriptor in their own file. In this way, each consumer presented a final list of attributes. In the third session, called the sorting stage, the pods were again presented simultaneously and in random order, and each consumer carried out the sensory evaluation considering the attributes chosen by him. For this purpose, they were asked to order the samples in increasing order of in-tensities for each of the attributes defined above, on an ordinal scale; equal results were allowed; each session lasted approximately 20–30 minutes for each consumer [31,32].

2.10. Statistical analysis

A completely randomized design (CRD) was applied, with five treatments of compost dosage levels. The response variables were physicochemical, textural, and color characteristics. The results were expressed as mean values ± standard deviation (SD). In the case of significance, Tukey's comparison of means was performed with a 95 % confidence level. The discriminative Sorting test was evaluated using the FAST function of the SensoMineR package, while the Flash Profile data were subjected to generalized procruster analysis using the FactoMineR package. The data were processed using R soft-ware and XLSTAT 2022.

3. Results and discussion

3.1. Soil characterization

The results of the soil analysis of the experimental area show an electrical conductivity of 1.44 mS/cm (measured at a dilution of 1:2.5), pH of 7.1 (measured at a dilution of 1:2. 5), organic matter 1.90 %, Nitrogen 0.09 %, Phosphorus 13.45 ppm; Potassium 135.07 ppm, $CaCO_3$ 0.0 %, cation exchange (mEq/100 g soil) of Calcium 6.54, Magnesium 1.15, Sodium 0.54 and Potassium 0.35 [33]. These results show a neutral pH value, a low concentration of organic matter and nitrogen, but adequate phosphorus and potassium according to the values of Prialé [34]. Regarding cation exchange values, calcium, magnesium, sodium, and potassium are within the values recommended by McKean [35].

The green beans plants were sown with a distance of 0.25 m between plants and 0.6 m between twin furrows, in 2 seeds per stroke, whose soil fertility was as follows: Electrical conductivity (1:2.5) of 0.73 mS/cm, pH (1:2.5) 8.00, organic matter 0.51 %, nitrogen 0.03 %, phosphorus 17.05 ppm, potassium 115 ppm, $CaCO_3$ 5.72 %. After 20 days, the compost doses of the different treatments were applied to the plants.

3.2. Characteristics of organic compost

The compost was made from solid organic waste generated in the supply markets, which was composted for 3 months. From the compost obtained, a 1 kg sample was taken for a complete analysis of elements at the National Institute for Agrarian Innovation (INIA), the results of which showed a content of pH of 8.54 (dilution 1:2.5), E.C. (1:5) 4.22 mS/cm, humidity 10.82 %, organic matter 12.93 %, nitrogen 1.06 %, P_2O_5 2.17 %, K_2O_5 0.65 %, CaO 1.81 %, MgO 1.30 %, C/N 7.07, 4583.03 ppm Fe, 79.22 ppm Zn and 12.53 ppm Cu.

3.3. Nutrient analysis of green beans leaves

Fig. 1 shows green bean (Phaseolus vulgaris L.) plants during their vegetative phase, treated with organic compost. According to the nutrient analysis of green beans leaves (Table 1), carried out at the INIA, it was determined that as the doses of compost based on market residues increased, the concentration of nitrogen, phosphorus, potassium, calcium, magnesium, iron, copper, zinc and manganese increased. It is deduced that, according to the plant physiology, the higher the dose of this fertilizer, the higher the quantities of these elements, especially N, P, and K, which influence many biochemical reactions such as carbohydrate formation, evapotranspiration, together with the microelements, improve strengthening, thus obtaining higher yields and better pod quality. Leaf analysis depends on the type of plant, which is reflected in the ranges of deficiency, normality, and toxicity between species and cultivars in the variation of elements also when the comparisons are of the same physiological age [36].

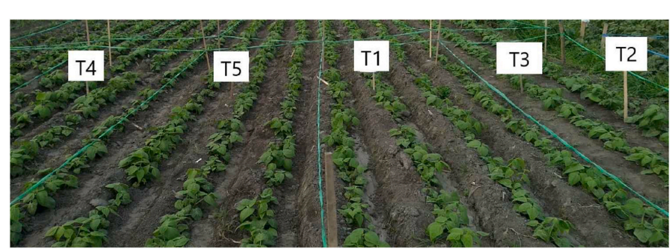

Fig. 1. Comparison of green bean (*Phaseolus vulgaris* L.) plant development by treatment. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Leaf analysis of pods by treatment.

Treatment	T1	T2	T3	T4	T5
Percentage (%)					
N	3.6650 ± 0.0212[e]	4.0100 ± 0.0141[d]	4.2200 ± 0.0141[c]	4.5050 ± 0.0071[b]	4.5700 ± 0.0141[a]
P	0.3350 ± 0.0071[b]	0.3550 ± 0.0071[b]	0.4225 ± 0.0106[a]	0.4000 ± 0.0141[a]	0.4150 ± 0.0071[a]
K	2.2550 ± 0.0345[d]	2.1900 ± 0.0141[d]	2.6500 ± 0.0141[c]	3.0750 ± 0.0071[b]	3.3900 ± 0.0141[a]
Ca	2.6850 ± 0.0212[c]	2.6450 ± 0.0071[cd]	2.6100 ± 0.0141[d]	2.8700 ± 0.0141[b]	2.9400 ± 0.0141[a]
Mg	0.3250 ± 0.0071[e]	0.4050 ± 0.0071[d]	0.5550 ± 0.0071[c]	0.5850 ± 0.0071[b]	0.6450 ± 0.0071[a]
ppm (mg/kg)					
Fe	133.7900 ± 0.0141[c]	115.1300 ± 0.0071[e]	132.2600 ± 0.212[d]	136.0700 ± 0.0141[b]	179.4700 ± 0.0141[a]
Cu	8.2200 ± 0.0283[d]	12.2000 ± 0.0283[c]	16.7050 ± 0.0071b	18.9050 ± 0.0071[ab]	20.0000 ± 1.4100[a]
Zn	60.7000 ± 0.0283[c]	68.6150 ± 0.0071[b]	51.2900 ± 0.0141[e]	60.0150 ± 0.0071[d]	86.3800 ± 0.0141[a]
Mn	61.2000 ± 0.0283[e]	73.6950 ± 0.0071[c]	92.4000 ± 0.1410[a]	72.1050 ± 0.0071[d]	84.6050 ± 0.0071[b]

Values followed by different letters in the same column show significant differences ($p \leq 0.05$) according to Tukey's test.

3.4. Biometric and textural characteristics

Table 2 shows that there are no significant differences ($p > 0.05$) in the biometric characteristics of greater or equatorial diameter, smaller diameter, length, and weight of pods produced with 5 levels of organic compost. However, there was a higher average mean equatorial diameter in T5. According to their equatorial diameter, T1 and T3, corresponding to type B "fine" (≤6.1 ≤ 9), while T2, T4, and T5 are classified as "untypified" [1]. The length T2, T4, and T5 are classified as type I "large" (min 150 mm; max. 190 mm), while T1 and T3 are considered as type II "medium" (min 110 mm; max. 149 mm), the length values are close to those obtained by Tarabata [37]. Concerning weight, T3 shows a higher average mean, although there are no significant differences ($p > 0.05$) between the samples.

Pod firmness measured in N (Table 1 and Fig. 2), related to maturity and pressure resistance, did not show significant differences ($p > 0.05$) between samples, both for horizontal and vertical strength.

Table 3 shows that there are no significant differences ($p > 0.05$) in the physicochemical characteristics of moisture, dry matter, ash, acidity, and pH of the different samples. However, there was a higher mean average moisture in T3 and inversely higher dry matter in T1. Moisture quantifies the water content, being its value high because it is a fresh product [4,10,14,38]. Dry matter is a parameter that totals the content of organic components as many macronutrients (carbohydrates, fat, proteins) and micronutrients (vitamins and minerals). The pH and acidity are in the normal range for fresh vegetables, characterized as a low acid product [39].

Table 4 shows that the colorimetric parameters did not show significant differences ($p > 0.05$) in all parameters on the international color system scale, both L*, a*, b*, C*, and h* in the pericarp (peel), mesocarp and kernel, however, the kernel is lighter than the epicarp (see Table 4).

According to the analysis of leaf and fruit areas in Table 5, it is observed that at the highest dose (T5) the area of the adverse and reverse part of the leaves decreased, but the area of the fruit increased considerably, increasing by more than a quarter about the control (T1). This finding can be understood as the effect of applying a higher amount of compost, which resulted in the incorporation of nutrients into the soil. This, in turn, increased the availability of nutrients for plant uptake. These nutrients played a key role in driving optimal biochemical reactions, such as photosynthesis and efficient translocation of carbohydrates to the pods. These processes significantly strengthened the plant, resulting in higher crop yields. This statement finds support in the work of Deaquiz-Oyola [40], where it is pointed out that the photosynthesis process in immature fruits occurs similarly to what happens in leaves. However, this dynamic is modified during the ripening process, since chlorophyll degrades its presence and other pigments come into play, such as carotenoids, α-carotenes, and β-carotenes.

The images of the fruits (Fig. 2), show great variability in the shape and intensity of the coloration and shape of the leaves.

3.5. Sensorial analysis

A sensory study was conducted with 80 participants (56 % women). All participants were able to purchase and consume green beans as part of their meals. Consumers were between 18 and 30 years old. They were in good health and resided in the city of Barranca.

3.5.1. Free sorting task

Fig. 3 shows the sensory map and the confidence ellipses corresponding to the different pod samples in two dimensions, explaining 59.51 % of the total variability of the data. To explain the positioning of the samples based on the information provided by consumers, the formation of four groups is observed: the first group formed by T1, the second group T2, the third group T3 and the fourth group T4 and T5. The positioning of the samples is mainly explained by the concentration of the compost, increasing the concentration allows consumers to differentiate the samples up to 10 t/ha, after this concentration (>10 t/ha) they perceive it as similar. The T1 sample was differentiated by being juicy, thin, green, shiny, and flexible. T2 was described as hard, less green, rough, opaque, and straight. Sample T3 was characterized by a uniform color, flaccid, dark, and strong odor. Samples T4 and T5 were described as lighter, dry, deep green, long, thin, torn, and round. The method allowed finding a consensus on how consumers perceive the similarities and differences between the pods.

3.5.2. Flash profile

The application of the flash profile allowed each consumer to generate between seven and ten terms, making a total of 101 sensory descriptors subdivided into appearance (36), texture (25), odor (18), color (20), and flavor (05). In addition, a consumer consensus index value (Rc) of 58.3 % was obtained.

When applying the generalized procrustes analysis to the flash profile data, it was observed that two dimensions explain 64.07 % of the total variability of the data. To determine if there are significant differences between the samples, their respective confidence ellipses were

Table 2
Biometric and firmness characteristics.

Treatment	Largest or equatorial diameter (mm)	Smaller diameter (mm)	Length (m)	Weight (g)	Horizontal firmness (N)	Vertical firmness (N)
T1	8.4440 ± 1.3330[a]	7.4440 ± 1.1300[a]	0.1437 ± 0.0316[a]	6.9120 ± 2.8500[a]	68.6500 ± 12.0300[a]	31.9300 ± 7.8500[a]
T2	9.1110 ± 2.1470[a]	7.1110 ± 1.1670[a]	0.1628 ± 0.0106[a]	7.0770 ± 2.0300[a]	62.9800 ± 10.36000[a]	32.9100 ± 6.6700[a]
T3	8.1110 ± 1.1670[a]	7.0000 ± 1.2250[a]	0.1478 ± 0.0207[a]	7.4180 ± 1.8950[a]	65.7000 ± 5.7800[a]	35.6300 ± 5.7800[a]
T4	9.2220 ± 1.6410[a]	7.0000 ± 2.0000[a]	0.1557 ± 0.0172[a]	7.1150 ± 2.9630[a]	64.7200 ± 13.5500[a]	34.9800 ± 5.2800[a]
T5	9.4440 ± 1.6670[a]	8.1110 ± 1.3640[a]	0.1503 ± 0.0210[a]	6.6210 ± 2.7640[a]	59.7100 ± 12.1900[a]	36.2800 ± 5.4600[a]

Values followed by different letters in the same column show significant differences ($p \leq 0.05$) according to Tukey's test.

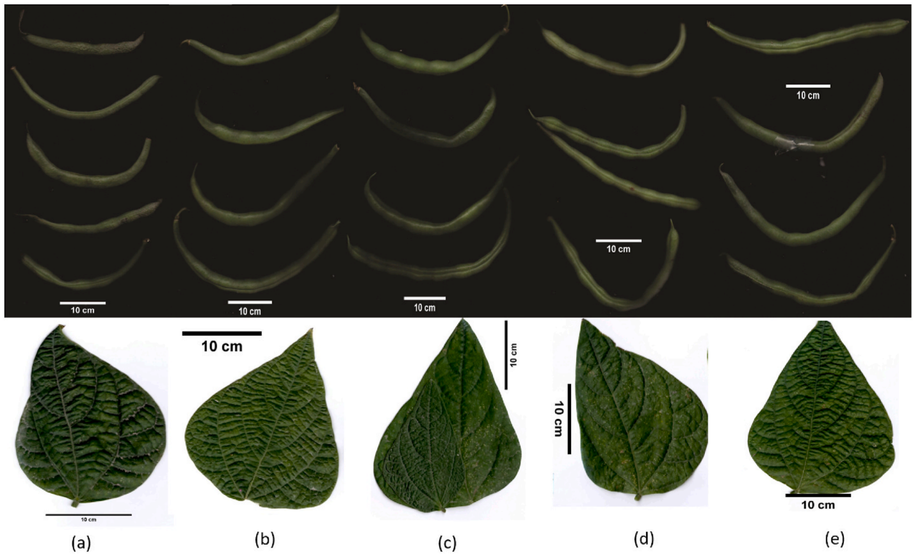

Fig. 2. Images of fruit and leaf structure of pods according to treatments (25 mm × 25 mm image area). (a) T1, (b) T2, (c) T3, (d) T4 y (e) T5.

Table 3
Physicochemical characteristics of vanitas.

Treatment	Moisture (%)	Dry matter (%)	Ash (%)	Acidity (% citric acid)	pH
T1	88.0600 ± 4.2300^{a}	11.9400 ± 4.2300^{a}	0.7559 ± 0.154^{a}	0.0014 ± 0.0003^{a}	6.3467 ± 0.0153^{a}
T2	88.8700 ± 0.0790^{a}	11.1330 ± 0.0797^{a}	0.6845 ± 0.130^{a}	0.0011 ± 0.0006^{a}	6.3900 ± 0.0100^{a}
T3	89.7500 ± 0.7620^{a}	10.2490 ± 0.7620^{a}	0.7020 ± 0.1371^{a}	0.0011 ± 0.0000^{a}	6.3533 ± 0.0981^{a}
T4	89.4500 ± 2.6700^{a}	10.5500 ± 2.6700^{a}	0.5486 ± 0.1325^{a}	0.0012 ± 0.0002^{a}	6.3233 ± 0.0462^{a}
T5	89.4700 ± 1.0380^{a}	10.5270 ± 1.0380^{a}	0.5947 ± 0.1489^{a}	0.0011 ± 0.0001^{a}	6.2567 ± 0.0252^{a}

Values followed by different letters in the same column show significant differences ($p \leq 0.05$) according to Tukey's test.

constructed (Fig. 4a), showing the conformation of three groups: the first one constituted by samples T1 and T2, the second one only T3 and the third one constituted by T4 and T5. These results show the capacity of the flash profile method to describe the products according to the attributes generated by the different treatments submitted for the cultivation of the pods. Fig. 4b describes the sensory ratios of these groupings, showing the attributes generated in consensus by each evaluator. Samples T1 and T2 were characterized by their thickness, size, earthy odor, elasticity, and presence of spots. On the other hand, T4 and T5 were described as moist, pulpy, smooth, hard, and rough. T3 was perceived as fresh, green, shiny, sandy, and dry. Thus, the use of compost at low or high concentrations allows for describing the samples similarly to each other, although an intermediate concentration generates different descriptors. In general, the flash profile method allows consumers to evaluate the pods simultaneously and to have a quick positioning of the attributes generated in the sensory map.

4. Conclusions

Green beans produced with organic compost inoculation show a direct influence of compost concentration level on foliar characteristics, as compost concentration in-creases, the properties of % N, P, K, Ca and Mg and mg/kg Fe, Cu, Zn, Mn are increased. However, no direct influence was observed on biometric characteristics (equatorial diameter, length, and weight), firmness, physical-chemical characteristics (moisture, dry matter, ash, acidity, and pH), or color. The sensory evaluations made it possible to describe the attributes and to group the pods by the similarity of descriptors. The Sorting Task test according to descriptors established by consumers allowed identifying 4 groups: first made up of T1, second T2, third T3, and fourth T4 and T5; while the Flash Profile test allowed grouping them into 3 groups: first made up of T1 and T2, second T3 and third made up of T4 and T5; among the main descriptors identified by attributes we have texture: juicy, flexible, hard, rough, rough, rough, flaccid, soft; appearance: thin, uniform, straight; color:

Table 4
Color of rind and mesocarp of the pod.

Sample	L*	a*	b*	C*	h*
	Pericarp (shell)				
T1	46.260 ± 1.557^{a}	−7.354 ± 1.153^{a}	27.660 ± 2.122^{a}	28.631 ± 2.256^{a}	104.860 ± 1.720^{a}
T2	48.570 ± 3.670^{a}	−6.960 ± 1.926^{a}	31.184 ± 2.272^{a}	31.544 ± 2.523^{a}	102.710 ± 3.210^{a}
T3	46.870 ± 3.880^{a}	−7.344 ± 2.133^{a}	30.420 ± 4.220^{a}	31.320 ± 4.480^{a}	103.340 ± 3.010^{a}
T4	48.740 ± 5.360^{a}	−8.810 ± 3.010^{a}	30.620 ± 4.440^{a}	31.920 ± 4.920^{a}	105.700 ± 4.040^{a}
T5	45.310 ± 5.250^{a}	−8.127 ± 2.420^{a}	28.310 ± 5.430^{a}	29.470 ± 5.850^{a}	105.770 ± 2.150^{a}
Mesocarp					
T1	41.094 ± 1.807^{a}	−1.208 ± 1.092^{a}	23.997 ± 1.886^{a}	24.051 ± 1.895^{a}	92.872 ± 2.572^{a}
T2	45.360 ± 3.890^{a}	−4.432 ± 2.979^{a}	27.520 ± 3.680^{a}	27.970 ± 4.040^{a}	98.680 ± 5.060^{a}
T3	42.073 ± 2.937^{a}	−3.128 ± 1.825^{a}	26.430 ± 3.620^{a}	26.650 ± 3.750^{a}	96.530 ± 3.310^{a}
T4	44.550 ± 6.370^{a}	−5.370 ± 3.610^{a}	25.860 ± 5.640^{a}	26.530 ± 6.170^{a}	100.970 ± 5.640^{a}
T5	41.070 ± 3.640^{a}	−4.148 ± 2.440^{a}	23.866 ± 2.726^{a}	24.313 ± 2.895^{a}	99.650 ± 5.280^{a}
Grain					
T1	73.120 ± 4.250^{a}	−11.194 ± 2.928^{a}	38.520 ± 4.880^{a}	40.140 ± 5.460^{a}	105.960 ± 2.350^{a}
T2	70.470 ± 3.600^{a}	−12.246 ± 1.484^{a}	43.210 ± 4.520^{a}	44.930 ± 4.490^{a}	105.900 ± 1.890^{a}
T3	69.060 ± 3.370^{a}	−12.937 ± 0.816^{a}	42.750 ± 3.220^{a}	44.680 ± 3.090^{a}	106.900 ± 1.570^{a}
T4	72.520 ± 5.190^{a}	−12.508 ± 2.775^{a}	42.250 ± 7.800^{a}	43.480 ± 9.350^{a}	106.450 ± 1.770^{a}
T5	72.172 ± 2.362^{a}	−14.224 ± 1.445^{a}	41.730 ± 3.310^{a}	44.621 ± 2.607^{a}	108.560 ± 0.979^{a}

Values followed by different letters in the same column show significant differences ($p \leq 0.05$) according to Tukey's test.

Table 5
Leaf and fruit shape and area analysis.

Treatment	Leaf area - Adverse (mm^2)	Leaf area - Reverse (mm^2)	Fruit area (mm^2)
T1	45145 ± 5817[a]	40487 ± 4114[a]	7726 ± 503[b]
T2	33051 ± 7605[a]	23380 ± 1760[b]	9338 ± 245[ab]
T3	28617 ± 2934[a]	30075 ± 3083[ab]	10300 ± 946[ab]
T4	32024 ± 2267[a]	29147 ± 2481[ab]	11271 ± 525[a]
T5	27139 ± 6094[a]	29857 ± 4702[ab]	10976 ± 555[a]

Values followed by different letters in the same column show significant differences ($p \leq 0.05$) according to Tukey's test.

green, shiny, opaque, dark; and strong odor.

CRediT authorship contribution statement

Ronald Fernando Rodriguez Espinoza: Investigation, Methodology, Writing – original draft, Writing – review & editing. **Juan Manuel Ipanaqué Roña:** Conceptualization, Investigation, Methodology. **Dante Daniel Cruz Nieto:** Conceptualization, Methodology, Supervision, Writing – original draft. **Joaquin José Abarca Rodriguez:** Formal analysis, Methodology, Validation. **Yolanda Maricruz Eguilas Caushi:** Data curation, Formal analysis, Validation. **Johnny Mitchell Gomero Mancesidor:** Data curation, Formal analysis, Methodology, Writing – original draft. **Hector Jorge Castro Bartolomé:** Data curation, Formal analysis, Investigation, Writing – original draft. **Nicodemo Crescencio Jamanca-Gonzales:** Data curation, Formal analysis, Methodology, Software, Supervision, Writing – original draft. **Reynaldo Justino Silva-Paz:** Data curation, Formal analysis, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial

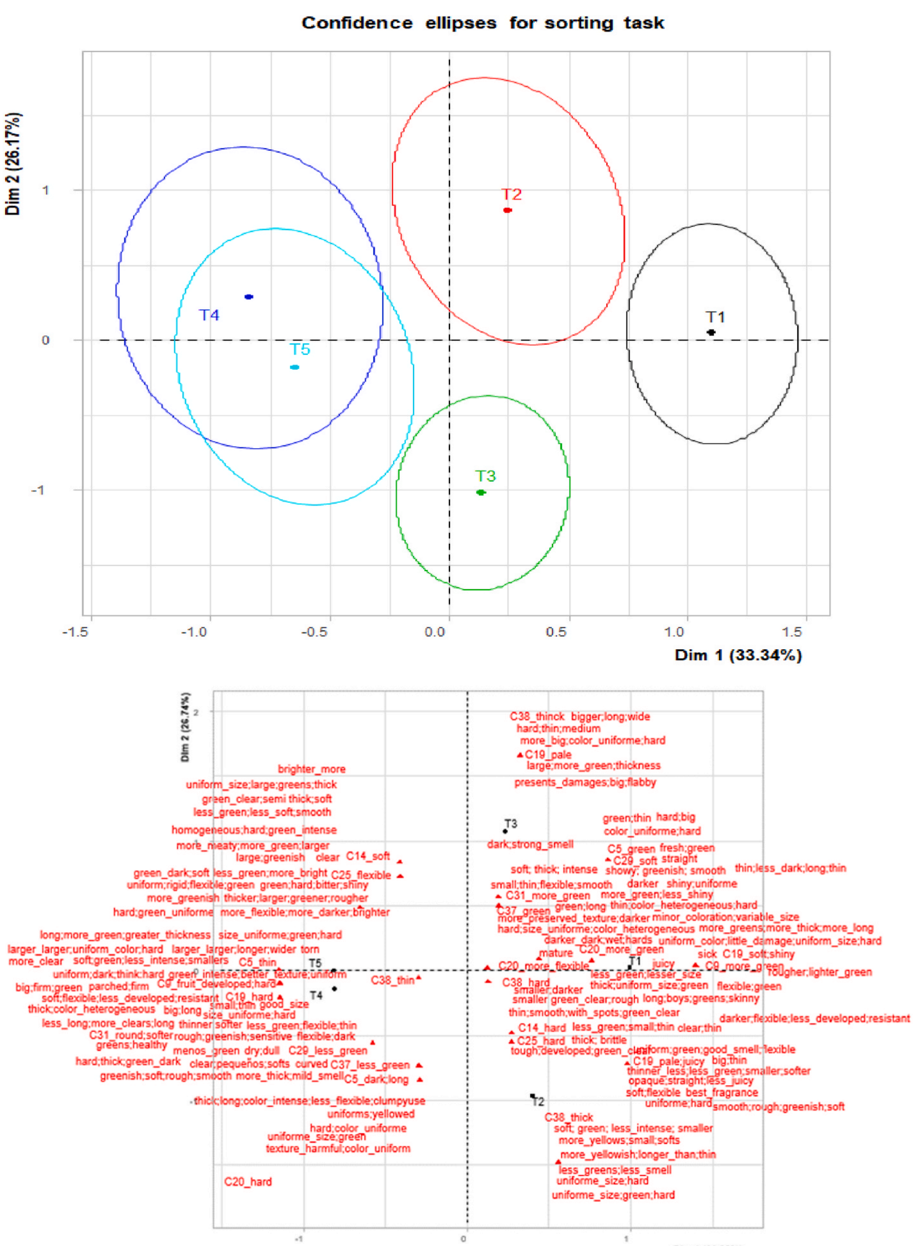

Fig. 3. Confidence ellipses (a) and descriptors (b) of the two-dimensional green beans generated by the Sorting test. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

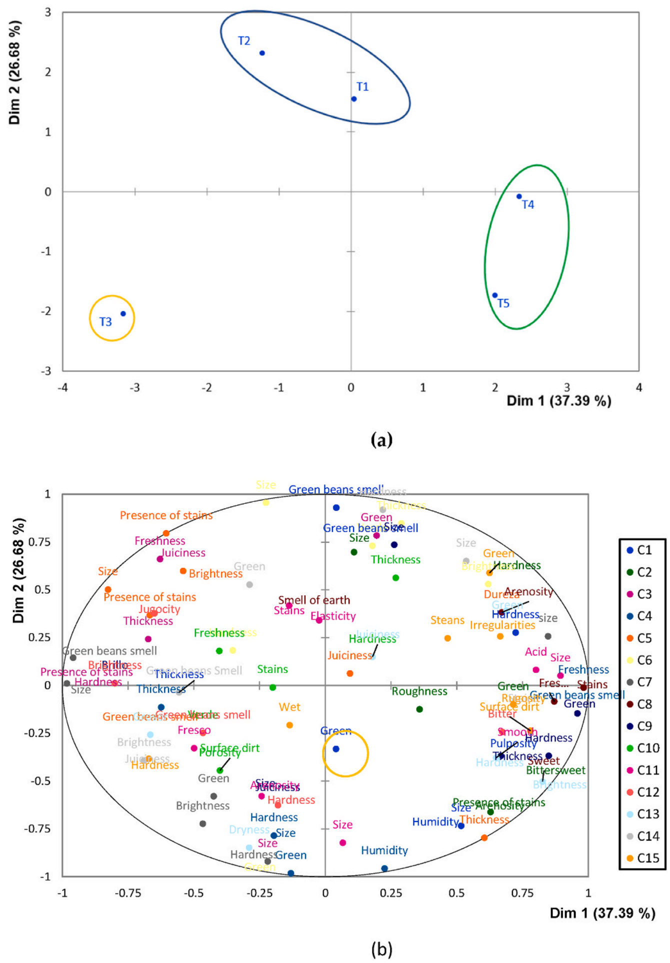

Fig. 4. Graph of samples (a) and descriptors (b) using Flash Profile generalized procrustes analysis.

interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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