



The appeal of bananas: A qualitative sensory analysis and consumers' insights into tropical fruit consumption in Italy

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ABSTRACT

The consumption of tropical fruits has been increasing throughout the world, especially in non-producing countries. Among the fruits in this category, bananas (*Musa* spp.) have consistently demonstrated a growing trend in both purchases and consumption throughout the world, and also in Italy. The following question therefore arises: is there a correspondence between the quality characteristics of bananas on the market and the consumers' preferences? The objectives of this study were twofold: 1) to qualitatively and sensorially characterize bananas at three different stages of commercial ripening (Banana quality assessment); and 2) to explore the consumption habits, perceptions, and preferences of Italian consumers regarding tropical fruits, focusing in particular on fruit quality, health, and sustainability (Consumers' perception of tropical fruits). The results indicated that ripe bananas were preferred by the sensory panel and maintained high-quality attributes even after five days of storage at room temperature. Moreover, the importance of the sustainability of tropical fruits and a preference for ripeness of bananas during the decision-making stage were found to be influenced by individual factors. Different levels of awareness and purchasing styles were identified. However, the connection between the findings of the sensory analysis and the declared preferences revealed several insights that can be used to improve managing the supply and assortment of bananas for distribution to satisfy the consumers' preferences, improve communication strategies, encourage waste reduction, and enhance supply chain sustainability.

1. Introduction

Significant social and cultural transformations have occurred on the food market as a result of the extensive global interconnectedness, the growing international economic and trade exchanges, and the entrenched phenomenon of globalization. These changes have resulted in shifts in individuals' dietary habits and consumption behaviours [1]. Italians, and Europeans in general, have been exposed to a wide variety of fruits in stores and markets, including non-traditional European cultivars. These fruits typically grow in warm and humid regions, and they are therefore classified as tropical fruits [2]. Such fruits include some widely consumed types, such as bananas, pineapples, and avocados, as well as some lesser-known exotic fruits, such as passion fruit, papayas, and lychees. However, the extensive supply chain of tropical fruits and the political and social situations that characterize many of the countries from which they are imported raise sustainability issues [3]. These

issues encompass not only environmental aspects, such as soil preservation, reduced water usage, and CO₂ emission reductions, but also ethical and social sustainability, including considerations related to the local economy, poverty prevention, and the respect of workers' rights [4].

This growing interest in new exotic ingredients has been accompanied by a preference for locally produced goods. Local products, with shorter supply chains and often harvested when fully ripe, have a reduced environmental impact and are often superior in taste [5]. Consumers are willing to pay a premium enhance price for products grown in Italy, even when produced using organic methods, compared to fruits that have been transported over long distances. Bananas (*Musa* spp.), despite being a tropical fruit, are now a common part of our daily diets. It should be considered that they were the most imported fruit in Italy in 2021, that is, about 777 thousand tons were imported, for a value of almost 510 million dollars [6]. The most important cultivars are

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“Cavendish” and “Gros Michel” of the *Musa acuminata* species, which are also known as dessert bananas. They are the most commercialized varieties throughout the world, and are eaten raw when fully mature [7]. They are triploid varieties, with more vigorous growth and larger fruit productions than diploid cultivars [8]. Banana production, on a global scale, is currently facing numerous sustainability challenges. Firstly, there is a recognized link between decreased productivity and soil degradation over time. Additionally, compared to other tropical fruits, the extensive intercontinental supply chain, from producer countries to consumer markets, presents environmental challenges [9]. Furthermore, it is important to consider consumers’ perceptions regarding the treatments that such fruits undergo to extend their shelf life.

However, despite the various critical points in this supply chain, bananas rank second among the fruit crops produced in subtropical and tropical regions of the world. Asia is the world’s largest producer of bananas: China is the third largest banana producer in the world. A total of 80% of global banana exports come from Latin America and the Caribbean [10]. Latin America is the leading supplier of bananas to the European market, with Ecuador being the world’s leading banana exporter (35 % of its Gross domestic production (GDP) is created by the banana export industry) [11]. Bananas are climacteric fruits that undergo postharvest ripening, during which physiological, structural, and biochemical changes affect the texture, appearance, aroma, and flavor of the fruits. Thus, the quality of bananas is influenced to a great extent by the state of ripening. The ripening periods vary according to the cultivar, but, in general, bananas marketed in consumer countries have already undergone ripening in the post-harvest stages (transport, marketing) [12]. This characteristic affects the homogeneity and quality level of the fruits at the point of sale, especially in large-scale retail trade, where the assortment of bananas varies not only in terms of ripening degree, but also in extrinsic aspects (color, brand, price) and credence attributes (i.e. certifications) [13]. In addition, the assortment planning of bananas in organized large-scale retail channels typically involves a wide selection of the ripeness level of the fruits in a standardized manner, which means all fruits that exceed a certain degree of ripeness (strong yellow-flecked brown) are discarded from sale.

Although several studies have dealt with the sensory analysis of bananas [14] and others have studied consumers’ preferences regarding sustainability aspects [15], no research has so far analyzed the sensory, physical, chemical, and nutritional aspects together with the perception of sustainability. Emphasizing the link between the sensory aspects of bananas and the importance consumers attribute to sustainability, in terms of social, environmental, and ethical characteristics, according to different degrees of awareness of the ecological and social issues of the supply chain of tropical fruits and bananas, can represent an advantage for the market. Such an approach could help direct the distribution of bananas and guide corporate communication and sales channels toward consumers who make informed purchases.

In this context, we asked ourselves the following research questions: what are the sensory and nutritional characteristics of bananas at sales points with reference to different ripening stages? What are the preferences of consumers regarding the characteristics of bananas? Is there a correspondence between the supply characteristics of bananas and consumers’ choices?

This research has had a two-fold aim: the quality characteristics of bananas were assessed in the “Banana quality assessment” by characterizing the fruits at three different ripening stages, and this was coupled with a sensory evaluation of the fruits available on the Italian market: (I) to understand what the consumers’ preferences were regarding the purchasable product; in the “Consumers’ perception of tropical fruits” section, the food consumers exhibited changing attitudes toward different market approaches to sustainability issues; (II) to investigate whether and how certain socio-demographic characteristics, such as age and gender, could influence food choices; (III) to find various clusters according to the consumers’ distinct perceptions of tropical fruits; (IV) to explore the consumption of bananas, and to establish whether it was

aligned with the general perceptions of tropical fruits or differed according to its commodity status.

2. Materials and methods

2.1. Banana quality assessment

The Colombian banana cv. Cavendish was provided by Battaglio S.p.a. (Piedmont, North-West Italy) in March 2023 at three different commercial ripening stages (Fig. 1), identified as 3, 4, and 6 according to [16] and in compliance with the United States Department of Agriculture (USDA) banana ripening guide. The bananas of each ripening stage were considered as a single sample. Each sample was made up of 15 bananas. The samples were named A, B and C, respectively, for the greener bananas to the ripest ones. The fruits were monitored, in terms of qualitative parameters, at the Department of Agricultural, Forest and Food Sciences (DISAFA) at the University of Turin (Grugliasco, Italy). Qualitative assessments were performed on day 0 and after 5 days of storage at room temperature, that is, at around 18 °C.

Weight loss and the ratio between the pulp and peel were monitored using an electronic scale (model SE622, VWR Science education, Radnor, Pennsylvania, USA) with a 10⁻² g accuracy. Weight losses were expressed in percentage and calculated according to the following formula:

$$\text{Weight loss \%} = \frac{\text{weight}_{\text{day 0}} - \text{weight}_{\text{day 5}}}{\text{weight}_{\text{day 0}}} \times 100 \quad (1)$$

The ratio between the pulp and peel was calculated with the following formula and expressed as a pure number:

$$\text{Pulp / peel ratio} = \frac{\text{weight}_{\text{pulp}}}{\text{weight}_{\text{peel}}} \quad (2)$$

The soluble solids content (SSC) was determined with a digital refractometer (model PR-101, Atago, Japan) at 18 °C, and the results were expressed as °Brix.

The titratable acidity (TA) of the banana juice was determined by titration, with 0.1 N NaOH to pH 7.0, using 10 ml of fruit juice diluted in 15 ml of distilled H₂O. The obtained results were expressed as meq l⁻¹.

A pulp texture analysis was conducted with a texture analyser

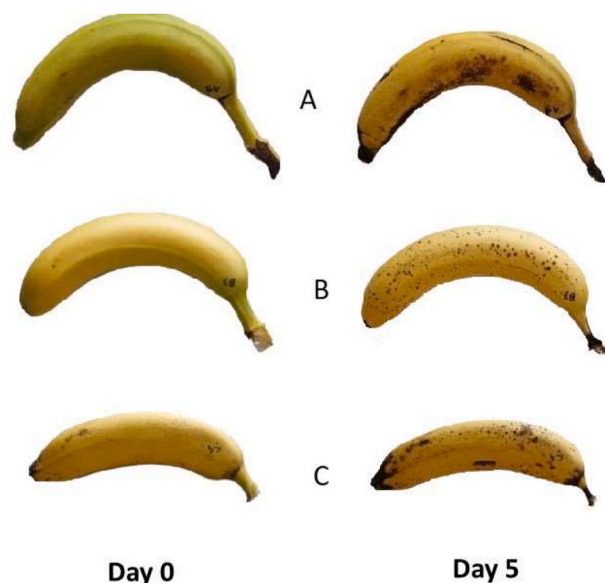


Fig. 1. Banana cv Cavendish at three different ripening stages on 0 day and after 5 days of storage at room temperature (18 °C). A = green banana; B = medium ripening; C = completely yellow banana.

(model TA.XT plus, Stable Micro Systems, Godalming, U.K.), as reported in a previous study [17]. The fruits were sliced to obtain 5 mm thick discs. The plunger was 75 mm wide. The trigger force was set to 5 g and the deformation to 30%. The pre-test speed was 2 mm s^{-1} , while both the test and post-test speeds were 1 mm s^{-1} . The considered parameters were: hardness (g), adhesiveness (g^*s), and gumminess. All the quality controls were performed immediately after purchasing (0 days) and after 5 days of shelf life at $18 \text{ }^\circ\text{C}$ (controlled room temperature). Each analysis was performed in triplicate. All the results were expressed as mean values \pm the standard deviation.

A sensory analysis was also performed on day 0 by untrained panellists (five men and five women, 25–30 years old) from DISAFA. These panellists provided an arbitrary opinion on 10 different attributes, in relation to texture, flavor, and odor. These attributes were selected from the work of Bagaud et al. [18], albeit with some modifications, as reported in Table 1. The panellists gave a rating to each attribute on a scale from 1 (very low/minimally perceived) to 5 (very high/fully perceived).

2.2. Consumers' perception of tropical fruits

In order to understand consumers' behaviors toward and preferences for tropical fruits in general, and bananas in particular, a survey was drawn up and administered online, via social media, in the North-West of Italy in the period between December 2022 and April 2023.

The only eligibility criterion for participation in the survey was that the participants needed to be at least 18 years old. The online survey was conducted anonymously, and the respondents were required to provide their consent before participating, after reading a disclosure sheet describing the project and survey aims. The questionnaire was developed in Italian language. The research adhered to the principles outlined in the Declaration of Helsinki.

The questionnaire was structured into the following sections:

1. The first section focused on collecting socio-demographic data from the respondents, including gender, age, place of residence, educational background, whether they had school-age children, the number of household members, employment status, and average annual household income.
2. In the second section, we explored the frequency of consumption of both traditional fruits (e.g., apples, pears, oranges, etc.) and tropical fruits (e.g., bananas, avocados, pineapples, etc.) using a 7-point Likert scale, ranging from 0 (I do not eat bananas) to 6 (I eat them daily).
3. Subsequently, we employed three scales to assess the participants' preferences and attitudes toward food in general, tropical fruits, and

Table 1

Description of the 10 sensorial attributes selected to describe the banana samples.

Attribute	Description
Firmness	The force needed to crush a sample with one's teeth. The score obtained for this attribute should give an idea about the texture of a banana.
Adhesiveness	The stickiness of the sample, evaluated considering the force required to remove the sample from the mouth.
Homogeneity	Homogeneity was evaluated as the degree of uniformity of the pulp.
Flour mouth sensation	Dried sensation in the mouth similar to crumbling, like dried flour in the mouth.
Sweetness	Basic taste associated with the sugar content.
Sourness	Basic taste associated with the acid content.
Astringency	Acid taste associated, for example, with the content of tannins. Chemically, this sensation can arise from potassium sulfate.
Herbaceous	Grassy odor and flavor, like freshly cut green grass.
Banana flavor	Typical flavor associated with an ideal banana.
Fermented flavor	Typical flavor of fermentation, associated with an alcoholic sensation.

bananas (see Table 2). The respondents indicated their level of importance for each item for all the developed scales using a 7-point Likert scale, ranging from 0 (not important at all) to 6 (extremely important). The readability of all the scales was tested by means of Cronbach's Alpha test.

2.3. Statistical analysis

The data obtained from the qualitative analyses conducted for the first research aim (Banana quality assessment) were treated with one-way analysis of variance (ANOVA) and Tukey's post hoc test to compare the mean values and identify significant differences ($p \leq 0.05$).

A descriptive analysis of the samples was made by evaluating the socio-demographic aspects. Principal Component Analyses (PCA) were performed to define the different food consumption patterns on the basis of the answers obtained for the Food preference scale. Following other studies that already applied PCA [19–21]. Any loading values that exceeded 0.35 were considered to define the components. We utilized the loadings from PCA as variables in a cluster analysis to group the consumers on the basis of their food choice patterns, employing the k-means technique and the hierarchical cluster analysis procedure with Euclidean distances. A 3-cluster segmentation was deemed suitable to determine the appropriate number of segments (k) on the basis of cohesion and silhouette separation, as assessed through the Two-step method, using both BIC and AIC indexes. Consequently, the K-means clustering method was employed to define the clusters. We used ANOVA to assess whether the clusters differed significantly from each other, and conducted post-hoc Tukey's multiple comparison tests [13].

Each cluster was explored and compared, in terms of socio-demographic variables, traditional purchasing behaviors toward tropical fruits, and preferences for tropical fruit and bananas. Chi-square tests were conducted to test for independence between the variables in the different consumer groups.

All the statistical analyses were performed using SPSS for Windows, version 27.0 (SPSS Inc., Chicago, IL 60606).

3. Results

3.1. Banana quality assessment

All the samples had lost weight after 5 days of storage at $18 \text{ }^\circ\text{C}$ (Table 3). Weight loss due to respiration and senescence processes is mainly related to water loss [22] and was greater for the greener bananas (sample A $14.05\% \pm 0.97$) than for the yellow ones (sample C $11.49\% \pm 0.94$), and statistically significant differences were observed among the values after storage.

Evaporation and transpiration from the peel also decreases the weight of bananas, and this justifies the observed ratio between the pulp and peel values (Table 3). All the samples showed a significant ($p \leq 0.05$) increase in the ratio after 5-days of shelf life, thus indicating an increase in the pulp weight and a decrease in the skin weight. The highest ratio between the pulp and peel on day 0 was observed for sample C (1.737 ± 0.003), which consisted of the ripest bananas. After 5 days, the highest values were encountered for samples A (2.338 ± 0.17) and C (2.572 ± 0.06).

The hydrophilic soluble solid level is obtained from $^\circ\text{Brix}$ measures and is correlated with degradation of the starch in bananas. The increase in SSC on day 5 was significant for samples A and B ($p \leq 0.05$), passing from $16.13^\circ \text{Brix} \pm 3.48$ – $27.00^\circ \text{Brix} \pm 1.57$ and from $19.13^\circ \text{Brix} \pm 1.01$ – $25.1^\circ \text{Brix} \pm 1.41$, respectively (Table 3). The highest level of sugars was observed in the bananas with the highest ripening stage on day 0. The sugar levels were almost comparable on day 5.

The acidity of the samples did not show any statistical differences between day 0 and day 5. Moreover, no differences ($p \leq 0.05$) were highlighted for the different ripening stages (data not shown).

The texture profile analysis parameters are reported in Table 4. The

Table 2
Scales employed in the survey.

Scales	Questions	Items	Cronbach alpha
Food preferences	When making food selections, how significant are the following food characteristics for you?	Organic production method; Use of alternative energy sources; Biodegradable or recyclable packaging; carbon footprint certification (low co2 emissions); Water footprint certification (limited water use); Fairtrade certification; Short supply chain; National origin; Local origin; Reduced use of chemical compounds (e.g., pesticides).	0.85
Tropical fruit preferences	How important do you consider the following characteristics of tropical fruits during purchasing?	They are fruits that have undergone extensive manipulation; They are delicious; They are expensive; They are heavily treated with pesticides; They are good for your health; They always have the right degree of ripeness in a store or market; I would prefer them to be produced in Italy; They are part of a supply chain that is environmentally unfriendly; I would prefer it to have ethical certifications; They are seasonal; I would prefer them to be organic; The brand is a guarantee of quality; I do not know how they are produced.	0.90
Banana consumption	Why do you eat bananas?	I like them; They can be consumed easily and quickly in many situations; They are good for your health; They provide essential minerals; Because I am sporty.	0.75
	What degree of ripeness do you prefer when purchasing bananas?	Already very ripe, I eat them immediately; Ripe because I eat them in a few days; Still unripe, thereby allowing them to ripen at home; I prioritize other characteristics, such as the price and brand, over ripeness; I am unable to discern variations in the ripeness levels.	0.82

Table 3
Qualitative analyses of bananas: weight loss evaluation, pulp/peel ratio, and soluble solids content (SSC).

Sample	Weight losses (%)	Pulp/peel ratio		SSC (°Brix)	
		0 days	5 days	0 days	5 days
A	14.05 ± 0.97 a	1.358 ± 0.096 b	2.338 ± 0.17 a	16.13 ± 3.48 b	27.00 ± 1.57 a
B	9.67 ± 1.03 b	1.207 ± 0.069 b	1.711 ± 0.11 b	19.13 ± 1.01 b	25.1 ± 1.41 a
C	11.49 ± 0.94 c	1.737 ± 0.003 a	2.572 ± 0.06 a	21.17 ± 2.31 a	26.77 ± 1.56 ab

The data are expressed as mean ± standard deviation (n = 3). Values followed by the same letter in the columns do not differ significantly for each quality parameter, according to Tukey's HSD test (P ≤ 0.05). A = green bananas; B = medium ripened bananas; C = completely yellow bananas.

hardness, adhesiveness, and gumminess of the pulp decreased over time. The hardness values of the samples on day 0 did not show any clearly significant difference (p ≤ 0.05). After 5 days of shelf life, the ripest banana samples were those with the lowest hardness values (1765.53 g ± 301.80). As far as adhesiveness is concerned, no statistical difference (p ≤ 0.05) was highlighted for the different ripening stages at the same time. Adhesiveness was greater for the samples on day 0, and then decreased to a great extent after 5 days (p ≤ 0.05). A reduction in gumminess was experienced in relation to the different ripening stages, for both 0- and 5-days of storage: the highest level of gumminess was linked to the more mature samples. The highest gumminess values on day 0 were those of the greenest bananas (1154 ± 117.76). The gumminess results underwent a reduction in value during the 5 days of

Table 4
Texture profile analysis parameters.

Sample	Hardness (g)	Adhesiveness (g*s)	Gumminess
	Day 0		
A	3172.84 ± 732.31 a	-98.98 ± 34.06 a	1154.58 ± 117.76 a
B	2931.68 ± 693.43 as	-145.83 ± 33.44 a	990.04 ± 92.18 b
C	2567.49 ± 278.36 ab	-108.10 ± 33.05 a	1024.62 ± 30.38 b
Day 5			
A	2497.34 ± 289.14 ab	-282.83 ± 66.71 b	735.35 ± 34.54 c
B	2378.57 ± 486.82 ab	-352.66 ± 105.85 b	731.67 ± 53.98 c
C	1765.53 ± 301.80 b	-282.50 ± 64.38 b	602.11 ± 67.64 d

The data are expressed as mean ± standard deviation (n = 3). Values followed by the same letter in the columns do not differ significantly for each parameter, according to Tukey's HSD test (P ≤ 0.05). A = green bananas; B = medium ripened bananas; C = completely yellow bananas.

storage at 18 °C (p ≤ 0.05).

A sensory analysis was performed on the fruits on day 0. Fig. 2 shows how six of the ten sensory attributes were particularly relevant to describe sensory diversity in the samples, because they represented over a wide range of intensities: sweetness, astringency, typical banana flavor, herbaceous flavor, flour mouth sensation, and homogeneity. According to the obtained results, the ripened bananas (sample C) were those that were perceived by the panellists as being sweeter and having an intense typical banana flavor. On the other hand, the greener bananas (sample A) were associated with the greatest firmness and recall of herbaceousness. Adhesiveness was perceived as almost comparable for the three samples, that is, between 3 and 4 points on the evaluation scale. Fermented flavor was absent for all the maturity stages, as was

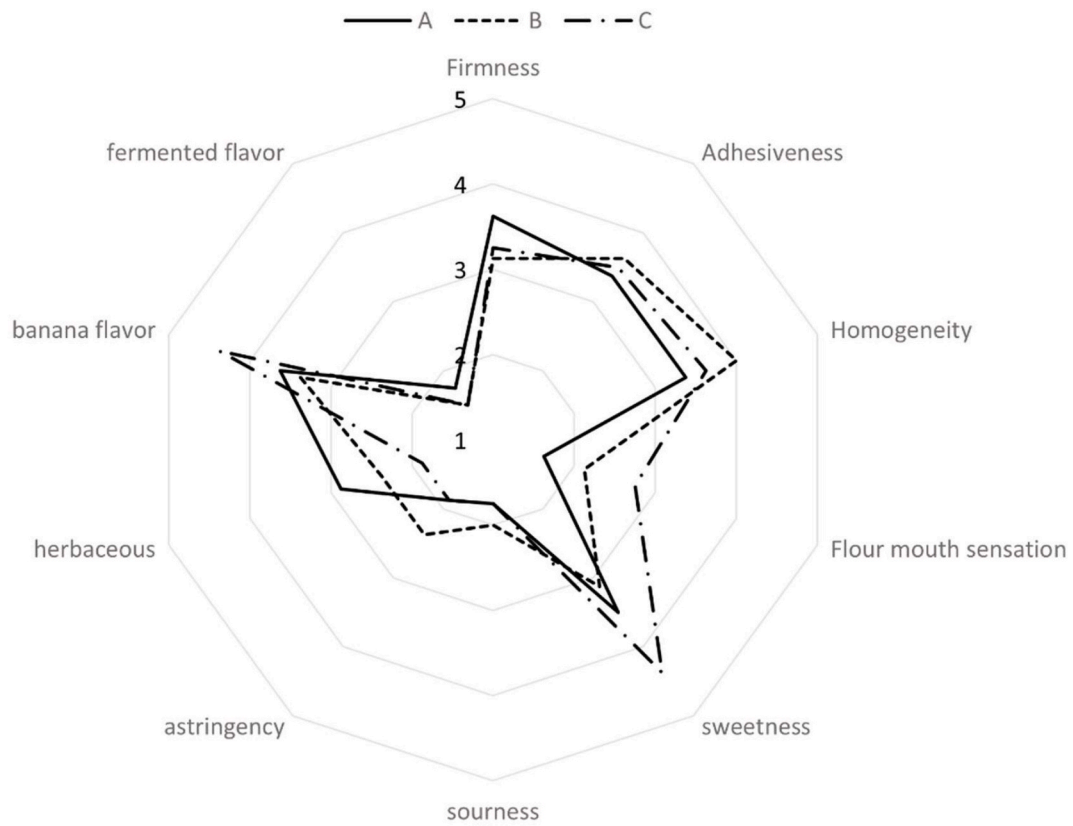


Fig. 2. Sensory analysis on banana cv Cavendish samples on 0 day. A = green bananas; B = medium ripened bananas; C = completely yellow bananas.

sourness. Marked differences were highlighted for the flour mouth sensation, which was considered negligible for the green bananas (sample A), but increased as ripening increased, reaching an average value of around 3 points in relation to sample C. This parameter was opposite to that of homogeneity: the ideal maturity stage (sample B) showed the highest homogeneity level, followed by sample C and, lastly,

sample A.

3.2. Consumers' perception of tropical fruits

A total of 360 individuals filled out the questionnaire correctly. All of the participants consumed fruits, including bananas (n = 342, 90 %).

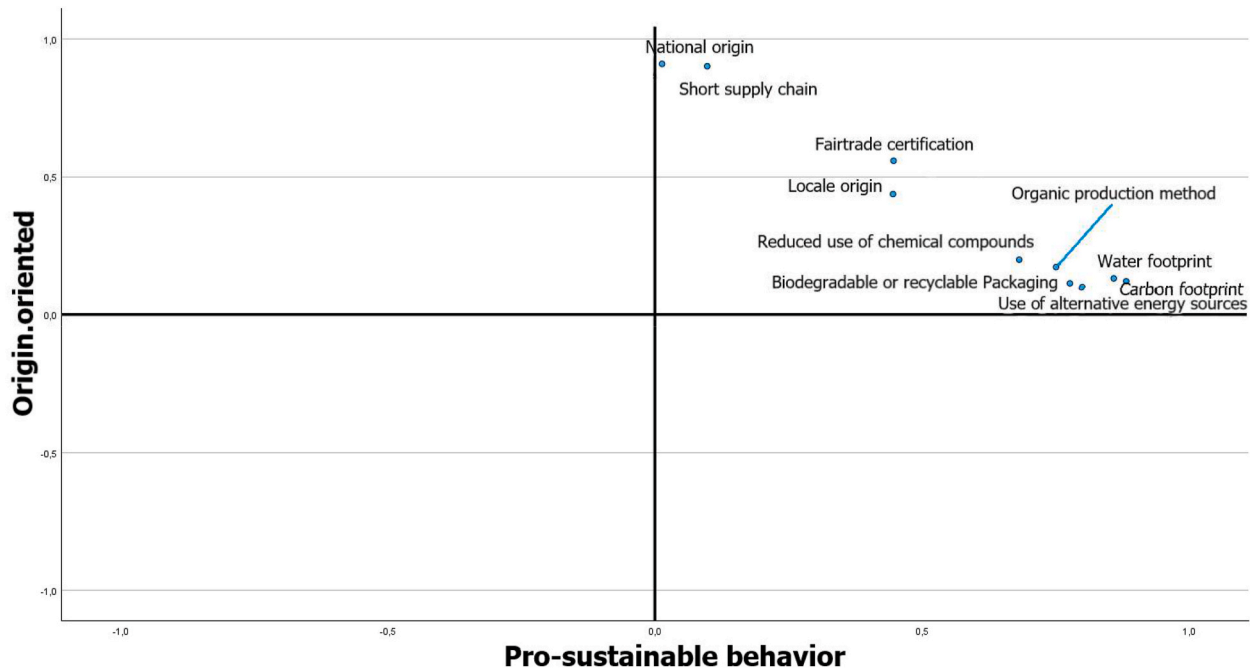


Fig. 3. Rotated component matrix.

The main reason for not consuming bananas (95% of the non-consumers) was for taste reasons (they did not like the taste).

The sample of banana consumers was mainly made up of women (62%), from a middle-to-old age, and a medium-to-high level of education (more than 90 % of the respondents had a high school diploma or a bachelor's degree). The interviews showed that 36% of the respondents were part of a 4-member household, with an average income that was in line with the national average income.

The results of the Principal Component Analysis (Fig. 3) about the different food consumption patterns are shown in Table 5. Two main components (explaining 64.6 % of the total variance) were defined. The first component (called Pro-sustainable behavior) explained 47.7 % of the variance and defined a food choice orientation dictated by an interest in sustainability issues, also considering both environmental and ethical certifications as important drivers. Furthermore, this component was explained by the participants' attention to biodegradable or recyclable packaging, which highlighted an interest in organic food production. This consumption pattern was guided by attention to sustainability induced by a responsible choice of and active behavior toward sustainable materials and production processes.

The second component (called Origin oriented, explaining 16.9% of the total variance) may not be directly related to sustainability, but the participants prioritized the origin of food by opting for national or local food productions. This choice reflects a sustainable preference, although with a lower awareness of sustainability of the participants.

Three clusters have been identified from the Principal Component Analysis (Table 6) on the basis of the general food preferences. The first cluster, Sustainable individuals (29.5% of the total sample), consisted of environmentally conscious individuals who consider the environmental impact of food highly important. They prioritize ecological production from a circular economy perspective and also express interest in ethical certification and a company's social impact. The second group, called Local supporters (35%), comprises individuals interested in short supply chains, that is, those who prefer national and local food productions. The third cluster, Holistic individuals (35.5%), falls somewhere in between; these individuals seek sustainable products and are aware of the fact that local food can be sustainable, due to the reduction in emissions from the reduced transportation. They made food choices from a holistic perspective, considering several aspects of the food supply-chain.

The heterogeneity of clusters, in terms of socio-demographic variables, is shown in Table 7. The Chi-square Test revealed no gender differences among the clusters. However, there was a statistically significant variation in the age distribution of the respondents in the three groups. The Sustainable individuals group was composed of younger members, while the Local supporters group included people between 26 and 55 years hold. Finally, the Holistic group was almost half composed of over 55-year olds and half of younger people.

Table 5
Principal component analysis of the samples.

When making food selections, how significant are the following food characteristics for you?	Components	
	Pro-sustainable behavior	Origin-oriented
Organic production method;	0.682	
Use of alternative energy sources;	0.800	
Biodegradable or recyclable Packaging;	0.777	
Carbon footprint certification (low CO2 emissions);	0.882	
Water footprint certification (pertaining to the limited use of water);	0.859	
Fairtrade certification;	0.751	
Short supply chain;		0.558
Reduced use of chemical compounds (e.g., pesticides);	0.446	
National origin;		0.901
Locale origin.		0.910

Table 6
Identification of clusters.

Components	Cluster		
	Sustainable individuals	Local supporters	Holistic individuals
Pro-sustainable behavior	0.1267	-1.034	0.913
Origin oriented	-1.272	0.422	0.637

Table 7
The socio-demographic characterization of clusters according to the Chi-square test.

Socio-demographic		Clusters			Chi - square	Sig.
		Sustainable individuals	Local supporters	Holistic individuals		
Gender	Woman	31.7%	35.3%	33.0%	0.407	
	Man	24.6%	35.4%	40.0%		
Age	18-25	41.3%	15.4%	43.3%	0.000	***
	26-45	30.1%	43.4%	26.5%		
	46-55	17.9%	49.1%	33.0%		
	>55	29.0%	19.4%	51.6%		

A comparison among clusters, in terms of the consumption habits of traditional fruits (such as apples, oranges, and pears) and tropical fruits (such as bananas, avocados, and pineapples), as well as the consumers' opinions of tropical fruits, and the motivation and preferences for consuming bananas, was performed and the results are shown in Table 8.

A significant variation in the consumption of traditional fruits among the clusters emerged from the findings. In particular, the Holistic individuals demonstrated a higher propensity to eat fruits, and a less marked but still significant variation in the consumption frequency of tropical fruits.

Several options were presented to explore the consumers' opinions about tropical fruits. The Holistic individuals viewed tropical fruit as delicious, but subjected to extensive manipulation, as they are often treated with pesticides and other chemicals, and are environmentally unfriendly. They expressed doubts and mistrust due to the lengthy supply chain and would have preferred the fruits to be grown in Italy. They considered brand as a possible quality index, but their preference was for organic products to enhance food safety. The consumption of bananas by this group was driven by their micronutrient content, particularly minerals, which are considered important for sporty individuals. Additionally, they reported limited knowledge about the production of tropical fruits, and they stated they were unfamiliar with the banana supply-chain.

Local supporters believed that tropical fruits underwent extensive processing and were often treated with a large number of pesticides. Like the Holistic individuals, they placed their trust in Italian production, due to their perception of it offering higher quality products. However, unlike the Holistic group, the Local supporters shared the belief that a specific brand could be linked to a guarantee of product quality. Consequently, they preferred to buy Italian food and they did not prioritize organic production or ethical certification.

The Sustainable individuals exhibited a considerable degree of concern about environmental and ethical factors when purchasing food in general, as evidenced by their focus on sustainability certification and eco-friendly packaging. However, when it came to tropical fruits, their responses indicated a somewhat milder level of concern regarding both environmental sustainability of the supply chain and ethical considerations. The consumers within this group claimed they had knowledge of the tropical fruit supply chain, but unlike other clusters, their perception of its unsustainability was relatively moderate. Compared to the other clusters, the Sustainable individuals did not place a high level of

Table 8

Questions about the consumption of fruits, the opinion of the participants on tropical fruits, and the consumption of bananas.

Descriptors	Clusters			F	p-value	Sign.
	Sustainable individuals	Local supporters	Holistic individuals			
	Mean	Mean	Mean			
Which of these two categories of fruit do you consume more frequently?						
Traditional fruits (apples, oranges, pears, etc.)	3.887 ^a	4.222 ^a	4.961 ^b	12.653	0.000	***
Tropical fruits (bananas, avocados, pineapples, etc.)	3.264 ^a	3.873 ^b	3.461 ^{a,b}	4.277	0.015	*
How important do you consider the following characteristics of tropical fruits during purchasing?						
They are fruits that have undergone extensive manipulation.	2.632 ^a	3.635 ^b	3.492 ^b	12.167	0.000	***
They are delicious.	3.934 ^a	4.063 ^a	4.609 ^b	7.808	0.000	***
They are expensive.	3.472 ^a	3.770 ^a	4.352 ^b	10.370	0.000	***
They are treated heavily with pesticides.	2.877 ^b	3.500 ^a	3.641 ^a	8.060	0.000	***
They are good for your health.	3.877 ^a	3.722 ^a	3.969 ^a	0.920	0.399	
They always have the right degree of ripeness in the store or market.	1.981 ^a	2.222 ^a	2.336 ^a	1.556	0.212	
I would prefer them to be produced in Italy.	2.689 ^b	3.817 ^a	4.008 ^a	14.446	0.000	***
They are part of a supply chain that is environmentally unfriendly.	2.604 ^a	3.071 ^a	3.680 ^b	12.151	0.000	***
I would prefer them to have an ethical certification.	2.604 ^a	1.730 ^c	3.992 ^b	47.184	0.000	***
They are seasonal.	2.708 ^a	3.151 ^a	2.750 ^a	1.930	0.147	
I would prefer them to be organic.	2.038 ^a	1.024 ^c	3.867 ^b	80.218	0.000	***
The brand is a guarantee of quality.	2.613 ^a	3.437 ^{a,b}	2.938 ^b	6.608	0.002	**
I do not know how they are produced.	2.632 ^a	2.627 ^a	3.555 ^b	10.440	0.000	***
Why do you eat bananas?						
I like them.	4.623 ^a	4.881 ^a	4.781 ^a	0.844	0.431	
They can be easily and quickly consumed in many situations.	4.047 ^a	4.524 ^{a,b}	4.578 ^b	3.270	0.039	*
They are good for your health.	4.198 ^a	4.183 ^a	4.430 ^a	0.955	0.386	
They provide essential minerals.	2.991 ^a	2.492 ^a	4.469 ^b	38.681	0.000	***
Because I am sporty.	1.698 ^b	0.960 ^a	2.219 ^b	13.492	0.000	***
What degree of ripeness do you prefer when purchasing bananas?						
Already very ripe, I eat them immediately.	2.057 ^a	2.468 ^a	2.133 ^a	1.578	0.208	
Ripe, because I eat them in a few days.	3.255 ^a	4.500 ^b	2.875 ^a	23.019	0.000	***
Still unripe, thereby allowing them to ripen at home.	3.642 ^a	3.944 ^a	3.500 ^a	1.990	0.138	
I prioritize other characteristics such as price and brand over ripeness.	2.019 ^a	2.429 ^b	1.586 ^a	5.868	0.003	**
I cannot discern variations in ripeness levels.	1.047 ^a	1.452 ^a	1.023 ^a	2.832	0.060	

importance on the production of tropical fruits in Italy.

The ripeness level of bananas was not a significant factor for Local supporters. Instead, they prioritized other characteristics, such as price, origin or brand, thus aligning themselves with their preferences for tropical fruits in general. There were no differences in ripeness preferences for the other clusters, in part because they believed that the right degree of ripeness was always available in the stores or markets.

4. Discussion

This study has investigated consumers' preferences for the consumption of fruits at three levels. Their interest in traditional fruits (such as apples, oranges, and pears) and tropical fruits (such as bananas, avocados, and pineapples) was examined in the first stage, while their opinions on tropical fruits were collected in the second stage. Finally, the importance consumers place on the ripeness level of bananas was explored in the last stage. The investigation was preceded by a qualitative and sensorial evaluation of the fruits available on the market, mainly in relation to the ripening stage.

4.1. Banana quality assessment

The bananas at an advanced ripening stage on day 0 (samples B and C) showed a reduced weight loss because the phenomenon was only analyzed in the later stages of their life (Table 2): they had already lost part of their water content between the harvesting phase (green fruit) and the maturity stage. Bananas, as climacteric fruits, are in fact harvested at a mature green phase and ripening takes place postharvest, when they are treated with ethylene before distribution [23,24]. It is possible to hypothesize that the water loss in the first stages of post-harvest ripening may be greater because of physiological transpiration phenomena, result of the excess in energy produced from sugar [25]. Thereafter, the increase in soluble solids in the flesh, due to the transformation of starch into sugars, determines the migration of

moisture from the peel to the pulp, thereby inverting the process [26, 27]. This causes a reduction in the water loss and, consequently, in the weight loss [26,28].

Changes in the ratio between the pulp and peel are mainly due to water loss from peel transpiration and the osmotic release of water from the peel to pulp [29,30]. This happens because the ripening process involves the degradation of starches and, consequently, the growth of SSC. Moreover, a thinning of peel occurs as a result of the collapse and degradation of cellular walls and a consequent creation of air spaces [26]. For these reasons, an increase in the ratio between the pulp and peel is generally expected during ripening. The ratio between the pulp and peel grew over the 5 days of storage for all the samples. Sample C, that is, the ripest bananas, showed the highest ratio between the pulp and peel at both day 0 (musa) and day 5 (2.572) (Table 1), in agreement with the findings of Thuy et al. [26]. After 5 days of storage at 18 °C, no statistical difference was observed between the greener bananas (sample A) and the ripest ones (sample C) (Table 1). This may be result of rapid ripening phases caused by the relatively high storage temperature (18 °C), finally reaching a maturity plateau. Indeed, bananas are fruits particularly susceptible to temperature issues which causes modification in respiration rate, thus leading to quality changes [31,32].

Unripe bananas are rich in complex carbohydrates, mainly starch, which is degraded into simple sugars during the ripening phase [26,27]. The transformation of starches into simple sugars leads to sweeter fruits, which are more appreciated by consumers, and to less sourness, even though acidity increases during the whole post-harvest ripening phase [26]. We actually observed this behavior of the SSC in our data (Table 1). At 0 days of storage, the yellow bananas (sample C) showed a value of 21.17 °Brix, which was statistically higher than samples A and B. After 5 days of storage, the situation was reversed: sample A, that is, the greener bananas, and sample B, which were yellow bananas, statistically increased, reaching values of 27.00 °Brix and 25.10 °Brix, respectively. From these results, it is possible to hypothesize that the bananas that were not completely ripe underwent a rapid ripening

phase. Instead, the bananas that were already yellow and ready to eat continued ripening but to a lesser extent, because the starches were being consumed, and were therefore lower in quantity [33].

The growth behavior of the SSC is an index of a softening of the fruit pulp and is coherent with literature studies [34]. A loss of hardness, adhesiveness, and gumminess was experienced after the 5 days of shelf-life at room temperature (18 °C). Differences were noted in the firmness (a loss), which occurred because of the transformation of starches and the degradation of cell walls [26]. According to [27], in a work pertaining to the specific case of banana ripening, the softening and loss of texture is more likely to derive from the degradation of starch into simple sugars rather than to the degradation of cellular walls. As expected, the ripest sample reached a low consistency value; in fact, sample C was the sample in which the metabolisms lasted longer. The softening of bananas is a physiological reaction that is related to all the metabolic changes that happen during the ripening phase [35]. Adhesiveness showed more negative values after storage, which means a more pronounced sticky behavior. This was also stated in the work of [36], who considered it to be a consequence of the ethylene gas used for the ripening phase, which causes cell rupture and cell debonding. This has an alteration effect on the banana texture. In relation to gumminess, a similar trend to hardness was noticed, thus indicating a decrease in value due to ripening, as also observed by Chauhan et al. [36].

After the preliminary characterization of the different kinds of fruits available on the market, a panel test was conducted in DISAFA to obtain a further characterization of the product from the sensorial point of view. The results confirmed the lack of difference in acidity among the samples and the absence of a fermented flavor, probably because the bananas were not overly mature. It was also possible to observe a link between the typical flavor of bananas and the sweetness of the samples, which are indexes of the ripening stage of bananas and a particular characteristic of Cavendish bananas [18].

An astringent sensation is generally linked to unripe fruits, where high levels of acids and tannins result in a specific sensation in the mouth [37]. In this case, a great difference was not perceived among the samples and the astringency level was quite low because of the similar ripening stage of A, B and C. Another interesting phenomenon can be observed between the perception of a herbaceous flavor and the typical flavor of bananas: the herbaceous aspect was mainly linked to unripe bananas, and was almost absent in the overripe ones (sample C). A typical banana flavor was recognized in all the samples to a certain extent, although it hid the herbaceous flavor in sample B and sample C. This phenomenon was expected, as grassy sensations are typically related to unripe fruits [38].

4.2. Consumers' perception of tropical fruits

The identification of three clusters, on the basis of general food choices in relation to sustainability, supply chain, certification, and origin, did not always yield consistent results with the statements made in reference to tropical fruits and bananas: although the Sustainable individuals showed a general interest in sustainability issues in their food choices, and declared a high degree of knowledge on the tropical fruit supply chain, their level of awareness of sustainability issues in this supply chain appeared limited.

The importance given by Sustainable individuals to certification confirmed the results in the literature [39], because a sustainable label ensures a specific standard to people who are interested in social and/or environmental issues, and leads the consumers toward making sustainable choices [40]. According to Moshtaghian et al. [41], the younger generation, which in our case was predominantly composed of the Sustainable individuals' category, express concern about the environmental impact on food, but their attitude toward food does not differ between the age groups. However, having grown up in a globalized world, where tropical fruits are readily available on the shelves, they might not have questioned the journey these exotic fruits undergo [42].

At the same time, other young respondents of the Holistic individuals' group showed they were mindful of climate change and demonstrated interest in ethical, social, and environmental sustainability certifications. Simultaneously, they recognized that the origin of food products, whether local or national, can be associated with sustainability in various ways [43]: therefore, awareness of the link between an interest in sustainability and the decision to purchase tropical fruits was concrete and evident in the opinions they expressed [39]. The consumers liked both tropical and traditional fruits, but it appears that the Holistic individuals were more interested in the consumption of traditional fruits because it is well-known that fruits are rooted in the Italian culinary culture [44]. In fact, according to Menozzi and Mora [35,] this finding suggests that fruit consumption is not only driven by conscious decision-making, but also has a strong habitual aspect. Frequent behaviors, like consuming fruits, can become routine and be repeated automatically. The holistic view of the third cluster is evident, and, contrary to the results of the study of Arumugam et al. [45] on organic food, the considerations related to the expensiveness of tropical fruits and the choice of organic products are not in conflict. Consumers know that organic products are generally more expensive because of their production process [39], but they still buy them.

In agreement with a Spanish study on the role of the origin of food in purchasing habits [46], the respondents belonging to the "Local supporters" cluster preferred national or local food because they were more familiar with the producers and perceived this food as healthier and safer [13,47]. Although they expressed a strong preference for food of national or local origin, the opinions collected regarding the tropical fruit supply chain revealed an improved awareness of its environmental implications. This outcome is aligned with the findings of Carfora et al. [48], who stated that such consumers are generally well-informed about the environmental impacts of buying local food, and this positively influences their purchasing decisions.

However, the later aspect leads consumers to view certifications with skepticism and reluctance, particularly concerning tropical fruits [39]. Although tropical fruits are not typical of the Mediterranean region, it could be interesting for the Italian market to follow new trends and cultivate tropical fruits, such as mangoes, avocados, and papayas, in the south of Italy, as in fact is already happening [5]. Thus, an advantage of national production has been recognized, in terms of the supply chain, as it would be shortened and valorized, thus promoting national production. As in this research, other food consumer choice studies [13,49] have pointed out the importance of brand for consumers, even concerning organic choices; an Italian brand could ensure and the best quality, linked to the territory, especially for local consumers.

People eat bananas because of their taste, as pointed out by Hendrarini et al. [50], and, in our investigation, all the clusters agreed. The ripeness stage is not always significant for Italians, and there were no significant differences among the clusters, except for when referring to the purchase of ripe bananas, because they were consumed within a few days. The ripeness stage is generally considered important for consumers in countries where banana consumption is not limited to their being eaten as a standalone fruit after a meal or as a snack. Moreover, it is particularly significant for those people who prepare them in various ways, such as boiling, roasting, frying, mashing, making porridge, and using them as flour [51].

5. Conclusions

This research has evaluated whether there is a correspondence between the sensory preferences expressed by a panel of consumers for bananas available on the market (Banana quality assessment) and the preferences declared by consumers in an administered questionnaire (Consumer perception of tropical fruits).

The investigation of consumers' preferences and attitudes involved quality attributes related to food sustainability. The identification of distinct consumer clusters on the basis of their perceptions of tropical

fruits and as characterized through socio-demographic factors, led to several insights related to individual choices concerning bananas and tropical fruits in general. Three clusters, based on different food choice approaches, were found from the results: Sustainable individuals, who care about environment and social issues, Local supporters, who prefer to support national and local productions, and Holistic individuals, who know the importance of environmental sustainability but are also aware of the local problems and support social and environmental issues. The three groups were also characterized in terms of socio-demographic features: age and gender resulted to be important factors that affect food choices.

As far as the stage of ripeness of bananas is concerned, the consumers in the test panel preferred the taste of riper bananas because they are sweeter. However, it emerged, from the purchase intention surveys, that consumers are not aware to the degree of ripeness during their decision-making. Nevertheless, bananas in general are removed from the market when they are less mature, even when they are just slightly more than yellow, thus causing significant food waste. According to the authors, the practical implications of the obtained results could be related to the storage times of fruits in supermarkets and, in general, across all the distribution channels. Retailers could keep these fruits on the market for a longer period as they would thus be aligned with consumers' preferences, thereby reducing the environmental impact of waste. The practical implications of this work for companies, retailers, and large-scale retail distribution (GDO) could be the need to improve and implement communications with consumers, and to inform them about the safety and wholesomeness of bananas, even those whose color has turned to a dull yellow.

The limitations of the study are rooted in the use of a non-probability sampling method, which, in our case, affects the representativeness and uniformity of the resulting samples. Future research efforts will focus on enlarging the samples and ensuring their balance to conduct new assessments with representative samples. Moreover, it could be interesting to conduct a cross-country comparison at European and intercontinental levels pertaining to the purchasing and consumption of tropical fruits and specifying different supply chains, for example, for bananas, avocados, mangoes and other fruits. In relation to the qualitative assessment of bananas, it would be interesting to compare more than three ripening stages, and if possible, to collect more representative samples from different selling points and to evaluate the consumer's preferences. In this way, a complete scenario could emerge, in terms of both quality and sensorial characteristics.

CRedit authorship contribution statement

Nicole R. Giuggioli: Investigation, Formal analysis, Data curation, Conceptualization. **Selene Ollani:** Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Raffaele Zanchini:** Software, Investigation. **Borra Danielle:** Writing – review & editing, Visualization, Validation. **Antonina Sparacino:** Writing – original draft, Resources, Project administration, Methodology, Investigation. **Stefano Massaglia:** Validation, Supervision. **Valentina M. Merlino:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The data that has been used is confidential.

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