Analysis of the consumer's perception of urban food products from a soilless system in rooftop greenhouses: A case study from the Mediterranean area of Barcelona (Spain)

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Abstract

Soilless crops are commonly used in rooftop agriculture (RA) because they easily adapt to building constraints. However, acceptance of the produce derived from this system may be controversial. This paper evaluates consumers' acceptance of food from RA in Mediterranean cities, focusing on the quality of the product, production system, and consumers' motivations. We surveyed 238 respondents on the UAB university campus as potential consumers. The survey was distributed via an Internet-link that was provided along with a sample of tomatoes from RA. The results showed that most people approved the quality of RA products and perceived them to be local and fresh (94%). The respondents exhibited acceptance of soilless-produced tomatoes and considered them to be environmentally better than conventionally produced ones (69%). Cluster analysis revealed that consumers with high income levels and a university education had a better perception of the quality and proposed a higher price for RA products, but no difference was found regarding their environmental perception of this products. Moreover, people who possessed more information about the product also had a higher perception of the quality and production system (it was perceived to be environmentally friendly) and would pay more for them. The main concerns of

consumers were related to food safety and the social impact of RA. Additional research is needed to improve the sustainability of RA, and the applied measures should be communicated to potential consumers to enhance their acceptance and success.

Keywords: urban agriculture; rooftop agriculture; local food production; local consumption; food self-supply

Abbreviations

ICTA-ICP	Institute of Environmental Science and Technology and the Catalan Institute of Paleontology
i-RTG	Integrated rooftop greenhouse
RA	Rooftop agriculture
RTG	Rooftop greenhouse
SCS	Soilless culture system
UA	Urban agriculture

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Introduction

Peri-urban and urban agricultural activities are increasing worldwide, thereby providing citizens with local and fresh produce from vacant spaces in urban areas (Mok et al., 2013). In this paper, we focus on a concrete type of urban agriculture developed on rooftops, i.e., rooftop agriculture (RA). Previous studies have analyzed the acceptance of these projects among stakeholders from public administration and companies with different backgrounds, such as architects, planning lawyers and food distributors (Sanyé-Mengual et al. 2016; Specht et al. 2016a; Specht and Sanyé-Mengual 2017). However, none of these studies has focused on the valuation of taste by potential consumers and their perception of RA despite some level of opposition towards these products. Specifically, (Specht et al. 2016a) found that the highest acceptance occurs in

multifunctional UA projects that combine commercial, ecological and social goals and that UA tends to be rejected when it is driven purely by productivity.

Urban agriculture and innovative rooftop agriculture

Urban agriculture (UA) dates back to the very beginning of the urban phenomenon, and it aims to increase the food security of cities. Examples can be found throughout history, from Egyptian societies to the European 20th century war and postwar periods (Calvet-Mir and March, 2017). Currently, UA addresses a myriad of motivations, ranging from food production (Block et al., 2011; Vogl et al., 2004) to mitigation and adaptation to climate change (Lwasa et al., 2014) and promoting sociocultural relationships (Calvet-Mir et al., 2016; Zasada, 2011).

There are different types of UA, including small family and community gardens, educational and research projects, and commercial initiatives using high-tech solutions (Association for Vertical Farming, 2016; Opitz et al., 2016). UA projects include traditional soil-based agriculture typologies and building-based typologies, among which RA is the most common (Thomaier et al., 2015).

RA is defined as "the development of farming activities on the top of buildings by taking advantage of the available spaces in roofs or terraces" (Sanyé-Mengual 2015). It can involve many technical processes, as well as generate synergies with the building holding the crops (Despommier, 2011, 2010; Fischetti, 2008; Germer et al., 2011). The method used for RA crops is generally soilless culture systems (SCSs), which are "any method of growing plants without the use of soil as rooting medium, in which the inorganic nutrients absorbed by the roots are supplied via the irrigation water" (FAO, 2013). These are the most intensive and productive methods available in agriculture (Putra and Yuliando, 2015), and they avoid potential problems of structural overload of the building (Nadal et al., 2017).

This study focuses on rooftop greenhouse (RTG) systems that produce food crops inside a greenhouse on the top of buildings, which aim to improve efficiency in the use of resources (Cerón-Palma et al., 2012; Pons et al., 2015). Large rooftops (e.g., supermarkets, hotels, shopping malls or prisons) may be optimal surfaces for RTGs (Caplow, 2009), but their implementation would require a high investment and might involve legal restrictions (Cerón-Palma et al. 2012; Sanyé-Mengual et al. 2018) and problems with social acceptance, since people generally prefer green and open spaces

(Specht et al. 2016a). The first commercial RTGs were built in America, including a 1,400 square meter farm from Gotham Greens (2011) in Brooklyn (USA) and a 2,900 square meter farm from Lufa Farms (2013) in Montréal (Canada). In Europe, despite the growing interest in urban farms and several initiatives, the construction of RTGs is still limited. There are RTGs in Urban Farm Market (2017) in The Hague (Netherlands), in the QO Amsterdam Hotel (2018) in Amsterdam (Netherlands) and in Ecco-jäger Früchte und Gemüse AG (2017) in Bad Ragaz (Switzerland).

Social acceptance and perception of urban rooftop production

UA is normally associated with crops at ground level (Sanyé-Mengual et al. 2018) and is appreciated for its benefits to the community. Indeed, it is mainly perceived as a socially oriented activity, including recreational and leisure projects that are highly valued by citizens (Sanyé-Mengual et al. 2016; Specht et al. 2016b). However, for-profit UA initiatives are less accepted, since food security is currently not perceived as a problem in most European cities, and UA relies on a recreational goal that is currently prioritized over commercial UA (Specht et al. 2016a). In accordance with this viewpoint, the main perceived benefits of RA are increased consumer awareness, education and creation of experimental spaces (Sanyé-Mengual et al. 2016; Specht et al. 2016b). Additionally, RA has some benefits due to its location and the techniques used. The production of fresh and/or organic food with the purpose of saving resources and promoting local economy is considered a good commercial opportunity (Cerón-Palma et al. 2012; Sanyé-Mengual et al. 2016; Sellers 2016). Furthermore, the implementation of RA is perceived as an opportunity for a productive urban use, even for private RA initiatives, as roofs are commonly unused urban spaces (Specht et al. 2016a). Among consumers, UA is expected to be fresher and to have a higher quality because harvest is performed just before consumption. Consumers prefer UA products to conventional rural products if the former fulfill specific criteria: high quality, regionality, organic production or the inclusion of additional social benefits. This is related to a greater willingness to pay for products that are free of pesticides and herbicides and connected with local well-known producers (Miličić et al., 2017). Thus, RA must adhere to very high production standards (e.g., organic) or consider other values that are appreciated by consumers (e.g., provide additional social benefits) (Specht et al. 2016a).

As mentioned above, RA is usually associated with SCSs. Moreover, growing food in cities takes advantage of using innovative and high technology systems, such as a closed system for water efficiency (Putra and Yuliando, 2015; Sanjuan-Delmás et al., 2018). The widespread phenomenon of low social acceptance of innovations has already been described in different social contexts. In the agricultural context, organic farming (Padel, 2001) and precision farming (i.e., a farming management concept based on observing, measuring and responding to inter- and intrafield variability in crops using high technology, such as GPS-equipped drones) initially faced low social acceptance (Kutter et al., 2011). The development of new types of (urban) agriculture depends largely on the social acceptance of its products, particularly in the early stages of its implementation (Specht 2016b; Sanyé-Mengual et al. 2018). For example, Specht and Sanyé-Mengual (2017) found that stakeholders from Barcelona and Berlin involved in UA projects share the opinion that soilless or hydroponic systems are "too artificial" and "unnatural".

The quality of a product is commonly associated with its intrinsic characteristics (color, size, shape, the no presence of physiological disorders and texture). These characteristics strongly influence consumer preference and demand (Moser et al., 2011). Nevertheless, consumers and farmers also consider other aspects that are not immediately detected at the time of purchase, such as the nutritional value, taste and environmental production characteristics (Torjusen et al., 2001). For food producers and farmers, quality is an important factor because consumers often express a greater willingness to pay for quality (Hussein et al., 2015). However, the acceptance of RA products and their valuation by consumers has not yet been studied. This study aims to address this research gap by focusing on consumer assessment of taste and perceived quality of RA foods.

For this purpose, the following research questions are addressed:

1- How is the quality of the products grown in soilless RA perceived by consumers?
2- How do consumers value the soilless production systems for RA?
3- How should business models be focused in the case of RA?

This study is important because it provides insights for farmers and food marketers about quality perceptions of RA foods. It can also be used to identify economic barrier to the development of UA.

Methods

This research study utilized the results of a survey conducted from 2015-2016. We sampled different types of consumers (i.e., consumers with and without previous knowledge regarding the production system) for a specific case study: tomato production in an experimental rooftop greenhouse in Barcelona (Spain) with hydroponic systems.

Case study: tomato production in the ICTA-ICP building with i-RTG

The integrated rooftop greenhouse (i-RTG) at the Institute of Environmental Science and Technology and the Catalan Institute of Palaeontology (ICTA-ICP) building was considered a case study (Figure 1). The case study is located on the campus of the Universitat Autònoma de Barcelona (Bellaterra, Barcelona) and holds a system for the exchange of flows between the i-RTG and the building (in terms of water, energy and CO_2) (Sanyé-Mengual et al. 2014; LLorach Massana 2017; Montero et al. 2017). The symbiosis between the building and the greenhouse enables year-round production (Nadal et al., 2017) and considerably reduced water requirements (Sanjuan Delmás, 2017).

The system produced 30.1 kg of tomatoes per square meter over 15.5 months (Sanjuan-Delmás et al., 2018). Moreover, these farms have the potential to reduce the environmental impacts of conventional production grown in a standard multitunnel greenhouse in five impact categories.[1] For example, it can provide a reduction of 1.12 kg of CO_2 equivalent per kg of tomato (Sanjuan-Delmás et al., 2018).

Cultivation system

The i-RTG covers a total area of 122.8 square meters, including 171 plants. The protected cultivation is performed under a steel and polycarbonate greenhouse structure. The soilless cultivation system employs bags of inert perlite substrate and a drip fertirrigation system, i.e., the nutrient solution satisfies both water and nutrient

[1] The production method resulting from the Green Revolution that dominates the current food market and entails the use of chemical products (i.e., fertilizers and pesticides) and specific cultivars (e.g. hybrid and transgenic varieties) to boost productivity and reduce production costs.

requirements of the plants (Savvas et al., 2013). As the use of pesticides is a sensitive issue in vertical farming due to the proximity to people's living or working places, only low doses were used when necessary. The mildest available option was always selected for environmental and health reasons, and only products allowed in Catalan organic production ((CE) no 889/2008, 2008) were used. Nevertheless, certification as organic product is not allowed ((CE) no 889/2008, 2008) since the regulations do not permit hydroponic systems.

Crop production

The beefsteak tomato (*Solanum lycopersicum* Arawak) is the food product under assessment in this research study (Figure 1). This variety is important because it is highly appreciated in the vegetable market and highly used in the local gastronomy. This implies an economic value that has a very good projection in the market outside of the summer season. As experimental trials, four tomato crops were grown since the i-RTG was built. The tomatoes from two crops were employed for the consumer perception study: a summer crop (cultivated from February to July 2015) and a winter crop (from September 2015 to February 2016).

<Figure 1>

Data collection

This section describes the design of the survey performed for the evaluation of consumers' perception and the sampling procedure.

Survey design

The complete survey included 27 open and closed questions and was structured into four sections. The first section (general information) included questions regarding the socioeconomic profiles of the participants, namely, *age, gender, level of education, profession and income*.

The second section (perception of the product quality) consisted of closed questions that evaluated different aspects of the quality of the product, i.e., *appearance, texture, size and* taste, *and ripeness*, as proposed by (Boizot-Szantai et al., 2005). A Likert-type scale was used in this section for rating each aspect (Bernard, 1994). This

scale is a psychometric response scale that is primarily used in questionnaires to assess subject's perception and usually comprises a 5-point scale (ordinal data), assigning a numeric value to each level (Wadgave and Khairnar, 2016). For example, the question *"How do you rate the condition of the tomato eaten?"* had 5 options*:* "very good", "good", "acceptable", "bad" and "very bad".

The third section (sale of the product) encompassed closed and open questions regarding the motivations and preferences for purchasing food products from soilless cultivation system from rooftop greenhouses, including proposed price, *preference for type of packaging, preferred sales channel, regularity of purchase and environmental information about the product*. The third section was only performed in the second campaign with the aim of collecting advice about how business models should be focused.

The survey finished with an open question referred to the methods for food production and supply, i.e., *Is there any comment or opinion you want to add to the answers?*

Sampling

The study was performed in two separate campaigns to evaluate differences between people who knew the i-RTG project and people who did not. In the first campaign, the target population was the ICTA-ICP community (i.e., students and workers at the ICTA-ICP building), who were already consumers of the food products from the i-RTG and thus had previous knowledge about it. Respondents attended a demonstration seminar that explained how the technology allows cultivation of tomatoes all year round. Details about the soilless cultivation system were described, as well as the water harvesting system, the fertirrigation system, the connection with the building and other relevant aspects of the greenhouse design and environmental considerations taken into account. In the second campaign, the population did not have knowledge about the i-RTG and the facilities that allow growing of the tomatoes that they tasted. The sample were given without extra information, and when they were invited to participate in the study, no extra information was given. They just knew that the survey was for a quality study of tomatoes conducted by researchers of the ICTA.

A convenience sampling method was used to create the sample. Participation was voluntary and consent obtained. In this type of sampling, subjects are selected because they are easily accessible and/or they are close to the case study. As the

objective was to evaluate a local product, the most important criterion in the sampling during the first campaign was that the participants interacted or cohabited in the building that hosts the case study. To our knowledge, the ICTA-ICP building is the only one that hosts an integrated rooftop greenhouse in the south of Europe. For this reason, in the first campaign, the entire ICTA-ICP community was invited to participate in the survey. In the second campaign, we tried to maintain the same conditions but change the location of recruitment: outside the ICTA-ICP building, thereby approaching people with no relationship to the case study. However, this implies that the possibility of generalizing the results to the target population (due to the potential bias of the sampling technique) was not prioritized (Cea D'Ancona, 1996). Despite the important statistical inferences drawn from convenience samples (Peterson and Merunka, 2014), this approach allows the identification of potential boundary conditions of RA perceptions with real users of a building with a running i-RTG.

The objective of the sampling was to include potential consumers for the case study. Moreover, it was intended to ensure comparison between two groups: those aware of the project and those who were not. Moreover, it was important to differentiate between users of the building on which the product is grown and people who are only close to the building. The survey was computerized as a form and was distributed via an Internet link. In both campaigns, the link to the survey was distributed with the tomato samples that the participants should taste. People were informed about the objectives of the research, and all personal data were anonymized.

Specifically, the study was performed in two separate campaigns, coinciding with the yield peaks of the summer and winter tomato crops, respectively (Table 1):

<Table 1>

The summer campaign took place in July 2015 to harvest tomatoes at the optimal point of ripeness at the i-RTG. Tomatoes were harvested and offered in fruit boxes in the common spaces of the ICTA-ICP building (e.g., kitchen). The ICTA-ICP community was informed about and invited to participate in the study via the mailing lists of both institutes. Members of the community who were willing to participate were able to take as many tomatoes as they wanted and were provided with information about the study and the link to the digital form of the survey. Participants were asked to complete the survey only once. The winter campaign was performed in February 2016

on the university campus and included students and workers from the entire UAB campus. The samples were provided at seven different restaurants within the campus. Additionally, in this case, the tomatoes were harvested at the optimal ripeness point. The tomato samples were delivered in closed paper envelopes containing four fruits and the address of the survey response form with the i-RTG information. In this campaign, we included the third section of the survey to identify the most interesting marketing pathways. There were 135 responses received in the July campaign and 103 in the winter campaign, for a total of 238 responses.

Data analysis

The survey results were analyzed using descriptive statistics, multivariate analysis and cluster analysis. All statistical analyses were performed using IBM SPSS Statistics (Statistical Package for the Social Sciences) for Windows (Version 22.0, SPSS Inc., Chicago, IL). A p-value < 0.05 was considered to be statistically significant (IBM Corp, 2013).

In the first step of the analysis, the independent variables were identified and summarized, including the socioeconomic profile of the sample (i.e., sex, age, education level, occupation and income level) and the population's consumption habits (i.e., weekly consumption of tomato and use of packaging). We considered as dependent variables the perception of product quality (i.e., the condition of the tomatoes, taste of the tomatoes, quality texture of the tomatoes, content of the tomatoes and freshness of the product) and the sale of the product (i.e., whether participants reported that they would buy the tomatoes, the importance of the origin of the products consumed at home or in restaurants, and the environmental impact of these tomatoes compared with those available in the supermarket).

In the second step, the data were analyzed to evaluate the association between the socioeconomic characteristics and consumption habits (independent variables) across the dependent variables: (a) perception of the tomatoes consumed and (b) perception of consumer preferences for UA products. To confirm the correlational relationships, a bivariate analysis (Pearson's chi-square test) was performed (Díaz-Garcés et al., 2016). Moreover, a regression was conducted to ascertain whether specific associations, $p<0.05$ in the bivariate analysis, would remain significant to model the

predisposition to buy RA tomatoes and the taste perceived. Taste was selected because it was determined that of all the perceived quality attributes, taste generates the highest impact on consumers (Asensio et al., 2019). Tomato taste is directly related to its chemical composition, which varies depending on the maturity of the fruit (Piombino et al., 2013). The data collected for taste tomato perception were processed by classifying them in variable binary form (where 1 = Very good and good; and 2 = Neutral, Bad and Very bad). Binary logit models were run to obtain the linear probabilities of a) the perceived taste of tomato as good or very good and b) the affirmation to buy this kind of tomatoes. The predictor variables considered in the model were sex, age, education level, occupation level, income level, individual weekly consumption of tomato, environmental consideration and knowledge of the RA project. First, for each response variable, a model was created with all predictor variables, and the significance of each one was analyzed. The results were contrasted with the results of applying the Akaike information criterion (AIC) to determine the best model. The AIC is an estimator of the relative quality of statistical models that deals with the trade-off between the goodness-of-fit and the simplicity of the model. The smaller the AIC, the better is the fit of the model. The models were evaluated using a cross-validation. The objective was to assess how well it performs in predicting the target variable on different subsets of the data. Once the most appropriate model was selected, the parameter estimates were calculated to determine the strength of effects of predictor variables on response outcomes. The cross-validation was conducted with 10 partitions of equally sized segments (called 'folds'). Each created fold is held out for validation while the other 9 folds are used to train the model. This process is repeated 10 times. The results of the evaluation were the average of the 10 validations.

In the third step, a question was added in the analysis of the consumer preferences focusing on the proposed price for RA tomato. Although a contingent valuation method was not used, a double-question perspective was considered: the participants were asked whether they would buy the tomatoes, and a multiple-choice question proposed different price ranges. The goal was to observe the willingness-to-buy the product and the price range, focusing on the comparison with the price of the conventional product

Finally, a TwoStep cluster analysis was used to derive subtypes based on scores from the dependent variables. The TwoStep cluster method is a scalable cluster analysis algorithm that is designed to treat very large data sets with both continuous and

categorical variables or attributes (Tkaczynski et al., 2009). The cluster step takes subclusters (nonoutlier subclusters if outlier treatment is used) resulting from the pre-cluster step as an input and then groups them into the desired number of clusters. TwoStep uses an agglomerative hierarchical clustering method because it works properly with the autocluster method. Cluster analysis permitted the analysis of the demographic and behavioral consumption characteristics of the different population segments identified. Responses to open questions have been used literally to illustrate the statistical results.

Results

Overview of the sample

The study sample (N=238) consisted of people between 16 and 65 years old, of whom 62.3% were women. All respondents completed at least secondary education, mainly due to the location of the sampling (the campus of the Universitat Autònoma de Barcelona Autonomous University of Barcelona). Regarding the participants' occupations, 60% were employees, whereas nearly 40% were students. The monthly income rank of the sample was disparate, with the majority having a salary of less than 600€ (29.3% of the sample) (Table 2). As mentioned above, a portion of the respondents (54.2% of the total) had prior knowledge of the project, which implies that they had basic information about UA and the i-RTG.

<Table 2>

Cluster analysis of the sample

The cluster analysis allowed division of the population into two homogeneous groups (consumers1 and consumers2) according to certain key variables to observe their influence on the indicators under study. Among the variables assessed with clusters, the following had the greatest influence (Feature Importance, IF): occupation (FI: 1), age (FI: 0.82), income (FI: 0.73) and previous knowledge of the project (FI: 0.37).

The first group resulting from the cluster analysis (consumers1) corresponded to 38.5% of the population surveyed. This group consisted of 100% students. The age range was between 16 and 44 years, although the majority (67.4%) were between 16 and 24 years, and their income level in 69.6% of cases was below 600 €. In this case, 26.1% knew about the project beforehand. The second group (consumers2) included 61.5% of the population. The majority were contracted employees (82.3%), and 10.2% were self-employed. The ages in this group were more diverse. The majority ranged in age between 25 and 54 years (25.2% between 35 and 34 years, 28.6% between 35 and 44 years and 28.6% between 45 and 55 years), and the income level was higher than in the previous group, reaching on average between 1,500 and 2,000 €. In this case, 76.2% knew about the origin of the tomatoes.

Perception of the quality of tomatoes from rooftop agriculture

The results from all surveys revealed a good acceptance of rooftop agricultural products by the respondents, who positively valued the quality of the produce and its characteristics, such as taste, texture and freshness (see Table 3). When subjects were asked if they would buy tomatoes such as the ones they had eaten, 87% answered affirmatively. Concerning organoleptic perception, 87% described the condition as good or very good, and 74% of the sample stated that the taste was good or very good. Similarly, 64.9% marked the tomatoes as being full or very full inside, and 80% rated the texture as good or very good. When asked about ripeness, only 1% thought they were very unripe, compared to 40% who thought they were ripe or very ripe. Regarding the freshness of the produce, 94% of the sample considered that they had eaten a fresh product (Table 3).

<Table 3>

According to the chi-square analysis, income level was the most influential parameter when valuing the product (p value <0.5). Thus, people with a higher income level perceived better quality, including taste, tomato condition and texture. In the same line, the higher the income, the higher the % of people who would buy these tomatoes (Table 4). Nevertheless, the proposed price was not influenced by the income level of

the consumers. The key variables in this case were the influence of educational level on perception of the tomato condition and tomato content (p value <0.5) (Table 5). Nearly 73% of the people with high school studies rated with the highest punctuation the condition of the tomatoes, while just 35% of the people with university studies gave the maximum punctuation. Moreover, people with a high school education provided a better rating of the content of the tomatoes (40% of them considered as very full) than people who had a higher level of studies (i.e., university or vocational high school studies).

<Table 4 >
<Table 5>

Furthermore, in this study, 100% of the respondents who had information about the project before the survey was conducted considered the produce to be fresh, whereas for the rest, this percentage was 86%. This good acceptance was also detected in open questions of the survey. Some people explicitly remarked about the good taste of the tomato and emphasized that according to them, it was important to continue research regarding projects for sustainable production of vegetables in cities. Some feedback from the respondents is provided below:

> "It would be great to try to cultivate other varieties of tomatoes. In any case, I was lucky to be able to enjoy these tomatoes from 0 km away. Thank you very much!"

> "The most important challenge of the project is to serve as an example of urban gardening, given the complexity it requires."

Indeed, the results also revealed that the consumers proposed a higher price for products, which could be important for the economic feasibility of these projects. Specifically, the average price that consumers would pay is 3.25€/kg (weighted mean), and 34.7% of people proposed to pay 5€/kg.

The two cluster groups agreed on the valuation of some of the questions (p value < 0.05): "*How ripe was the tomato eaten?"* and *"How would you rate the taste of your tomato?".* Nevertheless, consumers2 rated some attributes of the tomatoes better: *How do you rate the condition of the tomato eaten? Was the tomato full inside? Do you*

consider that you have eaten a fresh product? How would you rate the texture of your tomato? Would you buy tomatoes like the one you have eaten? (Table 6)

<Table 6 >

In the open questions of the survey, an additional concern was detected in relation to the quality of the air in the cropping area. Three respondents were worried about the air quality in the cities and the possible effects on the produce, as shown in the following statement.

> "It bothers me to know that tomatoes have been produced on rooftops in the city and, in this case, that they have been exposed to the pollution of the city".

Another informant wondered whether the contents of vitamins and nutrients were similar to produce from soil crops cultivated in rural areas, writing,

> "I would like to know if these products grown on rooftops in the city have the same nutritional and vitaminic qualities as commercial tomatoes and if they are affected by the pollution of the city or by the fact that they have not been grown in soil".

Finally, other participants wondered about whether soilless RA could be considered organic:

> "I am not sure if it is considered ecological production - it would have to comply with this criterion to say that they are better than others."

Perception of rooftop agriculture (RA)

In general, the results indicated a favorable perception of (RA) grown inside a greenhouse using a soilless cultivation system. Consumers with prior information about RA and the project tended to have a better appreciation of the product (p value < 0.05) based on their answers regarding the organoleptic characteristics; 84% of those who knew the RA project rated the taste of the product as good or very good, and 90% rated

the texture as good or very good. In contrast, among those who did not know the origin of the product, these percentages decreased to 77% and 65%, respectively.

Moreover, the results showed that most consumers considered tomatoes grown in RA systems to be environmentally better than those from the market. On average, 69% of the participants perceived that the produce from the i-RTG had a lower environmental impact than the tomatoes derived from conventional means of production, increasing to 76% among respondents with further information about the project. The Pearson's Chi-square test showed a positive correlation between these two variables ($p<0.05$)

As noted above, the results also showed that the proposed price for tomatoes from RA systems was higher than the average market price. Nearly 55% would pay between 3 and 5 € per kg of tomato (the average price of beefsteak tomato is approximately 2.50 €/kg). Furthermore, 62% of those who were aware of the i-RTG project proposed a price between 3 € and 5 €, whereas among those who did not know about the project, the figure was only 44%.

Notwithstanding that the cluster analysis revealed no differences regarding the environmental perception of the RA products, we found that the consumers2 cluster proposed a higher price for the RTG tomatoes (p value < 0.05). This finding relies on two aspects: a greater purchasing power, as this cluster encompasses older people with university studies and employees with good salaries, and a better valuation of the quality of the RTG products, as mentioned above.

The open questions of the survey revealed different opinions about RA products. Most respondents valued the product and the technique of production (soilless system in i-RTGs) very positively. For example, one respondent expressed his satisfaction with RA as follows:

> "I think it's a great idea to take advantage of spaces on urban rooftops and the ecological treatment with which it is grown."

Nevertheless, some respondents highlighted the need to know more about the production of the tomato. Particularly, one person requested more information about the means of production (use of inputs), which s/he considered necessary to be able to assess the tomato from an environmental perspective:

> "I would provide more information about the method used to grow the tomatoes, such as the use of inputs, to not only take into account the proximity of the crop but also the manner in which it is produced".

This examples shows how some consumers do not think that the proximity of the product is a guarantee of good environmental performance and require additional information to make an informed judgment. Regarding the unnatural perception of the product, one participant adopted a political approach:

> "The priority is to support our farmers and cultivated land. As long as the abandonment of land and the difficulties to access it continues, the production of tomatoes on rooftops in cities should not be a priority".

In the same line, other people reported that this type of large-scale cultivation must be valued considering its influence on rural food production, in addition to other relevant aspects of the urban-rural balance. For example, one person indicated,

> "It is difficult to answer the question because it depends on what type of tomatoes we are talking about. I buy tomatoes only in season from an agroecological farmer. Then, the answer would be that they are not environmentally better because tomatoes grown in RA do not promote a living rural world or follow the principles of agroecology. On the other hand, if we refer to conventional tomatoes that have been grown in a greenhouse in Huelva through many intermediaries, then those of the ICTA would be better".

> "Large-scale tomato cultivation in UA has to be valued, taking into account its influence on the rural production means of proximity, as well as other relevant aspects of the urban-rural balance. (…) I wonder how these types of crops could increase the consumption of water in cities, for example."

For a better understanding of the influence of the variables under assessment on the perception of taste and the possibility of buying RA tomatoes, a specific analysis was performed.

The assessment of the results of the first step (using the 10 independent variables, AIC: 235.04) showed that “know the project” and rate “environmental positively” were the most significant variables. Nevertheless, after applying the AIC the model with the best fit, the following variables were included (AIC: 213.14): education level, income level, weekly consumption of tomato, environmental consideration, previous knowledge. This model explains 76% of the cases. There was no multicollinearity between the explanatory variables included in the regression analysis. Environmental consideration and previous knowledge were the most significant variables in the model. The removal of these variables worsened the model fit, as seen by the subsequent increase in AIC for each of these variables. The other three variables improved the model fit when individually removed, but only very slightly in each case. Table 7 presents the estimates of the variable effects (βk) with their standard errors, z-values, and corresponding p-values. The values that were most important for this analysis were the variable effects, as they quantitatively represented the association between each variable and the response variable.

<Table 7>

As mentioned before, the willingness to buy RA tomatoes is another important variable to consider. Again, 10 independent variables were used in a first approach (AIC, in this case, just three variables presented significance compared with the null model: age, environmental perception and previous knowledge of the project). Using the AIC, the best fit model, just two variables were necessary: environmental perception and previous knowledge (AIC: 168.98). Table 8 shows the results of the best fit model (AIC: 144.79). Nevertheless, if we focus on the parameters and their effects, this model cannot explain why people would not buy this product (this model explains 100% of the cases that would by the tomatoes and 0% of the cases that would not). In other words, it is not possible to detect rejection of the product using the 10 variables studied. For this reason, a third model was created using the results of the tomato quality variables (Table 9). Six variables were used: condition, taste, texture, content, freshness, environmental perception and previous knowledge of RA agriculture (AIC:101.54). The best fit model (AIC: 92.25) was defined by the following variables: perception of the texture, taste and previous knowledge; the model explained 96% of the respondent variables. Specifically, the chances of buying RA increased when consumers highly

rated the texture and taste. As in the valuation of taste, previous knowledge of the project entailed a greater willingness to purchase RA tomatoes, as also observed for better environmental perception.

<Table 8>
<Table 9>

Consumption habits and influence on RA perception

Concerning individual consumption habits, over half of the participants indicated that they eat between 0.5 and 1.5 kg of tomatoes a week, 23% between 1.5 and 2.5 kg, and 17% less than 0.5 kg. The results showed that 56% of the sample buy their tomatoes in bulk, 39% buy bulk and packaged tomatoes and only 4% buy only packaged tomatoes. The predisposition to buy RA products was similar among those who buy in bulk and those who buy both bulk and packaged. The results also revealed that the packaging is associated with consumption habits, as nearly all the respondents who buy in bulk wash the product before consuming it (95% of them), whereas only 70% of those who buy packaged tomatoes wash them.

In this sense, most of the respondents (89%) would enjoy consuming RA products at home, and half would enjoy eating them in a restaurant: 33% in restaurants in the studying and working environment (UAB campus), 27% in restaurants in the city and 17% in restaurants that only offer local products (slow food).

In contrast, the results revealed that consumers considered knowing the origin of the product an important factor, since nearly 100% believed it to be very important, which was also true for vegetables consumed in restaurants, with more than 90% of the respondents stating that knowledge of this information is important (Table 10).

In this section, the cluster assessment was not performed because the questions were included only in the winter campaign. Nevertheless, when assessing the preferable place for consuming the tomato, the influential socioeconomic characteristics (p value <0.05) were “Sex”, “Age range” and “Level of monthly income”.

Finally, regarding where they would prefer to buy the product, 55% preferred a shop, followed by 32% who would prefer to buy it directly at the production point. The socioeconomic variables that influenced these results ($p<0.05$) were “Sex”, “Level of

education", "Do you buy tomatoes in bulk or in specific packaging?" and "What quantity of tomatoes (approximately) do you estimate that you eat a week?"

<Table 10>

Discussion

The results of this study provided new information concerning consumers' perception of horticultural products from soilless RA systems. As shown above, most potential consumers have a good perception of the quality of RA products, and no rejection of soilless system products was found. This study focused on tomatoes because they are the most consumed horticultural product in Catalonia (Departament d'Agricultura, Ramaderia, 2016). Most of the participants showed higher tomato consumption than the average consumption in Catalonia. The average consumption of fresh tomatoes per capita in Catalonia is nearly 16 kg/year, with a cost of 24.96 €/year (Departament d'Agricultura, Ramaderia, 2016). According to the previous literature, different aspects contribute to defining the quality of food: some are intrinsic qualities, such as taste and other organoleptic properties, and others are external factors, such as the origin and labeling (Bernue et al., 2003). In this case, study, the quality of the product was positively evaluated in both senses.

Previous studies have demonstrated that when assessing food quality, consumers consider the product's sensorial characteristics (taste, appearance and freshness of the product) to be the most important aspects, which are also the main drivers for food purchasing choices (Honkanen and Frewer, 2009). Our results agree with their conclusions, as it has been shown that socioeconomic characteristics do not allow prediction of the willingness to buy RA tomatoes, in contrast to quality perception. A good evaluation of these parameters is usually associated with local products sold at markets (Torjusen et al., 2001). Moreover, this result is consistent with several previous studies performed with different UA and RA stakeholders, highlighting the ability of RA systems to supply products for which freshness is valued by consumers, which is an opportunity for this type of agriculture (Cerón-Palma et al. 2012; Sanyé-Mengual et al. 2016).

Providing fruits and vegetables with adequate ripeness is a major advantage of RA, since fruits can ripen on the plant and be collected immediately before being consumed, thereby adding quality to the product. In contrast, the majority of conventional production systems harvest the produce while it is still green, and the tomatoes subsequently ripen, which is in line with several previous studies analyzing the perception of different stakeholders from UA and RA. These studies highlight the ability of RF systems to supply products that are not only fresh but also perceived as such among consumers; this is an opportunity for this type of agriculture (Cerón-Palma et al. 2012; Specht et al. 2014; Sanyé-Mengual et al. 2016). Freshness, short transport, security and contributions to local economy and viability are associated with local food production (Roininen et al., 2006). Despite previous studies showing that some stakeholders perceive food produced in RA as less tasty and less nutritious than products from the supermarket (Cerón-Palma et al., 2012; Specht et al., 2014), this study did not identify this negative perception. One of the main findings of this study was that taste perception is not only related to socioeconomic characteristics (e.g., education, income) but also to environmental perception of the production system and their environmental impact.

The main concerns of consumers were related to food safety, heavy metal contamination, the use of organic practices in soilless production and the social impact of RA. These points should be addressed in UA initiatives, as they can be an inconvenience for acceptance of the product. In this sense, it is important to acknowledge that previous studies concluded that the origin of pollutants in the urban environment is largely human (Khan et al., 2008) and that food contamination can occur either by contact with contaminated soils or by air pollution (Khan et al., 2016; Voutsa et al., 1996) that can be generated by different sources, such as wheeled transport emissions (Manta et al., 2002), previous land uses and atmospheric deposits from industrial activities and incinerators (Chen et al., 2005; Vittori Antisari et al., 2013). RA has an advantage because no urban soil is used and heavy metal pollution risk in UA depends mostly on the previous uses of the soil (Ercilla-Montserrat et al., 2018; Pennisi et al., 2016).

People with higher salaries had a greater appreciation of the condition and texture of the tomato and their freshness compared with those with lower salaries. A good quality tomato is usually associated with local products that have been picked at exactly the right time for consumption. Sellers (2016) found similar results in Spain

when he assessed the willingness to pay for sustainable wine. Future market studies should take into account these preferences of potential consumers.

In accordance with (Hussein et al., 2015; Sellers, 2016), our results suggest that different types of consumers are willing to pay a higher price for sustainable products, such as vegetables from RA crops. In this study, the proposed prices are related to the perception that it is an environmentally friendly product and includes consumers with both higher and lower salaries. The added value of proximity could be included in the price, as consumers showed appreciation for these characteristics. This result is in accordance with (Feldmann and Hamm, 2015), who reviewed the literature regarding local food from the consumer's perspective and concluded that unlike organic food, local food is not perceived as expensive per se. It leads to more positive attitudes about local food in comparison to, for example, organic food. Consumers are willing to pay premium prices for products that have a clear indication of their local origin, with even greater increases for local plant products than for local animal products (Carpio and Isengildina-Massa, 2009). Moreover, this is especially relevant to products that are purchased in smaller quantities (premium products) compared with those that are highly consumed. Thus, it is an important factor to consider when deciding the kinds of crops that should be grown in UA.

Focusing on the perception of the system under study, prior studies in the issue showed that stakeholders (e.g., architects, local and regional administration, UA-related planning lawyers and food distributors) identified a range of potential environmental benefits associated with RA (Sanyé-Mengual et al., 2015; Specht et al., 2016a). The perception of consumers, which is a key element, might differ from those of the aforementioned stakeholders. Previous studies have indicated that there may be skepticism among consumers associated with the use of highly technical systems, which may be perceived as "unnatural" (Specht and Sanyé-Mengual, 2017). Organic products are usually associated with crops grown in soil systems with low inputs and that use natural resources instead of artificial nutrients, pesticides and water. Conversely, environmentally sustainable agriculture is usually linked to highly technological and innovative solutions, i.e., crop production in which the resources are optimized from a circular economy perspective and are isolated from nature (FAO, 2013; Randelli and Rocchi, 2017; Rantala et al., 2018). In the case of the i-RTGs, the environmental sustainability derives from the symbiosis between a crop and a building. This study showed that nearly 70% of the participants considered tomatoes from RA to be more

environmentally friendly than the tomatoes available on the market. Moreover, it was found that having knowledge about the project and its characteristics increases consumer acceptance (for example, 100% of those with prior knowledge considered the produce to be fresh). RA must address the social predilection for traditional images of agricultural production using low-tech production systems that are more likely to be accepted (Specht and Sanyé-Mengual, 2017), which can be linked to (Sanyé-Mengual et al. 2016), in which it was identified that demonstrative activities and pilot projects are necessary to facilitate the development and interpretation of RA in Barcelona. In fact, European citizens are increasingly optimistic about biotechnology, and they are more informed and more trustful of biotechnology systems. The European public is not risk-averse about technological innovations when these can provide tangible benefits. Nevertheless, in the case of agricultural biotechnologies, a general opposition has been detected (Gaskell et al., 2006). Traceability or personal control over exposure appears to be a key issue for the least-accepted technologies (Frewer et al., 2011). Whereas the majority of people are willing to delegate responsibility for new technologies to experts, who make decisions based on scientific evidence, a substantial minority want to reinforce moral and ethical considerations in decision-making about science and technology and to involve public opinion (Gaskell et al., 2006).

Although previous studies in the metropolitan area of Barcelona (the same area as the case study) have shown that UA is perceived as a socially oriented activity rather than a food production one (Specht et al. 2015; Sanyé-Mengual et al. 2016), our results showed that consumers were willing to buy these products (81.5%). In general, our results provide new information regarding the perspectives of potential consumers, which would dispel this inconvenient notion of stakeholders regarding vegetables grown in i-RTGs. Furthermore, the responses of potential consumers provided data about more attractive business models and marketing pathways for RA food products. In these previous studies, some stakeholders perceived consumers' acceptance as an economic barrier to the development of UA.

In the case of the results regarding the issue of marketing aspects, the surveys showed that people were willing to consume RA products either at home or in restaurants. Nevertheless, socioeconomic characteristics were also found to influence the preference for the point of consumption of these products and should be taken into account when marketing the products. The success of RA projects will depend greatly on the individual preferences of consumers, and its knowledge can be of help when

planning a commercial strategy. An important factor for the success of an RA project is preference regarding the place of consumption.

RA shortens the supply chain and increases the added value of products, promoting sales due to their specific characteristics and personal, transparent, and reliable producer-consumer relationships (Beauchesne and Bryant, 1999). The proximity to consumers' markets offers favorable conditions for direct marketing. In the present study, packaging was found to be an important factor influencing consumer's perception and the environmental impact of the crop. Packaging influences perceptions of food products, including not only sustainability perceptions but also several other benefits, such as perceived taste and quality (Steenis et al., 2017). In our study, people who usually buy tomatoes in bulk wash their tomatoes (95%), but not all of those who buy packaged tomatoes do so (70% of them wash the tomatoes). According to Steenis et al., (2017), this finding suggests that the type of consumer who buys packaged tomatoes considers them as sufficiently healthy to be consumed directly. Nevertheless, consumer's judgments about environmental benefits sometimes rely on misleading or inaccurate beliefs and are therefore susceptible to ineffective environmental decisions. For example, one of the most important environmental advantages in the UA and i-RTGs is that the use of packaging can be avoided, considerably reducing the environmental impact of the products (Sanyé-Mengual et al., 2013) without decreasing its health properties.

In contrast, in accordance with the consumers' perceptions, the concept of food quality seems to be closely related to the perception of safety. Quality and safety are concepts that cannot be easily defined because they are classified as credence attributes (i.e., product attributes that cannot be verified by the consumer) (Van Rijswijk and Frewer, 2006). Concerns regarding the safety and quality of food products involve every stage of the production chain. The debate about these topics has focused on several aspects of the product: organoleptic characteristics, health and hygiene safety, healthiness and nutritional qualities, place of production and ethical aspects (Mascarello et al., 2015). In this research, some of these concerns have been found: proximity to high-traffic areas, if this type of product is considered organic food, sustainability of the product and its freshness.

Integrating greenhouses in restaurant buildings opens a range of new possibilities. In such cases, there would not be an UA farmer; rather, the staff from the restaurant would produce its own products. The restaurant could also benefit from the

favorable perception of the products as a marketing strategy, including high appreciation of the freshness, taste or quality of the RA products. The restaurant could offer a highly valued product, taking into account both the intrinsic and external qualities, such as its sustainability due to the RA design. In contrast, other factors that influence restaurant managements' willingness to buy local products, such as the order processing time and uniqueness of the products, have been identified (Sharma et al., 2014). These advantages can be increased if the products come from the same restaurant.

Conclusions

This paper examines the social perception of soilless RA production through experimental research. The results show that perception is generally positive for both the product quality and the agronomic system. The study sheds light on motivations that can lead consumers towards RA products.

Previous literature has shown that there is a rejection towards urban food grown in greenhouses and soilless systems, representing a possible barrier to the implementation of RA. However, this perception might change if it were acknowledged that these methods are common practice in conventional agriculture, although it is not reported in the label (Specht and Sanyé-Mengual, 2017). This study unveiled a good perception of soilless RA products and a positive consideration of the production system. Indeed, consumers with more knowledge and interaction with UA projects (i.e., those close to the location and those aware of the case study) had a more positive perception of the food and production system: 100% of them considered the product to be fresh, and 62% would pay the highest possible price. In this sense, the information provided is key for consumers' perception.

Regarding the pricing of RA products, consumers who identified RTG tomatoes as environmentally friendly were the ones who proposed higher prices. This particularly affected the consumers who knew the RTG system, but it had no relationship with consumers' income. This finding is key to understanding how local production might increase the added value to become more attractive, since they have to compete with the lower prices of imported products with externalized social and environmental costs. Moreover, it should be considered that consumers with a higher educational level and a

higher income are the most appropriate target when selling RA products, since they are keener to appreciate the quality of the product.

It must be highlighted that consumers were mainly concerned about food safety, organic practices in soilless production and social impacts. UA initiatives should acknowledge this information to succeed. Regarding food safety, the dissemination of results from research on the risks of UA might contribute to boosting acceptance (Specht and Sanyé-Mengual, 2016), as it was demonstrated that risk is low and mostly linked to the previous uses of soil (e.g., incinerators, industry) (Vittori Antisari et al., 2013). Thus, RA has an advantage because no urban soil is used, and the location (roofs) is further from sources of air contamination (Ercilla-Montserrat et al., 2018; Pennisi et al., 2016). Moreover, the RTG is also protected from the exterior environment due to material insulation.

Public administration and UA companies should focus on strategies to improve the environmental performance of production, such as the reuse of leachates or rainwater in irrigation, the use of greenhouse heating systems in an environmentally friendly manner, or the use of renewable energy. All of these environmentally friendly measures should be communicated to potential consumers to improve perception of the product. These communication campaigns may include visits to the facilities (as is currently performed in the case study) and food tastings. Additionally, the implementation of quality control standards for products and growing facilities by administrations can help increase consumers' trust. Finally, further research is required to assess the impact on society and the environment, in addition to the effects of city pollution on UA. Efforts should focus on the study of further parameters, such as the effect of knowing the origin of the UA products and of taste them. As this study was conducted as a pilot project, the people who could visit and interact with the RA always had access to tasting the product; consequently, we could not desegregate such information. Future surveys could be designed to observe whether people's perceptions about soilless agriculture change after when they consume the tomatoes. Furthermore, the effects of participating in communication campaigns and knowledge about RA projects could be parameters under assessment.

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Table 1. Sampling campaigns: overview of participants and distribution of the samples

Campaign	**Period**	**Location**	**Population**	**Approach type**	**Survey response**
Winter	12-01-2016 to 27-02-2016	Common spaces in ICTA-ICP building	ICTA-ICP workers and students	Tomatoes were available for the entire community.	Consumers were invited to answer the survey online.
Summer	02-06-2016 to 22-07-2016	Restaurants at UAB Campus	UAB workers and students	Bags of tomatoes were distributed among the UAB population.	A link to the survey was provided with the tomato bag.

Table 2. Definition and descriptive statistics of the independent variables used (n = 238).

Aspect characteristic	**Categories**	**Answers (%)**		
		Total	**Summer campaign (n=135)**	**Winter campaign (n=103)**
Sex	Female	59.4	65.4	58.3
	Male	35.9	34.6	41.7
Age	16-24	26.8	7.4	52.4
	25-34	26.4	27.2	25.2
	35-44	19.2	28.7	6.8
	45-54	17.6	23.5	9.7
	55-65	10	13.2	5.8
	> 65	0	0	0
Education level	Not graduated	0	0	0
	Primary School	0	0	0
	High School	6.0	3.7	9.7
	Vocational School of Higher Education	11.2	13.2	9.7
	University	78.1	83.1	80.6
Occupation	Self-employed	6.0	11.0	0
	Worker	48.2	64.7	32.0
	Student	37.1	18.4	66.0
	Retired	1.6	2.9	0
	Unemployed	1.2	2.2	0
	House work	1.2	0.7	1.9
Income level	< 600€	29.3	8.1	57.3
	600-1000€	12.1	13.2	10.7
	1000-1500€	22.6	33.1	8.7
	1500-2000€	15.9	19.1	11.7
	2000-2500€	7.5	8.8	5.8
	2500-3000€	8.4	12.5	2.9
	> 3000€	4.2	5.1	2.9
Individual weekly consumption of tomato	< 0.5 kg	16.3	14.0	21.4
	0.5-1.5 kg	50.6	51.5	55.3
	1.5-2.5 kg	21.9	25.0	20.4
	2.5-3.5 kg	2.8	4.4	1.0
	3.5-4.5 kg	2.0	3.7	0
	> 4.5 kg	1.6	1.5	1.9
Use of packaging	Buys tomatoes in bulk	53.8	67.6	41.7
	Buys packaged tomatoes	4.0	2.9	5.8
	Buys both	37.5	29.4	52.4

Table 3. Social perceptions about the samples of tomato tasted

	Very good (%)	**Good (%)**	**Acceptable (%)**	**Bad (%)**	**Very bad (%)**
Condition of the tomatoes	38.9	47.7	11.7	1.7	0
Taste of the tomatoes	34.3	39.3	22.2	3.8	0.4
Quality texture of the tomatoes	32.2	46.9	14.2	6.7	0
	Very full (%)	**Full (%)**	**Acceptable (%)**	**Empty (%)**	**Very empty (%)**
Content of tomatoes	20.9	47.3	10.9	4.6	0.4
	Yes (%)	**No (%)**			
Is it a fresh product?	94.1	5.9			
Would you buy these tomatoes?	87.4	12.6			

Table 4. Difference between social perceptions of the tomato quality from RA in different income groups. *significant differences (P < 0.05) between groups

		Income level			
		less 1000	**1000-2000**	**2000-3000**	**>3000**
Taste of the tomatoes*	Very good (%)	28.3	39.1	39.5	30
	Good (%)	40.4	34.8	50	30
	Acceptable (%)	27.3	20.7	7.9	40
	Bad (%)	3	5.4	2.6	0
	Very bad (%)	1	0	0	0
Condition of the tomatoes*	Very good (%)	23.2	39.1	36.8	40
	Good (%)	51.5	38	57.9	40
	Acceptable (%)	16.2	16.3	5.3	10
	Bad (%)	9.1	6.5	0	10
Quality texture of the tomatoes*	Very good (%)	23.2	39.1	36.8	40
	Good (%)	51.5	38	57.9	40
	Acceptable (%)	16.2	16.3	5.3	10
	Bad (%)	9.1	6.5	0	10
Would you buy these tomatoes?*	Very good (%)	82.8	91.3	94.7	70
	Good (%)	17.2	8.7	5.3	30
Content of tomatoes	Very full (%)	26.3	18.5	23.7	20.0
	Full (%)	45.5	46.7	50.0	60.0
	Acceptable (%)	11.1	13.0	7.9	0.0
	Empty (%)	8.1	1.1	2.6	10.0
	Very empty (%)	1.0	0.0	0.0	0.0

Table 5. Difference between social perceptions of the tomato quality from RA in different educational level groups. *significant differences ($P < 0.05$) between groups

		Education level		
		High School	High School	High School
Taste of the tomatoes	Very good (%)	60,0	39,3	31,6
	Good (%)	26,7	50,0	38,8
	Acceptable (%)	13,3	7,1	25,0
	Bad (%)	0,0	3,6	4,1
	Very bad (%)	0,0	0,0	0,5
Condition of the tomatoes*	Very good (%)	73.3	50	34.7
	Good (%)	13.3	39.3	51.5
	Acceptable (%)	13.3	10.7	11.7
	Bad (%)	0	0	2
Quality texture of the tomatoes	Very good (%)	40,0	39,3	30,6
	Good (%)	46,7	46,4	46,9
	Acceptable (%)	6,7	10,7	15,3
	Bad (%)	6,7	3,6	7,1
Would you buy these tomatoes?	Very good (%)	86,7	92,9	86,7
	Good (%)	13,3	7,1	13,3
Content of tomatoes*	Very full (%)	40,0	21,4	19,4
	Full (%)	46,7	32,1	49,5
	Acceptable (%)	0,0	14,3	11,2
	Empty (%)	13,3	3,6	4,1
	Very empty (%)	0,0	3,6	0,0

Table 6. Difference between social perceptions of the tomato quality from RA in the two defined clusters (consumers1 and consumers2)

		Very good (%)	**Good (%)**	**Acceptable (%)**	**Bad (%)**	**Very bad (%)**
Condition of the tomatoes	Consumers 1	41.5	50.3	6.8	1.4	0
	Consumers 2	34.8	43.5	19.6	2.2	0
Quality texture of the tomatoes	Consumers 1	34	51	10.9	4.1	0
	Consumers 2	29.3	40.2	19.6	10.9	0
		Very full (%)	**Full (%)**	**Acceptable (%)**	**Empty (%)**	**Very empty (%)**
Content of tomatoes	Consumers 1	17	49	8.8	2.7	0
	Consumers 2	27.2	44.6	14.1	7.6	1.1
		Yes (%)	**No (%)**			
Is it a fresh product?	Consumers 1	96.6	3.4			
	Consumers 2	90.2	9.8			
Would you buy these tomatoes?	Consumers 1	91.2	8.8			
	Consumers 2	81.5	18.5			

Table 7. Parameter estimates in the best fit model (n=238): perception of tomato taste by consumers

Coefficients	**Estimate (βk)**	**Standard error**	**z value**	**Pr (> |z|)**	**Sig**
(Intercept)	1.42	1.01	1.41	0.16	
Studies 4	0.84	1.10	0.77	0.44	
Studies 5	-0.81	0.83	-0.98	0.33	
Income level 2	-0.28	0.46	-0.61	0.54	
Income level 3	1.19	0.66	1.80	0.07	*
Income level 4	-1.35	0.90	-1.50	0.13	
Nº tomatoes 2	0.80	0.47	1.71	0.09	*
Nº tomatoes 3	-0.85	0.52	-1.63	0.10	
Nº tomatoes 4	15.74	1355.84	0.01	0.99	
Nº tomatoes 5	0.21	1.30	0.16	0.87	
Nº tomatoes 6	16.60	1901.94	0.01	0.99	
Environmental	1.63	0.37	4.42	9.73E-06	***
Previous knowledge	-1.78	0.45	-3.95	7.95E-05	***

Signif. Codes: *** <0,001 * <0,1

Table 8. Parameter estimates in the best fit model (n=238): willingness to buy RA tomatoes

Coefficients	Estimate (βk)	Standard error	z value	Pr (> |z|)	Sig
(Intercept)	2.54	0.55	4.65	3.41E-06	***
Environmental	1.58	0.44	3.59	3,36E-04	***
Previous knowledge	-2.26	0.57	-3.99	6.60E-05	***

Signif. Codes: *** <0,001 *

Table 9. Social perception of tomato quality parameters estimates in the best fit model (n=238): willingness to buy RA tomatoes

Coefficients	Estimate (βk)	Standard error	z value	Pr (> |z|)	Sig
(Intercept)	0.21	0.78	0.27	0.78	
Texture	1.29	0.60	2.16	0.03	**
Taste	3.03	0.83	3.67	2,43E-04	***
Environmental	1.11	0.57	1.95	5,11E-02	*
Previous knowledge	-1.40	0.75	-1.87	0.06	*

Signif. Codes: *** <0,001 ** <0,05*<0,1

Table 10. Social perceptions about the importance of knowing the origin of the tomato consumed.

	Very important (%)	Important (%)	Irrelevant (%)	Unnecessary (%)	Totally unnecessary (%)
Importance of the origin of the commercial products	61.0	38.3	0.8	0.0	0.0
Importance of the origin of products consumed in restaurants	41.4	49.6	7.4	1.6	0.0
	Much better (%)	**Better (%)**	**Equal (%)**	**Worse (%)**	**Much worse (%)**
Environmental impact of these tomatoes and those available in the supermarket from conventional agriculture	0.8	2.1	27.8	45.6	24.5

Figure 1. ICTA-ICP building with the i-RTG on the top (left), the i-RTG with a crop in the vegetative stage (middle), and the i-RTG with a crop in the harvesting stage (right).