BSc Thesis

FRESHLY SQUEEZED ORANGE JUICE

Consumer usage, quality and shelf life extension

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Thesis code:	YSS-81812

10 July 2017

Summary

Worldwide the demand for fresh juices increases rapidly. In 2015 the US market saw an increase of 33,5% for fresh juices and drinks. Therefore, the quality of these juices becomes even more important. Other than the quality, the shelf life of these fresh juices is a point of improvement. The current shelf life of freshly squeezed orange juice from commercial orange juicers in the supermarket is 24 hours after purchasing. The aim of this research is to analyse how freshly squeezed orange juice, bought from commercial orange juicers in the supermarket, is consumed and how the quality and shelf life of the freshly squeezed orange juice can be extended throughout this period of usage. The consumption of the freshly squeezed orange juice is researched using a questionnaire, while the quality and shelf life improvements are researched using literature. The results show that the shelf life of orange juice is already longer than indicated on the package and could be extended using a multilayer cap. Consumers should store the orange juice in the fridge to keep the quality. Further research on the prevention of yeast and mould growth should be done to extend the shelf life of orange juice even longer.

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1. Introduction

1.1 Background

In the past couple of years an increase in fruit consumption by children and adolescents is noticed, as well as an increase in consumption of non-alcoholic beverage, which include juices. One of these trends is the consumption of fresh juices. Worldwide the demand for fresh juices increases rapidly. In 2015 the US market saw an increase of 33.5% for fresh juices and drinks (BeverageIndustry, 2016). Therefore, the quality of these juices become even more important.

For the traditional processed juices this means that a shift in the market has taken place. In this research the focus is on the most important juice product, orange juice (Berlinet, Brat, & Ducruet, 2008). Nowadays commercial orange juicers can be found in most supermarkets, which gives the customer the opportunity to exchange the processed orange juice for freshly squeezed orange juice. The downside to this is that the freshly squeezed orange juice has an expiration date of 24 hours after purchase, while the processed orange juice has an expiration date of several months.

The importance of the image a consumer has of a product is proven by Giménez, Gagliardi, and Ares (2015). In their research the consumers' purchasing decision and how the consumers' rejection of fresh products is affected by the setting is shown. Two studies were done, the first studied the consumers' rejection for home consumption and the second the purchase in the supermarket with orange juice samples with different storage times. The results from these studies were that the estimated shelf life based on the consumers' rejection to purchase were shorter than the estimated shelf life based on the consumers' rejection to consume. Therefore, it is important to know the different estimated shelf lives.

Another important factor for freshly squeezed orange juice is the freshness of the product. In Köppel, van Velsen, and Ganeshan (2016) the freshness of orange juice is tested. The quality of orange juice is characterized by the density of the fluid and the vitamin C content, though this does not represent the freshness of the product. In this research the fragmentation of the DNA in the orange juice is measured. The fragmentation of the orange juice shows correlation with olfactory and taste. The result was that the decline of DNA during the pasteurization process was shown. A pasteurization experiment shows the decline of the linkage during the continuation of the heat treatment of orange juice. Using this information, the freshness of the orange juice can be researched not only through its vitamin C content, but also through the fragmentation.

1.2 Research goal

The goal of this research is to analyse how freshly squeezed orange juice, bought from commercial orange juicers in the supermarket, is used by consumers and how the quality and shelf life of the freshly squeezed orange juice can be extended throughout this period of usage.

1.3 Research questions

The main research question of this research is:

How can the quality and shelf life of freshly squeezed orange juice be enhanced during the period of usage?

The sub-questions supporting the main research question are:

1. What is the process behind getting freshly squeezed orange juice?
2. What is the function of the package of freshly squeezed orange juice?
3. How do the consumers treat the freshly squeezed orange juice after buying it in the supermarket?
4. What processes can be enhanced in the squeezing process of orange juice?
5. How can packaging be improved to support the quality and shelf life of freshly squeezed orange juice?
6. How can consumers enhance the quality and shelf life of the freshly squeezed orange juice after the purchasing process?

2. Materials and Methods

For this research results are gathered from literature and through a questionnaire (see appendix I). The questionnaire supports the sub-questions by researching consumer preference and use of the freshly squeezed orange juice.

2.1 Study population and recruitment

The population the questionnaire is aimed at is consumers that buy and consume freshly squeezed orange juice. The questionnaire is spread through social media, where it reaches a lot of different people from the private network as well as different public groups. To filter the people that do not buy or consume freshly squeezed orange juice, the first question of the questionnaire asks whether freshly squeezed orange juice is bought by the respondent.

2.2 Data collection and data handling

The questionnaire is launched through the Qualtrics application of the Wageningen University. Information on and the link to this questionnaire is spread through personal, friend and public networks on social media, e.g. Facebook, Twitter and LinkedIn. The data collected from the questionnaire is used for research purposes only and is handled anonymously.

2.3 Data analysis and evaluation

The data collected is mainly used to answer research questions 3 and 6:

3. How do the consumers treat the freshly squeezed orange juice after buying it in the supermarket?
6. How can consumers enhance the quality and shelf life of the freshly squeezed orange juice after the purchasing process?

The other research questions are mainly answered through literature, but can also be supported by data collected from the questionnaire. The data collected from the questionnaire is divided over different topic, each serving a different part of the research.

2.3.1 General information

In the general information, personal and general consumption questions are asked. The personal information asked is the gender, age and number of consumers in the household of the respondent, see appendix I question 12-15. This information is collected at the end of the questionnaire, due to its personal nature. The general consumption questions are whether freshly squeezed orange juice is consumed, the frequency of consumption, average bottle size and purchasing place (appendix I, question 1-4). If the first question on whether the freshly squeezed orange juice is consumed by the respondent is answered with a no, the respondent is let to the end of the questionnaire. This information will not be used in the data analysis.

The general information is used to observe correlations between: gender, age, household size, frequency of consumption, storage time and bottle size. The expectations are that there might be a relation between, bottle size and storage time, number of consumers and storage time, number of consumers and bottle size and a differentiation in gender and age.

2.3.2 Product treatment by the customer

To find out how to optimize the process from buying till the final consumption of the freshly squeezed orange juice, knowledge on storage is needed. The answers to the questions (appendix I, question 6&7) how and where people store the freshly squeezed orange juice give insight into the way people handle the orange juice. With this information, the threats towards the quality of the freshly squeezed orange juice can be identified, to which solutions can be suggested. Changes in the production, packaging or storage process of the freshly squeezed orange juice might be necessary to increase the quality and shelf life of the orange juice.

2.3.3 Consumption and storage time

The quality and shelf life of the freshly squeezed orange juice should be as high as possible during the time people consume the orange juice. Therefore, it is important to know the timeframe within the orange juice is consumed. In the questionnaire, the questions “within what timeframe after purchase do you consume the freshly squeezed orange juice”, “what is the maximum time of consumption of the freshly squeezed orange juice” and “what is the maximum time of storage, before you consider the freshly squeezed orange juice as spoiled” help to create an idea of the consumption and storage time (see appendix I, question 5,8,9).

2.3.4 Quality expectations of the consumer

To identify the quality aspects of freshly squeezed orange juice the consumer find important, two questions, one rating different quality aspects and one ranking these quality aspects, are added to the questionnaire (appendix I, question 10&11). Using these questions a general vision of the ‘perfect’ orange juice can be created. With the rating of quality elements and the importance of these elements an image of an optimal orange juice can be sketched.

2.4 Questionnaire

After closing the questionnaire, 299 responses were counted. Of these 299 responses 137 could be used, this means that the first question, which asked if they ever bought freshly squeezed orange juice, is answered with a yes and the questionnaire is completed. From the 137 people that responded with a yes and completed the questionnaire, most respondents were female. Also, most respondents were within the age of 20-29 years old.

Table 1. Sample description according to age and gender.

Gender		**Female**	**Male**
Age	<= 19	15	2
	20-29	52	9
	30-39	7	3
	40-49	14	3
	50+	22	10
	Total	110	27

3. Results and Discussion

3.1 Squeezing and storage process of freshly squeezed orange juice

To answer the first sub-research question, 'what is the process behind getting freshly squeezed orange juice?', this section discusses the squeezing and the storing process for the freshly squeezed orange juice.

Commercial orange juicers are produced at lots of different companies, all in different ways and each using different squeezing techniques. The general process is that the oranges enter the machine and are cut in halves. Afterwards the juice is squeezed out, the peels are separated and thrown in the bin. The juice is filtered and pulp is filtered from the juice.

A different technique is the one used for the orange juicer sold by Woertman (2017). The orange juicers sold by this company use a different principle of extracting the juice. This principle is called the suction principle and it makes sure that the skin of the orange does not end up in the juice. The skin causes the bitter taste in the orange juice and through using this method the bitter taste can be avoided.

After squeezing a bottle of orange juice, the juice should be stored in a refrigerator and needs to be consumed within 24 hours. This is what is stated on the orange juice bottles of several supermarkets. In practice, the orange juice meets the minimum requirements for at least 48 hours (Corrêa De Souza, De Toledo Benassi, De Almeida Meneghel, & Dos Santos Ferreira Da Silva, 2004). The main reactions that occur during the deterioration of the quality of orange juice are the decomposition of ascorbic acid and non-enzymatic browning. The factors that influence the reaction according to Zerdin, Rooney, and Vermuë (2003) are 'temperature, salt and sugar concentration, pH, oxygen, enzymes, light, metal catalysts, initial concentration of ascorbic acid, the ratio of ascorbic acid to dehydroascorbic acid, microbial load and the protection provided by the container'.

3.2 Packaging of freshly squeezed orange juice

Freshly squeezed orange juice is almost always sold in plastic bottles, which the consumer can fill themselves at the supermarkets. In this section the second sub-question, 'what is the function of the package of freshly squeezed orange juice?', is answered.

The bottle that is most commonly used for freshly squeezed orange juice is made of polyethylene terephthalate (PET) plastic. PET is the most frequently used polyester for food packaging, because of its strong, clear and gas barrier properties (Lee, Yam, & Piergiovanni, 2008). Another characteristic of PET is that it has a low permeability of O_2, CO_2 and water vapor, therefore the bottle protects reactions of the orange juice from external factors. As the decomposition of ascorbic acid is one of the most important quality degrading factors (Bacigalupi et al., 2013), it is important to prevent this. Decomposition of ascorbic acid takes place through a reaction with O_2, therefore limiting the amount of O_2 in the bottle is one of the main priorities.

3.3 Consumer usage

The question answered in this section is 'how do the consumers treat the freshly squeezed orange juice after buying it in the supermarket?'.

In table 2 an overview of the purchasing locations is given. Most respondents (92.7%) buy freshly squeezed orange juice at the supermarket. Other places the freshly squeezed orange juice is bought is in canteens as well as in other catering facilities, for example restaurants. As this research considers freshly squeezed orange juice that is squeezed by the customer, the freshly squeezed orange juice consumed at restaurants and other catering facilities are out of the scope of this the research.

Table 2. Percentage of respondents buying the freshly squeezed orange juice at the locations.

Location	**%**
Supermarket	92.7%
Canteen	15.3%
Gas station	0.7%
Other	7.3%

Most respondents buy freshly squeezed orange juice monthly. The respondents that answered with other mostly buy freshly squeezed orange juice infrequently.

Table 3. Frequency of freshly squeezed orange juice purchase.

Frequency	**%**	**Count**
Daily	1.5%	2
Weekly	17.5%	24
Every two weeks	11.0%	15
Monthly	47.4%	65
Occasionally	22.6%	31
Total	100%	137

The most common bottle size in which freshly squeezed orange juice is bought is a 500-millilitre bottle. Others include multiple bottles and different size bottles than were given.

Table 4. Bottle size of freshly squeezed orange juice.

Bottle size	**%**	**Count**
250 ml	31.4%	43
500 ml	45.2%	62
1000 ml	21.2%	29
Other sizes	2.2%	3
Total	100%	137

Most respondents consume the freshly squeezed orange juice within an average of 1.51 days. The maximum days they would consume the orange juice in is on average 2.77 and the perception of the maximum days the orange juice can be stored before they presume it is spoiled is 4.30 on average (see table 5). This shows what is proven earlier in Giménez et al. (2015), a customer has different estimations of shelf life in different situations. Here the conservation time is shorter than the shelf life estimated by the consumers.

Table 5. Consumption and estimated spoilage time estimated by respondents (in days).

	Minimum	**Maximum**	**Mean**	**Standard Deviation**
Actual consumption	0.00	7.90	1.51	1.36
Maximum consumption	0.00	10.40	2.77	1.81
Presumed spoiled	1.00	14.00	4.30	2.43

In figure 1 the consumption time, maximum time of consumption and maximum time before considered as spoiled is presented based on the different sizes of bottles. From this data, can be concluded that consumption time increases with the size of the bottle as well as the consumer's perception of maximum shelf life.

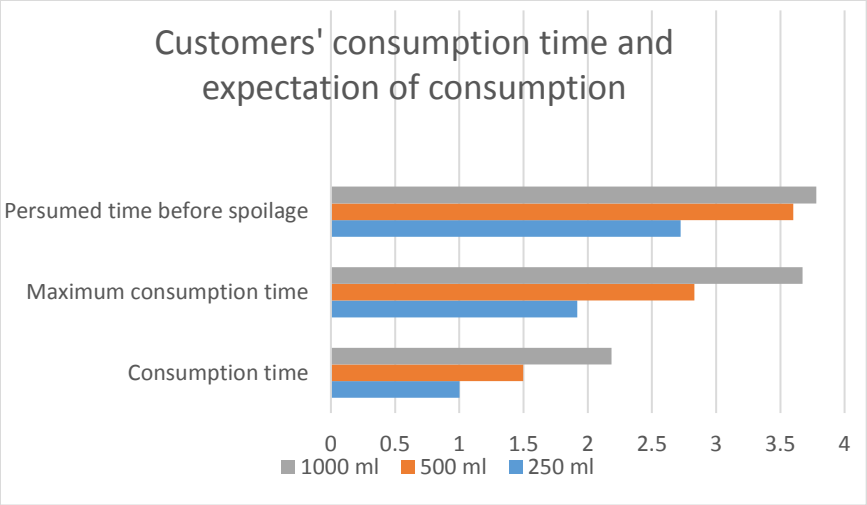

Figure 1. Average number of days for consumption and expected consumption according to bottle size.

Also, the way and place of storing the freshly squeezed orange juice is asked. All respondents keep the orange juice in the original bottle and store it in the refrigerator. Though some keep it in the backpack until they arrive at home.

Finally, the importance of having several quality aspects in the orange juice was asked. The respondents could rate the aspects on a scale from 1 to 10, with 1 being that it should not be present and 10 being that it should be present in the juice. In table 6, the scores of these different quality aspects can be found. The quality aspects are sorted in order of importance, according to the responses. The percentage given under 'importance' is the percentage of respondents that places this quality at the first place. The results show that the orange taste and vitamins are the most important quality aspects in the orange juice. The bitterness and sourness in the juice should be avoided, as it is rated as least important quality as well as rated with a low rating. This means that the bitterness and sourness should not be present in the orange juice.

Table 6. Importance and ratings of quality aspects in freshly squeezed orange juice.

Quality aspects	**Importance**	**Mean**	**Standard Deviation**
Orange taste	52.6%	8.79	1.30
Vitamins	19.7%	8.06	2.03
Orange smell	11.0%	7.79	1.77
Sweetness	8.8%	6.12	1.95
Orange color	6.6%	6.82	2.09
Pulp	0.7%	5.77	2.62
Bitterness	0.7%	2.80	2.10
Sourness	0.0%	5.39	1.93

3.4 Squeezing and storing process improvements

After analysing the current conditions of squeezing and storing freshly squeezed orange juice, this section focusses on possible improvements in the process. The question answered here is 'what processes can be enhanced in the squeezing and storing process of orange juice?'.

To increase the shelf life of the orange juice, the yeast count should be regulated. If the yeast count could be kept to a minimum, the shelf life could be increased from 48 to 72 hours. The high yeast count might be caused by the contamination of the orange during the harvest or due to recontamination during the processing (Corrêa De Souza et al., 2004). If contamination could be prevented in this process, shelf life increases with 24 hours. Therefore, it is advised to research the prevention of contamination during the harvest and processing.

As a bitter taste in the orange juice is a quality aspect that should be prevented in the orange juice, it is important to prevent the peels from ending in the orange juice. Therefore, the squeezing process as used for the orange juicers of Woertman (2017) is advised.

3.5 Packaging improvements

In this section the question, 'how can packaging be improved to support the quality and shelf life of freshly squeezed orange juice?, is answered.

To decrease the level of oxygen in the orange juice, a package with an oxygen scavenger could be used. Research done on oxygen scavengers show that the scavenger removes enough oxygen from the headspace of the bottle to extend the shelf life. It also provides an ongoing barrier to oxygen permeation, helping to protect the product from oxidative degradation (Zerdin et al., 2003). Another option for reducing the level of oxygen in the juice is by using glass bottles. Glass bottles have the lowest oxygen permeability (Ros-Chumillas, Belissario, Iguaz, & López, 2007).

The most important quality aspect of freshly squeezed orange juice is the orange taste in the product. The loss of orange aroma from the orange juice is mainly caused by permeation through the cap of the PET bottle. Therefore, it is recommended to use a multilayer cap to prevent aroma loss (Berlinet et al., 2008).

The use of a polylacetate packaging could also be considered. According to the research of Haugaard, Weber, Danielsen, and Bertelsen (2002) this package could be an "effective prevention of colour changes, AA degradation, and limonene scalping." Which means that using this package the loss of ascorbic acid, vitamin C, is reduced. Also, the orange colour will remain orange longer and the transfer of the packaging material in the orange juice is prevented.

3.6 Consumer usage improvements

Besides the production and packaging process, the customer handling the product after purchase also influences the quality and shelf life of the freshly squeezed orange juice. In this section the question 'how can consumers enhance the quality and shelf life of the freshly squeezed orange juice after the purchasing process?', is answered.

Firstly, storage conditions are discussed. When asking how and where the orange juice was kept, the answer was mostly in the fridge, while some people answered that they kept it in their backpack until they got home. When keeping the orange juice at a higher temperature, the mould growth increases at

a higher rate, causing the shelf life of the orange juice to decrease (Corrêa De Souza et al., 2004). Therefore, it is important that the customer stores the orange juice in the fridge as soon as possible after purchase.

The shelf life of orange juice, according to the packages provided by the supermarkets, is 24 hours. From figure 1 we can conclude that most of the orange juice bought by consumers is consumed in a period longer than 24 hour. The maximum consumption time as indicated by the consumers is also more than the expiration time as indicated on the bottle. From research we can conclude that the orange juice can be used for at least 48 hours (Corrêa De Souza et al., 2004), which is a lot shorter than the maximum consumption time and the time before consumers presume the orange juice to be spoiled. Therefore, the quality at the end of the consumption might be a lot lower than expected. To make sure the quality is at an acceptable level consumers should be made aware of the shorter shelf life or the shelf life should be extended.

4. Conclusion

The results stated above are used to answer the main research question 'how is freshly squeezed orange juice used by the consumer and how can the quality and shelf life be enhanced during this period of usage?'.

The juice can be extracted in different ways. The suction technique is as used for the orange juicer of Woertman (2017) is seen as the optimal process since it makes sure the skin of the orange does not end up in the juice, therefore avoiding the bitter taste in the orange juice.

The bottle in which the freshly squeezed orange juice is stored is made of polyethylene terephthalate (PET) plastic. PET is the most frequently used polyester for food packaging, because of its strong, clear and gas barrier properties (Lee et al., 2008). Another characteristic of PET is that it has a low permeability of O_2, CO_2 and water vapor, therefore the bottle protects reactions of the orange juice from external factors that degrade the quality of the orange juice.

Freshly squeezed orange juice is mostly bought in supermarkets in bottles of 500 ml. Consumers store and consume the orange juice on average after 1.5 days, which is a period longer than indicated on the bottle (24 hours). The perceived maximum number of days to consumption of the orange juice in is on average 2.77 and the perception of the maximum days the orange juice can be stored before they presume it is spoiled is 4.30 on average. The orange juice is kept in the refrigerator when the consumer is at home, while in some cases it is kept in a backpack during the day, before arriving home.

To increase the shelf life and quality of the freshly squeezed orange juice, some adjustments in the above described process should be made. Firstly, the yeast count in the orange juice should be controlled. Therefore, research should be done on the causes of contamination. This could be during the harvest or due to recontamination during the processing. During the squeezing process, it should be prevented that the peels of the oranges end up in the juice, as the bitter taste of the peels are unwanted by the customer. The suction technique should therefore be used when squeezing the oranges.

Using the current package of PET bottles, the quality and shelf life could be enhanced using an oxygen scavenger in the bottle and a multilayer cap. Other packaging should be considered as well, polylacetate packaging might even be more effective for storing freshly squeezed orange juice. To give an advice on the best packaging further research on the costs of both packages and the effect on the orange juice should be done. Finally, consumers should be informed about the actual shelf life and storage method.

5. Reflection

In this thesis, a questionnaire is used to create an image on the consumer usage of freshly squeezed orange juice. The questionnaire is completely answered by 137 respondents. Most of these respondents were female and between the age of 20-29 years, while male respondents were underrepresented. Therefore, the distribution of respondents is not equally divided between different gender and age groups. In this research the answers of the different groups did not differ significantly, though if a larger sample is taken some differences might occur. The sample taken in this research should thus not be generalized. Therefore, in further research a larger and more equally distributed sample is advised.

The questionnaire is used to create an image of consumer usage, though the image created from these responses might differ from the real consumer usage. This is mainly an issue for the questions on storage and consumption time, which might be answered differently in the questionnaire than actual storage habits and consumption time by consumers. An explanation for the difference could be that the respondent did not know the exact answers (especially in the case of consumption time) or that they gave socially desired answers. To create a better idea of the storage habits and consumption time, observations could be a suggestion.

Another limitation would be related to question 10 and 11 of the questionnaire, which ask about the consumer preference of quality aspects in freshly squeezed orange juice. From the responses on these questions can be concluded that sourness is a quality aspect that should be avoided in orange juice, even more than bitterness. This result differs from the expectation of consumer preference, which can be explained by the fact that the responses on these questions might differ from reality. Therefore, to create a better image on consumer preference, a sensory analysis is advised.

Finally, suggestions for improvements given in this thesis are deducted from literature. These suggestions are not tested in practice, as this was beyond of the scope of this research. Therefore, researching the feasibility of these options is advised before implementation.

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Appendix

I. Questionnaire

Voor mijn bachelorscriptie doe ik onderzoek naar versgeperst sinaasappelsap. Met versgeperst sinaasappelsap wordt sinaasappelsap verkregen uit een sinaasappelpers bedoeld, dat zonder verdere behandeling geconsumeerd wordt. Dit sinaasappelsap wordt vers door uzelf of voor u geperst op een andere locatie dan bij u thuis.

De enquête zal ongeveer 5 minuten duren.

Q1: Koopt u weleens versgeperst sinaasappelsap?

- ❍ Ja
- ❍ Nee

Condition: Nee Is Selected. Skip To: End of Survey.

Q2: Hoe vaak koopt u versgeperst sinaasappelsap?

- ❍ Dagelijks
- ❍ Wekelijks
- ❍ Tweewekelijks
- ❍ Maandelijks
- ❍ Anders, namelijk _____

Q3: Welke hoeveelheid versgeperst sinaasappelsap koopt u meestal?

- ❍ 250 ml
- ❍ 500 ml
- ❍ 1000 ml
- ❍ Anders, namelijk _____

Q4: Waar koopt u het versgeperst sinaasappelsap? (Er zijn meerdere antwoorden mogelijk.)

- ❑ Supermarkt
- ❑ Kantine
- ❑ Tankstation
- ❑ Anders, namelijk _____

Q5: Binnen hoeveel tijd na aankoop wordt dit sinaasappelsap geconsumeerd?

_____ Aantal dagen

Q6: Wanneer het sinaasappelsap niet onmiddellijk geconsumeerd wordt, hoe bewaart u dit dan?

Q7: Wanneer het sinaasappelsap niet onmiddellijk geconsumeerd wordt, waar bewaart u dit dan?

Q8: Wat is de maximale tijd na aankoop dat u het versgeperst sinaasappelsap zou consumeren?

_____ Aantal dagen

Q9: Wat is de maximale tijd na aankoop dat u het versgeperst sinaasappelsap zou bewaren, voordat u het als bedorven beschouwt?

_____ Aantal dagen

Q10: In welke mate zouden, volgens u, de volgende eigenschappen aanwezig moeten zijn in een versgeperst sinaasappelsap? U kunt de eigenschappen waarderen op een schaal van 0 tot 10, waarbij 0 = helemaal niet en 10 = heel veel.

_____ Sinaasappelgeur
_____ Oranje kleur
_____ Sinaasappelsmaak
_____ Zoetheid
_____ Zuurheid
_____ Bitterheid
_____ Vruchtvlees
_____ Vitamines

Q11: Welke eigenschappen van versgeperst sinaasappelsap vindt u het belangrijkst en welke het minst belangrijk? U kunt de eigenschappen slepen om deze van rang te verplaatsen.

_____ Sinaasappelgeur
_____ Oranje kleur
_____ Sinaasappelsmaak
_____ Zoetheid
_____ Zuurheid
_____ Bitterheid
_____ Vruchtvlees
_____ Vitamines

Q12: Wat is uw geslacht?

- ❍ Man
- ❍ Vrouw

Q13: Wat is uw leeftijd?

Q14: Uit hoeveel personen bestaat uw huishouden?

Q15 Hoeveel personen uit uw huishouden consumeren het vergesperst sinaasappelsap?

Bedankt voor uw medewerking aan dit onderzoek!

Voor vragen en/of opmerkingen kunt u contact opnemen met Djamila Lopulalan (Djamila.lopulalan@wur.nl)