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SENSORY CHARACTERIZATION OF JUICE OBTAINED VIA REHYDRATION OF POWDERED GRAPEFRUIT

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ABSTRACT

In this study, the effect of processing on some physical and sensorial properties of grapefruit juice has been studied. On the one hand, juices were prepared from powdered/cake grapefruit which was obtained by freeze-drying and spray-drying, and then it was rehydrated. These products were compared with both natural juice obtained from freshly-squeezed fresh grapefruit and with commercial juice. The rheological properties were measured using viscosity sweeps as a function of shear rate and the results were adjusted to the most appropriate rheological model (Ostwald-de Waele model) to determine the flow behaviour. All the samples presented pseudoplastic behaviour except for the spray-dried powder. In addition, colour and °Brix (solute concentration) were determined. The colour of the samples obtained by freeze-drying was the same as that of the natural juice while that of the spray-dried sample was far enough of the commercial sample. Finally, with regard to sensorial properties, a sensory evaluation was developed using a consumer panel in order to evaluate juice acceptability on a nine point hedonic scale: colour, aroma, flavour, bitterness, sweetness, acidity, astringency, consistency and overall acceptability. Furthermore, a penalty analysis was used to determine the attributes with improvement potential as well as some CATA questions where consumers marked the most characteristic attributes of each of the samples. The samples obtained by freeze-drying were associated with the terms ''viscous'' and ''with pulp'', whereas the spray-dried powdered juice was related to attributes similar to those found in natural juice, such as ''liquid'' and ''acid''. Concerning the penalty analysis, acidity, astringency and sweetness were rated as inadequate by the consumers in all the samples.

KEY WORDS: grapefruit juice, powdered grapefruit, freeze-drying, spray-draying, rehydration, sensory acceptability.

1. Introduction

The consumption of fruit is vital for our health owing to the fact that it is rich in vitamins, minerals and antioxidants. The composition varies in function of the type of fruit and degree of ripeness, but water is the major component in every case. Grapefruit, in particular, is a fruit of scarce value in terms of calories, mainly at the expense of carbohydrates, with a singular taste and properties. Its consumption is beneficial for several chronic illnesses, such as cancer and cardiovascular diseases (Mertens-Talcott, Zadezensky, De Castro, Derendorf, & Butterweck, 2006; Dow, Going, Chow, Patil, & Thomson, 2012). Grapefruit stands out as it is rich in folic acid (18 μg/100 g edible portion) and in vitamin C (36 mg/100 g edible portion), which is an antioxidant capable of neutralising the oxidation produced by the free radicals present in the organism (Xu, Liu, Chen, Ye, Ma, & Shi, 2008). This vitamin also plays a part in the formation of collagen, bones and teeth and red globules, favours the absorption of the iron present in foods and confers resistance to infections. Furthermore, the varieties with coloured pulp also have an abundance of flavonoids and provitamin A. Naringin is the prevalent flavonoid in grapefruit and is mainly responsible for its bitter taste (Hagen, Dunlap, & Wender, 1996). The bitter substance present in grapefruit whets the appetite and favours the production of bile, which is why it is considered to be digestive and good for the liver. β-carotene turns into vitamin A as and when the body needs it and this is essential for the eyesight, healthy skin, hair, mucous membranes and also so that the immunological system runs smoothly. However, its characteristic bitterness greatly limits its consumption, as do both its seasonal nature and short shelf-life. This is the reason why there is a downward trend to the consumption of fresh grapefruit while the market for fruit-based processed products is on the rise (Zulueta, Esteve, Frasquet, & Frígola, 2007).

One of the most widely used methods for stabilising and lengthening the shelf life of foodstuffs is dehydration (Bennett, Jegasothya, KonczakbFrankb, Sudharmarajana, & Clingelefferc, 2011), which also leads to a reduction in the volume and weight of the product, thus easing its transport and handling (Fazaeli, Emam-Djomeh, Kalbasi, & Omid, 2012). The powdered fruit format could be of interest as an ingredient in different food formulations or it could be rehydrated prior to consumption in the form of fruit juice. Freeze-drying and spray-drying are drying processes that stand out for the high quality of their end products.

Freeze-drying requires that the product be previously frozen so that the water may subsequently be sublimated, at low pressure, with the consequent reduction in the food's water activity (a_w). In this way, as heat is not used to carry out the process, the products that are obtained have only suffered slight losses in terms of their organoleptic and nutritional properties and thus are of a higher quality that those obtained when using heat treatments (Igual, García-Martínez, Camacho, & Martínez-Navarrete, 2010). Another of the advantages of this technique is the great capacity for rehydration of freeze-dried products due to the formation of a highly porous structure during sublimation (Barbosa-Cánovas, Ortega-Rivas, Juliano, & Yan, 2005; Berk, 2009). By grinding the cake, a powder is obtained. However, despite the advantages of freeze-drying, it is a costly process because of the amount of energy used in the freezing and sublimation (Mosquera, 2010); it is only feasible in cases where the products are ones of high added value and as long as it is very cost effective (Ratti, 2001; Berk, 2013). Furthermore, the highly hygroscopic nature of fruits makes it necessary to incorporate adjuvants that impart stability to the obtained product.

Spray-drying consists of pulverising a fluid inside a chamber with a controlled current of warm air, which permits the immediate evaporation of the water in the product, which dries gently with no thermal shock, thus obtaining the powder. (Nandiyanto, & Okuyama, 2011). One of the main drawbacks of this technique is the agglomerations of powder, which is due to the hygroscopic nature of many products, particularly fruit. Solutes, such as maltodextrin, modified starch or gum arabic, are added for the purposes of mitigating the problem of stickiness (Ozdikicierler, Nur, & Pazir, 2014); in addition, they protect the aromatic compounds from oxidation and volatilisation (Krishnan, Kshirsagar, & Singhal, 2005).

As one possible use of the powdered fruit obtained by freeze-drying or spray-drying is its rehydration in order to obtain juice of extremely high sensorial quality, it is of interest to know the possible differences between how the products obtained from both processes are accepted. Therefore, the aim of this study has been to discover whether there are significant differences in the acceptability of grapefruit juice elaborated from powder obtained by freeze-drying or spray-drying. To this end, both products have been characterised from a sensorial and physicochemical point of view.

2. Material and methods

2.1. Raw material

The grapefruits (*Citrus paradise* var. Star Ruby) used in this study were purchased in a local supermarket in the city of Valencia and were chosen in terms of size, firmness, colour and lack of visible surface damage.

A commercially-produced grapefruit juice was also used. It was purchased in a supermarket in the city of Valencia and, according to the label, it was made up of squeezed grapefruit juice containing 2% pulp.

In order to reduce the hygroscopicity of the dehydrated grapefruit, gum arabic (Scharlab, Sentmenat, Spain) and bamboo fibre (VITACEL®, Rosenberg, Germany) were incorporated to the fruit prior to freeze-drying/spray-drying.

2.2. Conditions for freeze-drying process

The grapefruits were peeled, cut and subsequently ground in a food processor (Thermomix TM 21, Vorwerk, Spain). 4.2g of gum arabic /100g of pulp and 0.58g bamboo fibre/100g pulp were added to the purée, following a formulation optimised in an earlier study (Agudelo, Igual, Camacho, & Martínez-Navarrete, 2017). The samples were then distributed on trays, forming a layer 0.5 cm thick and were frozen at -45°C (Liebeherr Mediline 7083 207-00, Austria) until they were freeze-dried (Telstar Lioalfa-6, 10^{-2} Pa and -55°C in the condenser, 48 h). Once freeze-dried, one part of the cakes obtained was placed into hermetically-sealed glass containers at 4°C until rehydration and another part was crushed in the same food processor and was sieved for the purposes of obtaining a homogeneous powder with particles of under 0.7mm in size. The powders were vacuum packed and stored, at 4ºC as well, until their subsequent rehydration.

2.3. Conditions for spray drying process

Previously washed, peeled and cut, the fruit was liquefied in a food processor (DELONGHI, Italy). The gum arabic (4g/100g of liquefied product) and the bamboo fibre (2g/ 100g of liquefied product) were totally dissolved in distilled water after stirring and mixed with the liquefied grapefruit in a ratio of 1:1 (solutes-water:liquefied product). A Büchi spray dryer (B-290, United Kingdom) was used to obtain the powdered product. The aspiration speed, the flow of the food and the spray drying air were 35 m^3/h, 9 mL/min and 473 L/h, respectively, in every case and the air temperature as it entered the spray dryer was 120 ºC. After spray drying, the powders obtained were vacuum packed and stored under the same conditions as the freeze-dried ones.

2.4. Rehydration

For the purposes of rehydrating the freeze-dried and spray-dried products, enough water was added to obtain a content of the grapefruit's own solutes which was equal to that present in the initial ground or liquefied fruit, respectively. To this end, the moisture content of both the crushed and the liquefied grapefruit was analysed, as was that of the freeze-dried and spray-dried products. The moisture content was determined by means of the gravimetric method carried out in a vacuum oven (Vaciotem, J.P. Selecta, Spain) at 60°C till constant weight was reached. The amount of water to be added was calculated from these values, by means of a mass balance (equations 1 and 2)

$$m^{rh} = m^{p} + m^{w} \quad (1)$$

$$m^{p}(1 - x_w^{p})x_{SP/ST} = m^{rh}(1 - x_w^{t}) \quad (2)$$

$$x_{\frac{SP}{ST}} = \frac{m_t(1 - x_w^t)}{m_{GA} + m_{FB} + m_t(1 - x_w^t)} \quad (3)$$

Where m^{rh} is the final mass of the rehydrated product (g); m^{w} is the mass of the added water (g); m^{p} is the mass of the powdered grapefruit (g); x_w^t is the initial moisture content of the ground/liquefied grapefruit (g water/g) y x_w^p is the moisture content of the powdered product (g water/g) and $x_{\frac{SP}{ST}}$ is the mass fraction of the grapefruit's solutes (SP) with respect to the total amount of solutes (ST) calculated following Eq. (3), m_t , m_{GA} and m_{FB} are the masses of the ground or liquefied grapefruit, the gum arabic and the bamboo fibre, respectively.

The rehydration processes are performed in a 50 mL jacketed beaker in which the powdered grapefruit sample and distilled water are placed. This glass is connected to a thermostated water bath. (Refrigerated Circulator 901, PolyScience, USA), for the purposes of keeping the sample at a temperature of 25°C during rehydration. Furthermore, the sample was maintained under constant magnetic stirring (750 rpm) for long enough to dissolve the maximum amount of powder.

2.5. Analytical determinations

The analytical determinations set out below were performed on freshly-squeezed grapefruit juice (N), on commercial grapefruit juice (C) and on the rehydrated products obtained from the freeze-dried cake (TL), the freeze-dried powder (PL) and the spray-dried powder. (PA).

2.5.1. Soluble solid content

The °Brix (grams of soluble solids per 100 g of liquid fraction) were determined for the samples of freshly-squeezed juice, those of the commercial juice and also those of the rehydrated samples using a refractometer (Abbe Atago 89553, Zeiss Japan) a 20°C.

2.5.2. Colour

For the purposes of measuring the colour of the samples, they were placed into a tray of 38 mm x 50 mm x 20mm, and a MINOLTA CM-2002 (Japan) colorimeter was used. The CIE*L*a*b coordinates were obtained on a black background, using illuminant D65 and observer 10° as reference, with a 30mm measuring window. From the CIE*L*a*b* coordinates obtained, the tone (h*), the chroma (C*) and the colour differences (ΔE*) (Hutchings, 1999) were determined and compared to the freshly-squeezed product through equations 4 to 6.

$$h^* = \mathrm{arctg}\left(\frac{b^*}{a^*}\right) \quad (4)$$

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (5)$$

$$\Delta E^* = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2} \quad (6)$$

2.5.3. Rheological properties

For the purposes of studying the rheological behaviour of the natural juice, the commercial one and that of the rehdryated samples, the flow curves were obtained by applying a velocity gradient sweep from 0 to 150 s^{-1} at a constant temperature of 25°C. A controlled velocity gradient rheometer (Thermo Electron Corporation, Hake RheoStress1, Karlsruhe, Germany) (Z34 DIN) with concentric cylinder geometry was used. The flow curves were adjusted to the Ostwald-de Waele model (Eq. 7) in order to obtain both the flow behaviour index (n) and the consistency index (K). The viscosity (η) at 100 s^{1} was calculated using both parameters through equation 8.

$$\sigma = K\ (\dot{\gamma})^n \quad (7)$$

$$\eta = K\,(100)^{n-1} \quad (8)$$

2.5.4. Sensory Analysis

The sensory analysis was performed by a panel consisting of 75 consumers aged between 18 and 65 years old in the standardized tasting room (ISO, 2007) of the Institute of Agrochemistry and Food Technology (IATA-CSIC). The presentation was designed in such a way that the samples were in randomized balanced complete blocks, identified by a random three-digit code. The panel members were asked to fill in a questionnaire on the five samples assessed (C, N, TL, PL and PA).

The consumers tasted the samples one by one and assessed the degree of acceptability (*liking*) of their appearance, colour, olour, taste, bitterness, sweetness, acidity, astringency, consistency and overall acceptability, using a 9-point hedonic scale (box-scale), the end points of which were ‘’dislike extremely’’ (on the far left corresponding to 1) and ‘’ like extremely’’ (on the far right corresponding to 9). A 5-point JAR-type (*just about right*) scale was used to assess the adjustment of different modifiable parameters of the samples, such as sweetness, acidity, astringency and consistency, by responding to the question: “do you consider the sample should be?” On this scale, 1 corresponds to ‘’much more…’’/ 3 to ‘’just right’’ and 5 to ‘’much less…’’. Also, the purchase intent was also assessed –in response to ‘’likelihood of purchasing product’’- on a 5-point scale, the end points of which were ‘’I certainly would not purchase it’’ (on the far left corresponding to 1) to ‘’I certainly would purchase it’’ (on the far right corresponding to 5).

After acceptability test, the consumers were asked to respond to some CATA (Check-All-That-Apply) questions that contain 12 sensory attributes in random order and to indicate the attributes that described each of the samples. These attributes were: grapefruit aroma, grapefruit taste, pleasant taste, artificial taste, weak grapefruit taste, cloudy, thin, thick, with pulp, bitter, sour and not overly sweet.

2.6. Statistical analysis

In order to determine the differences between the analyzed samples, a one-factor analysis of variance (ANOVA) was performed for a level of significance of $\alpha = 0.05$, using Fisher’s test. The Statgraphics Centurion XVI.I programme was employed to carry out the statistical analysis of the obtained results.

The XI-Stat 2009.4.03 programme was used for the statistical analysis of the sensory results. A one-factor ANOVA was performed with the data obtained about the samples’ degree of acceptability and the Tukey test was applied for the purposes of discovering the significant differences between the samples. A frequency analysis was performed to study the attributes assessed via the JAR scale and a penalty analysis was used to compare this data with the acceptability figures. Lastly, Cochran’s non-parametric test was applied for the purposes of analyzing the data corresponding to the CATA-type questions; this was done to determine the attributes that the consumers considered to differ depending on the sample being tested. The frequency of use of each significant attribute was subsequently analysed using a Correspondence Analysis and, finally, a Multifactorial Analysis was carried out in order to relate the CATA attributes to the overall degree of acceptability of the samples.

3. Results and discussion

The moisture content of both the ground and liquefied grapefruit used to prepare the formulations which were subsequently freeze-dried and spray-dried was 0.8710±0.0007 and 0.8752±0.0006 g of water/g, respectively. Similarly, the moisture content of the dehydrated products was 0.0241±0.0002 and 0.0190±0.0006 g of water/g, respectively.

Bearing this data in mind, the right amount of water (5.52 and 4.31 g of water/g freeze-dried and spray-dried powder, respectively) was added to each product to obtain one juice from the freeze-dried product with 0.1290 g grapefruit solutes/g and one juice from the atomized product with 0.1248 g grapefruit solutes/g (Eq. 1 to 3).

At this point, it is important to state that neither the ground nor the liquefied fruit will contain as many grapefruit solutes as the natural juice. Part of the albedo will be found both in the liquefied product and, to an even greater extent, in the ground one, enhancing the characteristic bitterness of the grapefruit. Nevertheless, the freeze-dried and spray-dried products were rehydrated to this degree so as they could be compared to the initial product in each case.

3.1. Analysis of soluble solid content

Figure 1 shows that significant differences ($\alpha < 0.05$) were found between the °Brix of the various juices being studied; the values were higher in the case of the juices prepared from the freeze-dried and spray-dried powder than those of the natural and commercial juices. This is due to the gum arabic and bamboo fibre added to the formulations. The highest value corresponds to the spray-dried sample, whose formulation contains a greater amount of solutes. As was to be expected, no significant differences ($\alpha > 0.05$) were found between the samples obtained from the freeze-dried grapefruit, whether in the form of a cake or powdered. The value of °Brix obtained for the freshly-squeezed juice was similar to that reported in the bibliography (Igual et al., 2010; Moraga, Igual, García-Martínez, Mosquera, & Martínez-Navarrete, 2012).

3.2. Colour analysis

Figure 2 shows the a*- L* (A) and a*- b* (B) colour charts where the samples currently being studied are located. In Figure 2a, it is possible to observe the significant differences in terms of the luminosity of the various products. It may be seen that there are two clearly distinct groups: as far as this parameter is concerned, the freeze-dried products are the ones with a higher value. The highest L*values correspond to the juices obtained from freeze-dried and spray-dried products that contain gum arabic and bamboo fibre. The isolines in Figure 2b have been traced bearing in mind the values of the samples of natural and commercial juices. As can be seen, the rehydrated products are to be found in between. Nevertheless, the a* and b*values of the samples obtained from the freeze-dried products were higher, which is reflected in a more intense chroma compared to the rest of the juices. All of this may be due to the fact that the entire edible part of the fruit is used in freeze-drying and so these juices contain a greater amount of pulp which makes them more luminous and imparts a tone which is more similar to that of the fruit than to that of its juice. The juice obtained from atomized powder, for its part, has been subject to a heat treatment that may also have led to its colour undergoing changes. However, despite the differences that exist between the samples, all of them are orangey-yellow in tone, which is characteristic of the grapefruit. In order to quantify the overall colour differences, the CIEL*a*b* colour differences of each sample were calculated with respect to the freshly-squeezed juice (Figure 3). It may be seen, in fact, that the samples that have been rehydrated from freeze-dried powder/cake exhibited greater colour differences, approximately 20 units, with regard to the freshly-squeezed juice than do those coming from the atomized powder and that the commercial juice was the one that bore most similarity to the natural one.

3.3. Analysis of rheological behaviour

The flow curves obtained for every sample were fitted to the Ostwald-de Waele model for the purposes of discovering the n, K and η values (Table 1). In the case of samples N and PA, n values of between 0 and 1 indicate behaviour which, although pseudoplastic, is more Newtonian (n=1) in nature. On the other hand, the most viscous sample 100 s^{-1} was TL, the one with the highest K value. By comparing it to the PL sample, highlights how grinding the cake to obtain the powder contributes to reducing the viscosity of the sample obtained. Silva, Agudelo, Camacho, & Martínez-Navarrete (2016) obtained similar results. Both samples were more viscous than C, N and PA because the latter three contain less fruit pulp.

3.4. Sensory analysis

The panel of consumers that took part in the study was 27% male and 73% female, of between 18 and 30 years old. It is worth pointing out that grapefruit is not commonly consumed in Spain; so, for 84% of the people, its juice is only drunk ‘’on occasion’’.

Figure 4 shows the degree of acceptability of the samples by means of a 9-point hedonic scale. On the whole, no significant differences were observed between the juices that were rehydrated from freeze-dried and spray-dried fruit; the exceptions were appearance and consistency that were rated the worst in the case of the juice obtained from the freeze-dried powder and cake due to the fact that they were both highly viscous. Nevertheless, as has already been mentioned, a more intense grinding of the powder would allow the viscosity of the rehydrated juice to be adjusted (Silva et al., 2016). On the other hand, the attributes of both the commercial and natural juices were all quite similar with the exception of colour. As far as overall acceptability with the samples is concerned, the best-rated ones were the commercial and natural; however, the likelihood of purchase was under 30% in every case, reflecting the fact that consumption of this fruit in Spain is limited. Every attribute of the juices obtained via spray drying and freeze drying differed significantly from those of the natural juice.

3.4.1. CATA-type questions

One simple sensory technique that permits information to be obtained about the sensory characteristics of a product that are perceived by consumers is via the use of "check-all-that-apply" questions (CATA). In a CATA question, the consumers have to check the options that they consider best describe the product from a list of words or expressions. The greatest difficulty of this technique is actually choosing the terms or attributes that are going to be presented to the consumers as it is necessary to ensure that all of them represent every possible sensation that can be perceived by the consumers. To this end, it is possible to obtain a list of attributes via the ''Repertory Grid Method'' with a smaller group of consumers; in this way, it is the consumers themselves who will generate the terms to describe the sensations perceived during the consumption of the fruit. In this case, the characteristic descriptors of the samples and the way in which their degree of intensity was assessed were determined in an open session with a panel of trained tasters, experienced in assessing similar products.

Cochran's non-parametric test was applied to the obtained results in order to analyse whether there were any significant differences in terms of the frequency of term use of the chosen sensory attributes. It was found that the frequency of term use of eleven out of the twelve attributes differed significantly; indicating that these attributes may be used to describe the significant differences between the juices assessed (Table 2).

Then, these eleven attributes were used to carry out a Correspondence Analysis (CA) (Figure 5). The first two dimensions of the CA graph explain 92.10% of the total variability of the data set. The first and second dimensions represent 66.54% and 25.56% of the total variability, respectively.

As can be seen in Figure 5, the terms ‘’grapefruit aroma’’ and ‘’grapefruit taste’’ were more closely associated with the natural and commercial juice, although the juices made from freeze-dried powder/cake are also similar as far as these terms are concerned together with the attributes “thick” and “with pulp”. The attributes “not overly sweet”, “bitter”, “sour”, “thin” and “artificial tasting” were associated with the juices that were rehydrated from spray-dried powder.

For the purposes of understanding which sensory characteristics were related with acceptability, the sensory data from the CATA question were studied in combination with the acceptability data from the consumers. This is because it is possible that they use the terms of the CATA question differently, which points to possible variations in terms of how the juices are perceived, leading to differences in how they are accepted. To this end, a Multifactorial Analysis (MFA) was performed (Figure 6), bearing in mind the responses to the CATA-type questions and their corresponding acceptability rating. The first two dimensions of the MFA represent 84.49% of the total variability of the experimental data. The first and second dimensions explain 57.54% and 26.95% of the total variability, respectively. The natural and commercial juices were the ones that the consumers most liked, perceived as having “grapefruit aroma”, “grapefruit taste” and “pleasant taste”. On the contrary, the samples with the lowest level of acceptability were those that were submitted to spray drying; they were associated with attributes such as “not overly sweet”, “bitter” and “artificial taste”. The presence of GA and FB and part of the albedo in the rehydrated products, together with the higher content in grapefruit solutes commented on previously, may justify these results.

3.4.2. JAR scales and Penalty Analysis

For the purposes of analysing the results of the attributes assessed using the JAR scale, this was reduced from 5 points to 3 in order to be able to visualize the responses more clearly. Then, a Penalty Analysis was performed to determine whether any of the attributes assessed using this scale need to be modified. This analysis is carried out so as the data on general satisfaction may be compared with that obtained for the attributes assessed using the JAR scales. The hypothesis behind this analysis is that a consumer will award the highest degree of acceptability when he/she believes the sample is ‘’just right’, which is to say at the middle point of the JAR scale (*just about right*). What the Penalty Analysis compares is the difference between the degree of acceptability expressed by the consumers who found a specific attribute of the product to be ‘’not…enough’’ or ‘’too…’’. In other words, it analyses how much acceptability decreases when different ‘’defects’’ are found in the aforementioned attributes of the samples. The attributes that the Penalty Analysis considers to be significant are those that over 20% of the consumers have found to deviate from the middle point “just right”; added to a decrease in acceptability of more than a point, this is seen as an attribute with potential for improvement.

Figure 7 shows the Penalty Analyses that have been performed on each of the samples. This analysis has not taken into account the juice that has been rehydrated from freeze-dried cake as it was the lowest-rated sample in the acceptability study and had scarcely any purchase intent.

A juice with an attribute in the top right-hand corner of the penalty graph is considered to be worse than one with an attribute in the bottom left-hand corner. Ideally, all the attributes would be found in the bottom left-hand section of the graph as this would mean that only a few consumers consider the level of the attribute concerned is not correct and the impact on the overall taste is slight. The opposite situation would be if all of the attributes were found in the top right-hand corner and would be subject to change as a means of obtaining new formulations of the product. These are the characteristics that are responsible for both the decrease in acceptability and for the high percentage of consumers who do not deem these attributes to be correct.

Overall, and for every juice assessed, the attributes that deviate the most from the ideal point, which is to say, from ‘’just right’’ are ‘’too’’ astringent and ‘’not nearly’’ sweet “enough”. Furthermore, with the exception of the juice produced from atomized powder, the attribute of acidity is also to be found a certain distance from the middle point. In the case of the commercial juice, however, it is the penalty for the sweet and sour taste that is noteworthy as it is the only sample whose formulation contains sugar. Despite this fact, it is this that makes its acceptability fall 1.5 points on the scale,

In essence, the fact that the juice samples are perceived as sour and not sweet enough is due to grapefruit being a citrus fruit that is noted for its acidity and natural astringency. However, this obstacle can be overcome by producing new formulations: for example, by adding differing concentrations of sugar to the samples for the purposes of obtaining a more readily accepted product regardless of purchase intent. It is worth highlighting that the attribute of sweetness has been penalized in every sample with a fall in acceptability of between 1 and 2 points. Nevertheless, as previously indicated, the commercial juice contains sugar whereas the rest do not; this is why juices obtained via freeze drying and spray drying are not so very different and would also be healthier.

4. Conclusions

In the main, every analyzed parameter of the samples obtained by means of the studied processes is significantly different from the commercial and natural juices. It has to be borne in mind that the products obtained via freeze-drying and spray drying contain gum arabic and bamboo fibre, carriers that are necessary not only for the spray drying process but also to ensure the stability of the powder that is obtained both via this process and also via freeze-drying, affecting both the colour and the rheological behaviour. Moreover, when the product is freeze-dried or spray-dried, part of the fruit pulp is present, particularly so in the former case, whereas this is not so in the other juices under study. The different content in fruit pulp would justify the greater viscosity of the freeze-dried product, particularly when obtained via rehydration of the cake, and the lower viscosity of the spray-dried product. The presence of the fruit pulp would also justify the greater overall difference in the colour of the juice obtained from the freeze-dried product as compared to the freshly-squeezed juice, in spite of the yellow-orange tone of all of the juices. These very differences may justify the differences found in the sensory characteristics of the analysed juices. In general, the consumers detect problems with the acidity, astringency and sweetness of every product; however, all of this may be due to the low declared intake of this fruit, which could be boosted by adding sugar to improve these attributes.

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Table 1. Consistency Index (K), flow behaviour index (n) and viscosity at 100 s^{-1} ($\eta_{100s^{-1}}$) of the juice samples under study (N: Natural; C: Commercial; PA: Rehydrated spray-dried powder; PL: Rehydrated freeze-dried powder; TL: Rehydrated freeze-dried cake).

Sample	**n**	**K (Pas ^{n})**	**η_{100s-1} (Pa s)**
PL	0.538 (0.014)^{ab}	0.41 (0.04)^{a}	0.048 (0.002)^{b}
TL	0.18 (0.10)^{a}	9.6 (3.4)^{b}	0.21 (0.02)^{c}
C	0.37 (0.11)^{a}	0.07 (0.03)^{a}	0.0033 (0.0002)^{a}
N	0.82 (0.02)^{b}	0.006 (0.003)^{a}	0.0027 (0.0009)^{a}
PA	1.2 (0.3)^{c}	0.003 (0.003)^{a}	0.0032 (0.0006)^{a}

Values in parentheses are standard deviations.

^{abc}Means with different letter in columns indicate significant differences among the samples ($p < 0.05$) according to the Tukey test.

Table 2. Frequency of mention of the CATA attributes and the p value from the Cochran test in order to determine which sample attributes exhibit significant differences.

Attributes	**p (test Cochran)**	**Frequency of mention**				
		Commercial (PA)	**Rehydrated freeze-dried powder (PL)**	**Rehydrated freeze-dried cake (TL)**	**Natural (N)**	**Rehydrated spray-dried powder (PA)**
Not overly sweet	0.028	25	41	38	35	38
Sour	<0.0001	20	35	21	53	42
Bitter	<0.0001	29	57	61	30	62
With pulp	<0.0001	28	29	58	28	2
Thick	<0.0001	3	48	61	3	1
Thin	<0.0001	38	7	1	44	41
Cloudy	<0.0001	13	41	43	6	10
Weak grapefruit taste	0.143*	14	16	15	7	18
Artificial taste	0.004	15	20	15	9	27
Pleasant taste	<0.0001	37	2	3	21	74
Grapefruit taste	<0.0001	28	19	9	31	16
Grapefruit aroma	<0.0001	27	15	12	43	6

*Attributes that do not present significant differences according to the Cochran test.

FIGURE LEGENDS

Figure 1. Sugar content of the analyzed samples (N: Natural; C: Commercial; PL: Freeze-dried powder; TL: Freeze-dried cake; PA: Spray-dried powder). a-d: Different letters indicate significant variations from treatment to treatment.

Figure 2. Colour Charts of the grapefruit samples assessed: (A) a*-L* and (B) a*-b*. (N: Natural; C: Commercial; PL: Freeze-dried powder; TL: Freeze-dried cake; PA: Spray-dried powder).

Figure 3. Colour differences compared to the sample of natural freshly-squeezed juice (C: Commercial; PA: Spray.dried powder; PL: Freeze-dried powder; TL: Freeze-dried cake). a-c: Different letters indicate significant differences between samples.

Figure 4. Acceptability of juice samples (C: Commercial; N: Natural; PA: Spray-dried powder; PL: Freeze-dried powder; TL: Freeze-dried cake). a-c: Different letters indicate significant differences between samples.

Figure 5. Correspondence analysis of the CATA-type questions for the purposes of assessing the grapefruit juice samples (C: Commercial; N: Natural; PA: Spray-dried powder; PL: Freeze-dried powder; TL: Freeze-dried cake).

Figure 6. Multifactorial analysis using the acceptability ratings and data from the CATA questions (C: Commercial; N: Natural; PA: Spray-dried powder; PL: Freeze-dried powder; TL: Freeze-dried cake).

Figure 7. Penalty analysis. Representation of significant penalties (drops in acceptability scores) by proportion of panellists. The cut-off point was the 20% of the consumers who said that an attribute was not ‘’enough’’ (-) or ‘’too much’’ (+). The important thing is to take the deviation above this point (> 20% of the consumers). (C: Commercial; N: Natural; PA: Spray-dried powder; PL: Freeze-dried powder).

Figure 1
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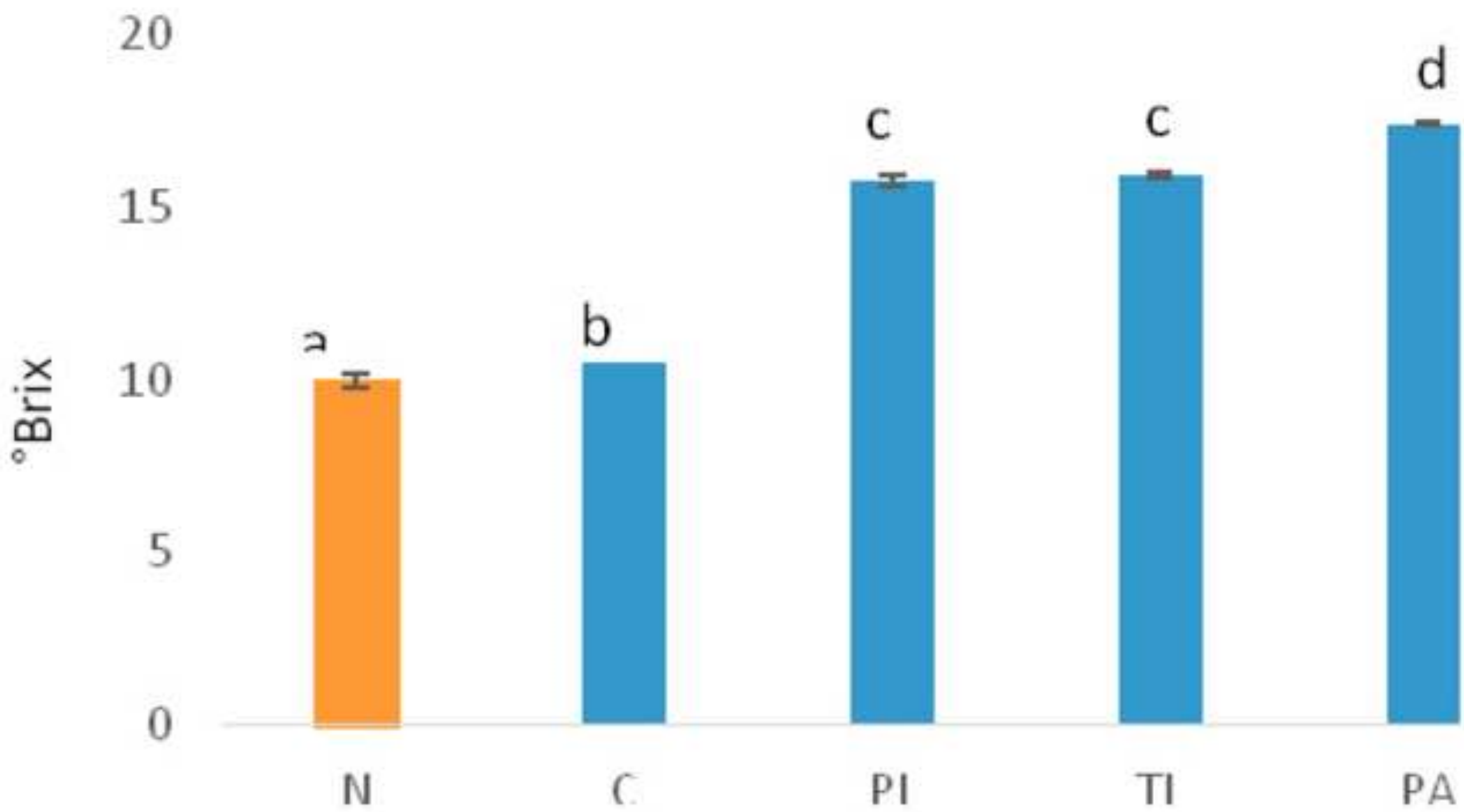

Figure 2a

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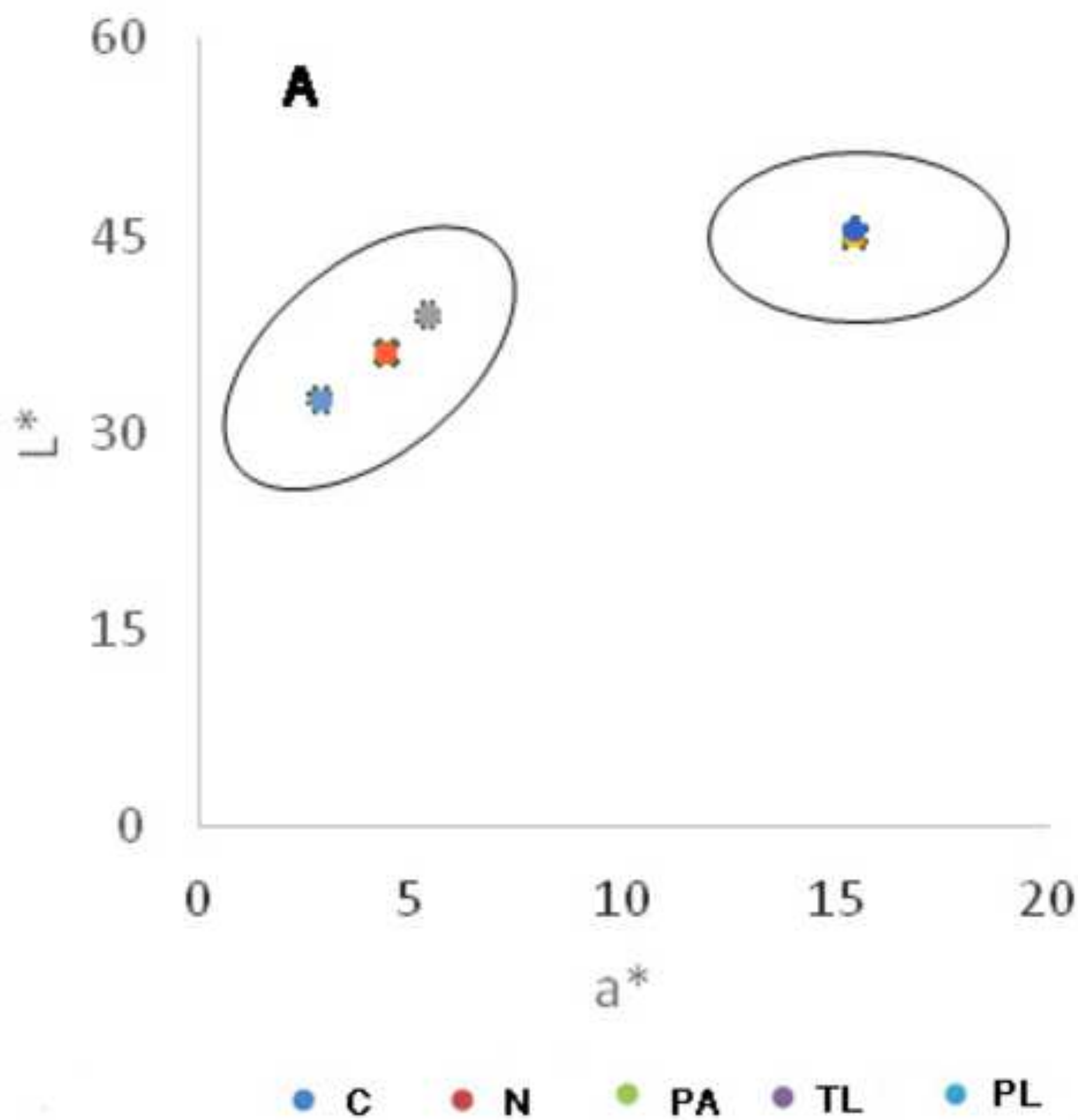

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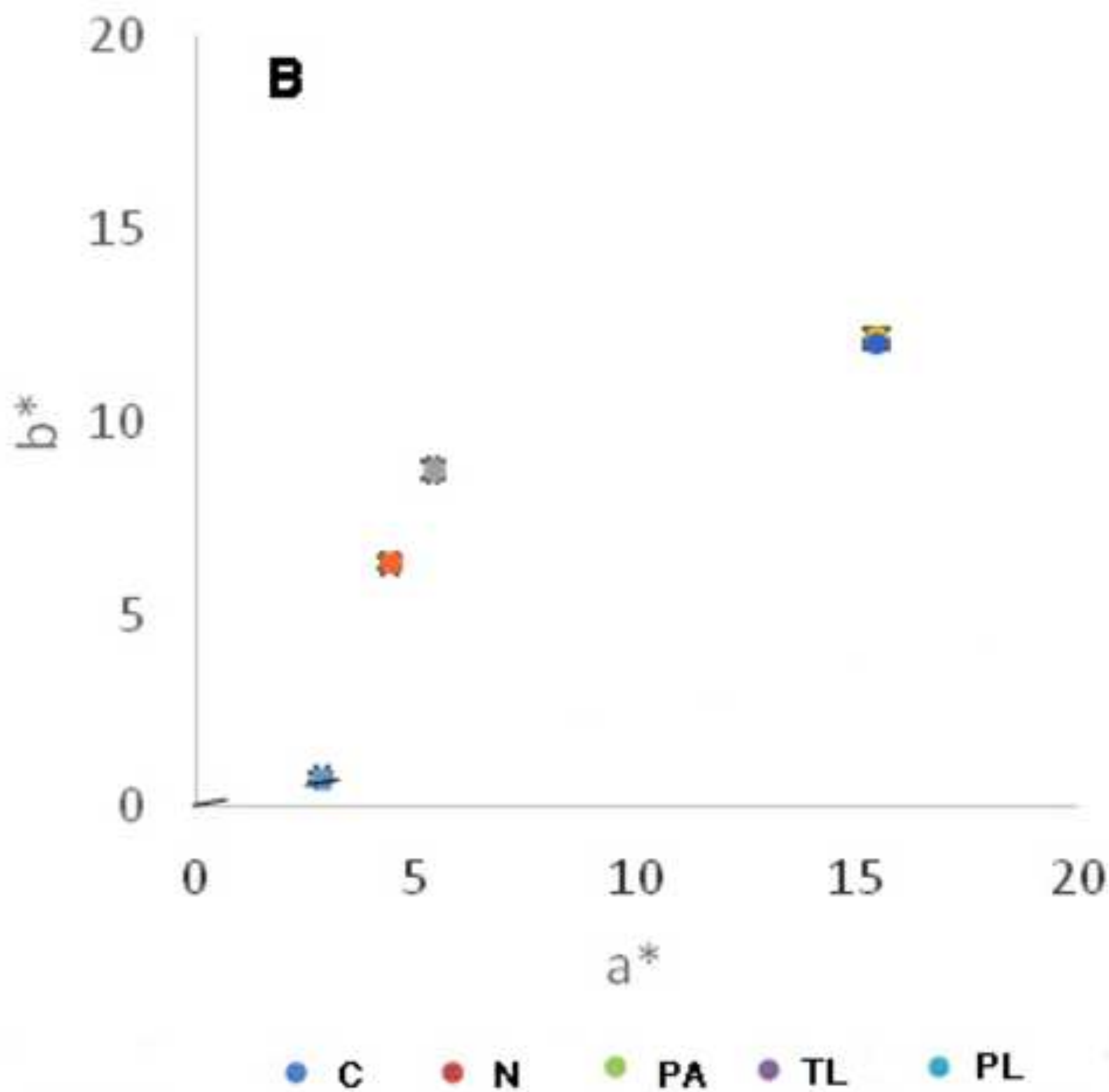

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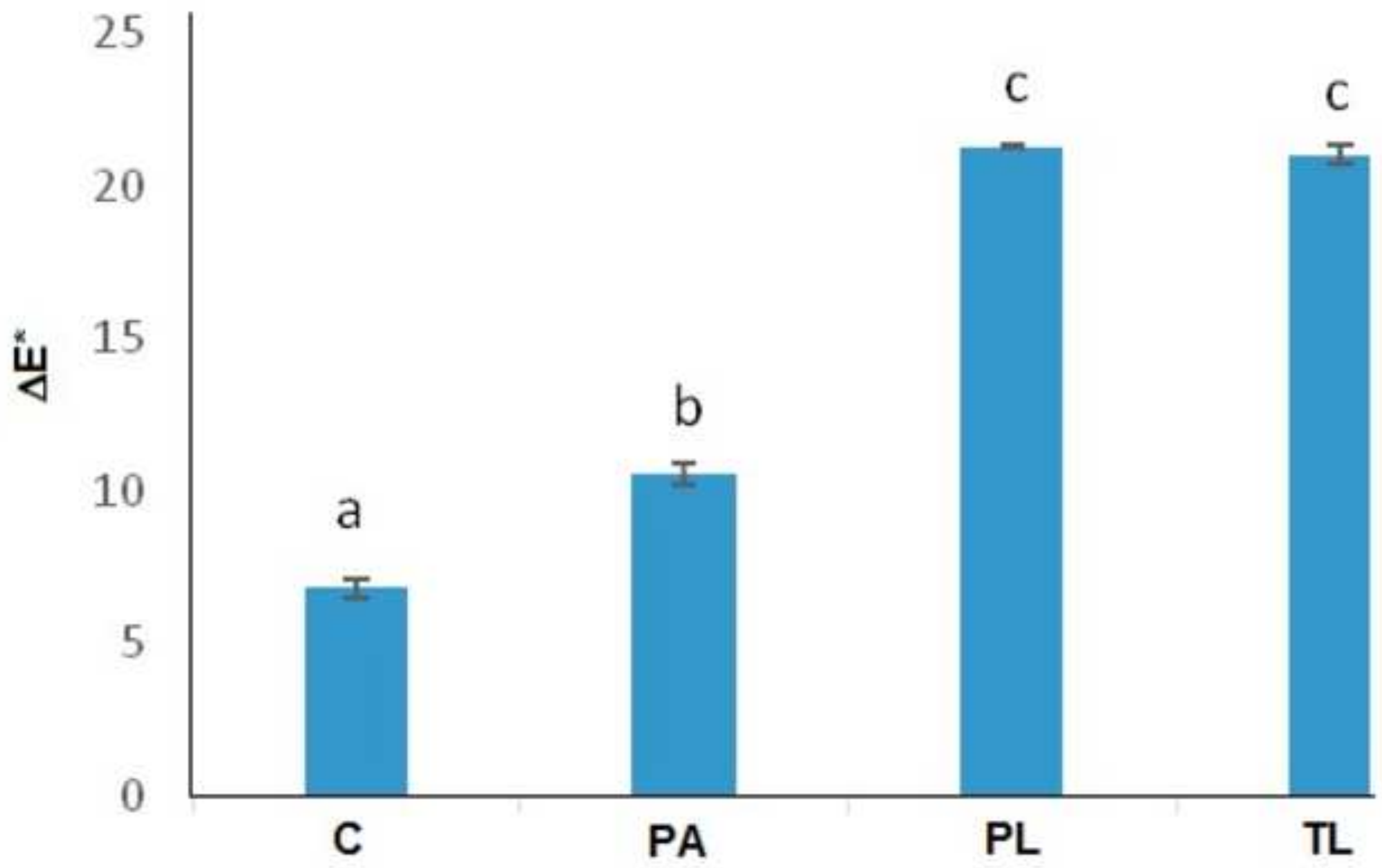

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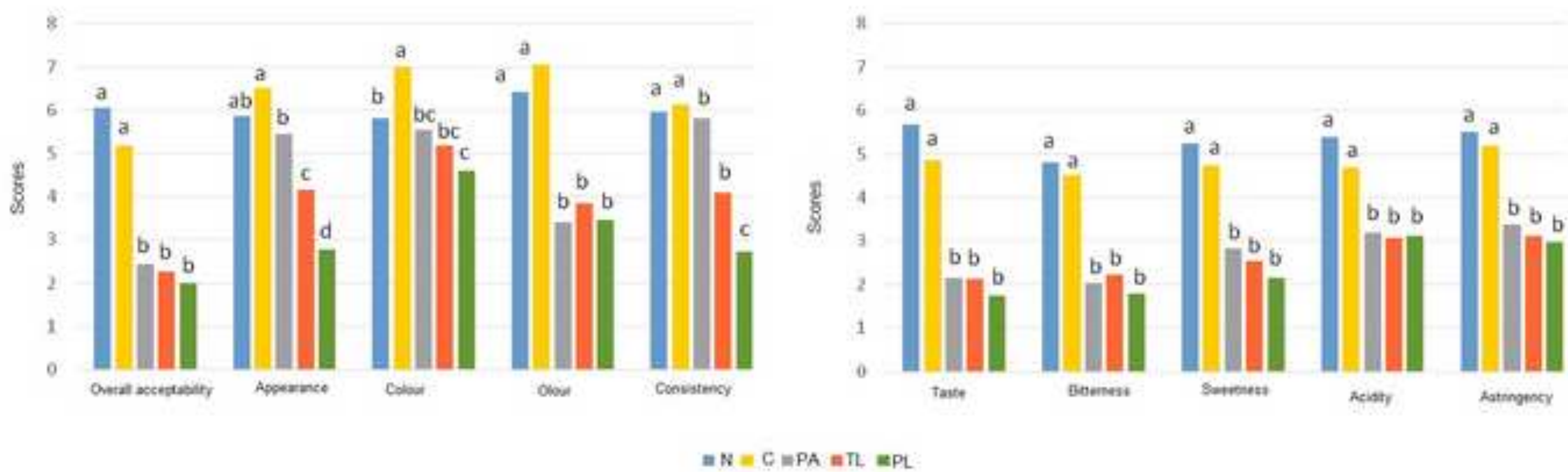

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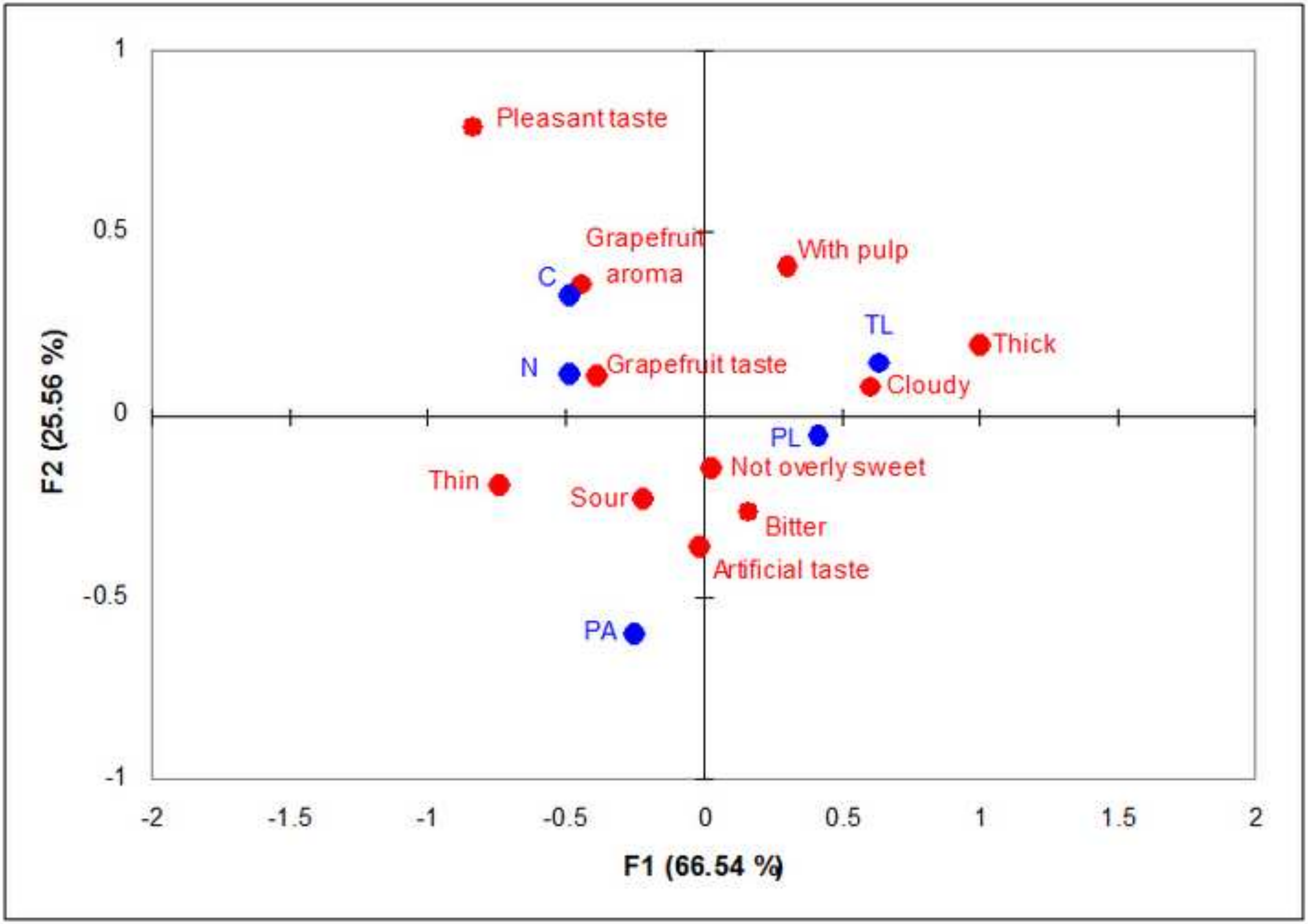

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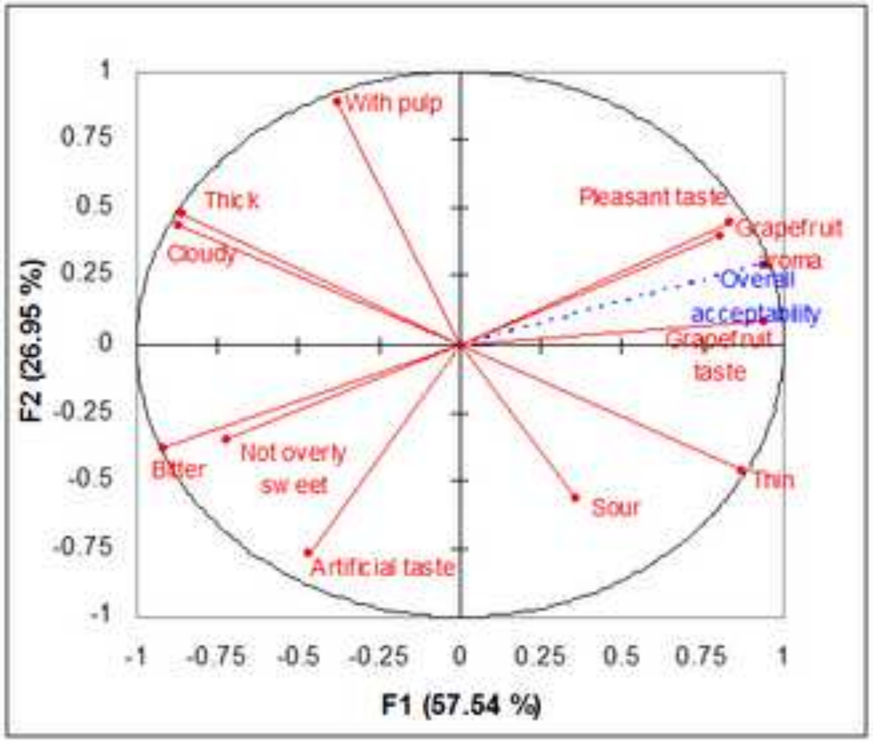

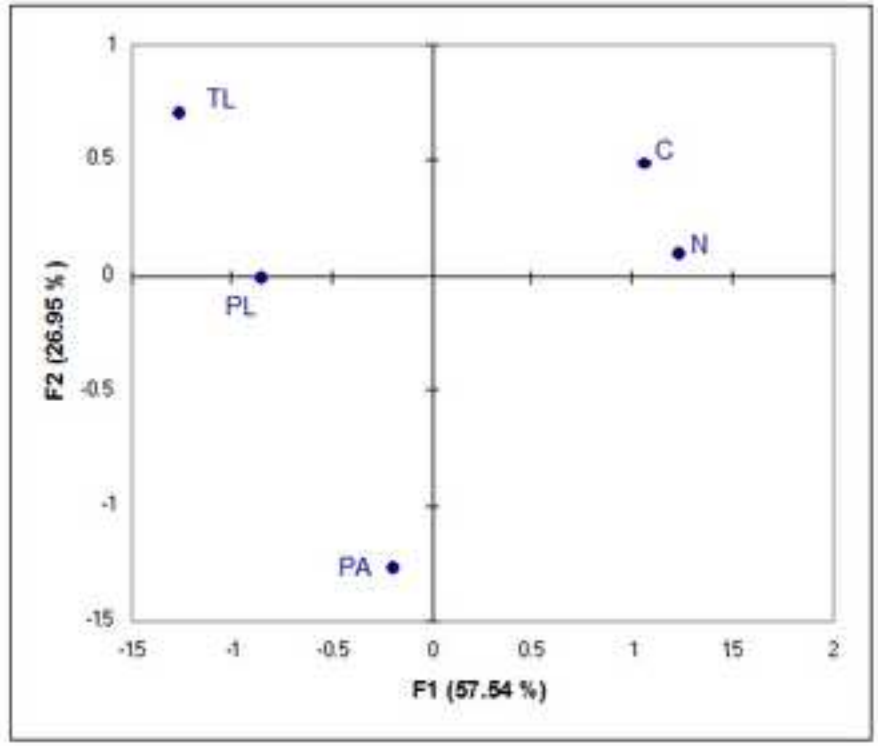

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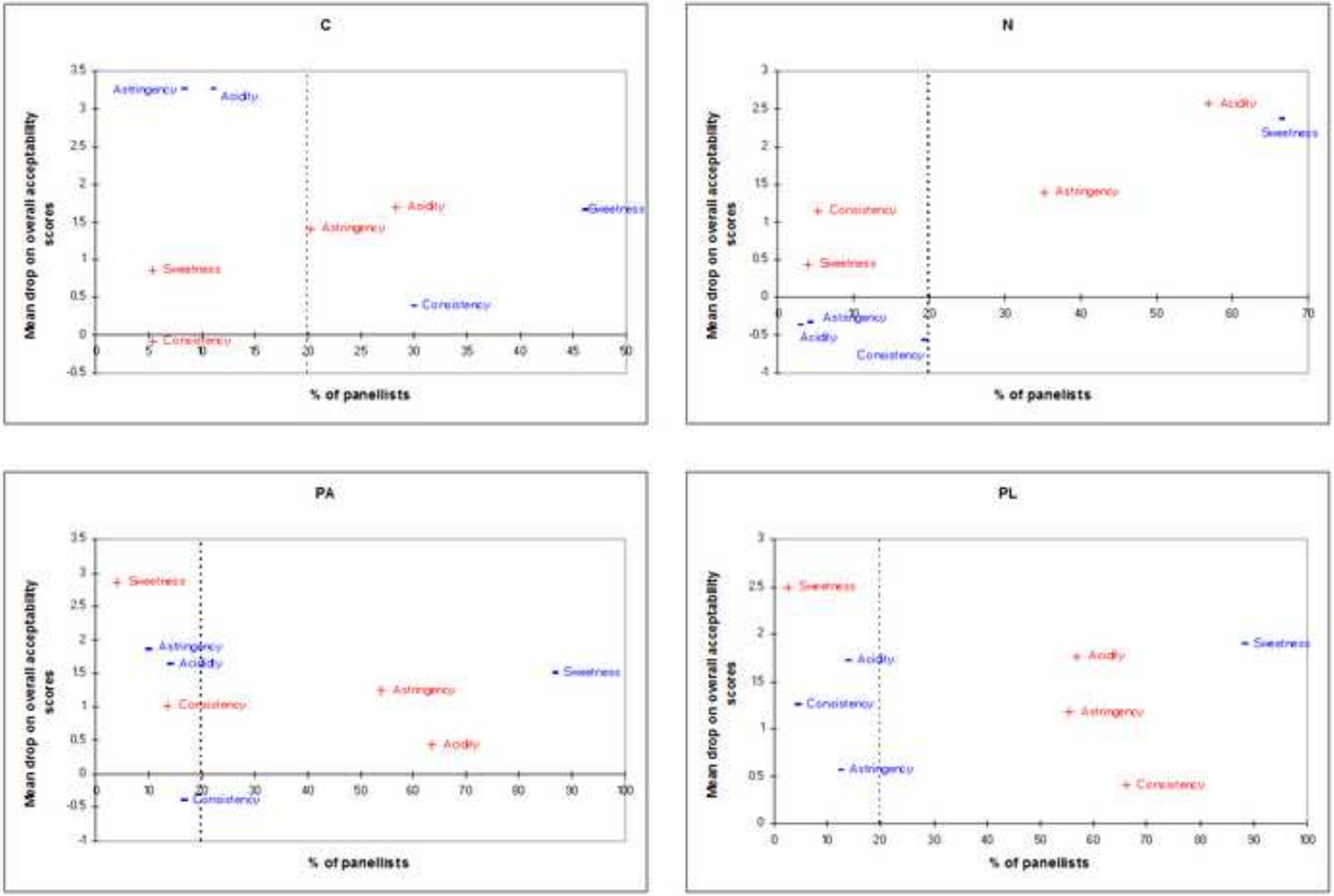

*Graphical Abstract
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