Influence of storage on the volatile profile, mechanical, optical properties and antioxidant activity of strawberry spreads made with isomaltulose

Influence of storage on quality parameters of isomaltulose strawberry spreads

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Abstract

This work represents the final step of a series of studies on the formulation of strawberry products with partial replacement of sucrose by healthier sugars such as fructose and isomaltulose. Previously, quality parameters of the formulated products such as colour, texture, rheology, aromatic profile and sensory evaluation were assessed. As a final step, in the present work, the volatile profile evolution of a strawberry spread-product during 90 days of storage at room temperature (20°C), and its relation with some physicochemical properties (a_w, pH, texture and colour) and antioxidant activity as well as anthocyanin content were studied.

Most of the volatile compounds modified their concentration during storage; some of them totally disappeared but 13 new compounds were formed: (methyl-2-methyl butyrate, E-2-butenal, 2-butenal-2-methyl, 2-buten-1-ol, 2-penten-1-ol, 2-etil-1-hexanol, 6-methyl-5-hepten-2-one, acetic acid, propanoic-2-methyl acid, butyric acid and butyric-2-methyl acid). Storage led to a dark pink colour and an increase in consistency and adhesiveness while the antioxidant activity considerably increased (from 18 ± 2 to 94 ± 2% DPPH inhibition).

Levels of citric acid and pectin influenced colour, texture and antioxidant activity as well as retention and formation of aromatic compounds, especially in fructose-isomaltulose products. Correlations via a PLS were found between the aromatic profile of the products after storage and some of their quality parameters such as texture, colour and antioxidant content. Future research might involve correlation and identification of specific volatiles with different quality parameters.

Keywords: strawberry, fruit processing, isomaltulose, volatile profile, storage.

Chemical compounds studied in this article

Isomaltulose (PubChem CID: 439559); Sucrose (PubChem CID: 5988); Fructose (PubChem CID: 5984); Citric acid (PubChem CID: 311); Potassium sorbate (PubChem CID: 23676745); 1,1-Diphenyl-2-picrylhydrazyl radical (DPPH) (PubChem CID: 2735032); isopropyl acetate (PubChem CID: 7915); Propan-2-ol (PubChem CID 3776); 2-buten-1-ol (Pubchem CID 20024).

1. Introduction

Strawberry spread-product refers to a spread sweet food with improved functionality due to the replacement of sucrose by healthier sugars, such as isomaltulose, and to the incorporation of a higher content of fruit compared to jams for instance. The usual cooking step of jam processing to reach a final soluble solid concentration is avoided in fruit spread-product manufacturing. In our previous study, the influence of processing parameters such as, fruit, sugars (isomaltulose-sucrose or isomaltulose-fructose), pectin and citric acid, on the volatile profile of strawberry spread-product formulated with isomaltulose and sucrose or fructose, was analysed (Peinado et al., 2013). A major effect of the formulation parameters (mostly pectin and citric acid levels), and their interactions, on the volatile fraction changes and aroma retention in the food gel was found. Two different phenomena could occur as a consequence of processing: (a) the modification (reduction or increase) of the compounds responsible of the aroma of fresh strawberry, and (b) the generation of new aromatic compounds. Some steps involved in processing of spreadable products, e.g. cutting or blending, sugar addition, etc., can lead to an increase in the activity of enzymes responsible for the development of new aromas. This fact has been also reported for many fruits under different condition such as osmotic stress, UV light, pH variations or under contact with metal ions (Escriche et al., 2000; Olías et al., 1993; Zabetakis & Holden, 1997).

In our previous study, 13 new compounds (6 aldehydes, 1 alcohol, 4 furans, 1 terpene and 1 nitrile) were found in strawberry spread-product after twenty-four hours of processing, compared to raw material. It has been previously reported that the generation of new aldehydes might be related to the bio-oxidation of lipids as a consequence of wall disruption (Yilmaz, 2001). Eucalyptol, the only generated alcohol, appears during the heat treatment of fruit juices as a consequence of the hydrolysis of their corresponding glycoside precursors (Barron & Etiévant, 1990). The activation of Maillard reactions, or the catabolism of carotenoids and non-saturated fatty acids lead to furans generation (van Boekel, 2006). In the studied spreads, the type of sugar influenced the concentration of furfural (known as the most representative furan related to cooked flavours) (van Boekel, 2006; Varlet, Prost, & Serot, 2007). From the 29 original volatile compounds detected in fresh strawberry, 5 of them completely disappeared and 24 compounds (mostly esters and alcohols) varied their concentration after processing. The retention of typical fresh strawberry volatile compounds was very influenced by the blend of sugars, as well as percentage of pectin and citric acid; the higher the percentage of both, pectin and citric acid, the higher the retention of volatile profile of fresh strawberries, especially in those spreads formulated with isomaltulose-sucrose. The strengthen of gelling structure increases with increasing amounts of pectin, and citric acid, therefore, the gel has a closer structure where the exposure to external factors and the possible enzymatic reactions, which induce changes in aroma profile, are minimised. The role of the food matrix in controlling flavour retention, and even their release, has been previously pointed out (Boland et al., 2006; Druaux & Voilley, 1997).

It is well known that volatile profile can continue evolving with storage time. Nevertheless, a few number of studies have investigated the effect of storage conditions on aroma changes of fruity products such as juices, jams, purées, etc. (Kopjar et al., 2008; Torres, Chiralt, & Escriche, 2012). The majority of works have studied the effect of postharvest conditions such as temperature, relative humidity, controlled-atmosphere, etc. (Ayala-Zavala et al., 2004; Berna et al., 2007; Mo & Sung, 2007; Nielsen & Leufven, 2008; Pelayo et al., 2003; Vandendriessche et al., 2013), or the influence of osmotic treatment (Blanda et al., 2009; Rizzolo et al., 2007) on the modification of strawberry aroma. Because foods are generally consumed after a certain time of storage, the evaluation of the changes taking place during this period would be also suitable. Since it is also expected that physicochemical properties such as mechanical and optical ones change, there is a need to better understand the link between flavour profile and texture or colour parameters evolution along storage, so colour and texture determinations might help to control aroma changes. In this sense, this study analysed the changes in the volatile profile occurring after 90 days of storage of 52 different strawberry spread-products formulated with healthier sugars to replace sucrose partially or totally. Additionally, the correlation between the aromatic compounds, some physicochemical properties (pH, water activity, texture and colour) and antioxidant activity as well as anthocyanin content were studied by means of a partial least squares regression (PLS regression).

2. Material and Methods

2.1. Raw material

For this study, fifteen different batches of raw strawberry (*Fragaria vesca,* Camarosa) were acquired from a local supermarket from February to June 2010. A selection based on colour, shape and ripeness were performed for each batch in order to reduce the variability of the raw material. Each different batch was enough to produce 3 or 4 different spreadable products, depending on the batch. Then they were cut and washed in chlorinated water to eliminate possible field residues.

2.2. Experimental methodology

Strawberry spread-products of 50 ºBrix were formulated according to a statistical central composite design 2^4 + start (Peinado et al., 2013, 2015). For the experimental design, four independent variables were taken into account: percentages of isomaltulose, pectin and citric acid, as well as time of heat treatment (table I). Concretely, two groups of spread-product were obtained following two replicates of the above statistical design:

one group containing 26 spread-products formulated with isomaltulose-sucrose, and another one of 26 spread-products formulated with isomaltulose-fructose. The ingredients in the spreadable strawberry products were: strawberries, sugars (sucrose or fructose, and isomaltulose), pectin (as gelling agent), citric acid, and potassium sorbate (as microbiological preserver); the formulation of the products has already been explained in detail and was the implementation of dry osmotic dehydration studied previously (Rosa et al., 2008, Peinado et al., 2013 & 2015). Basically, ingredients were directly mixed in the correct proportions to reach the established concentration of 50 °Brix, avoiding therefore the typical equilibrium stage which takes place during osmotic dehydration. The quantities of raw strawberry and sugar were calculated according to the correspondent mass balance and they were dependent on the soluble solids content in the raw strawberries. Once the ingredients were mixed, the product was heated until it reached 85°C. This temperature was necessary so the gel structure would not break up during storage as well as to make ‘‘hot canning’’ effective. Then, the product was placed in glass jars and some of the samples, depending on the statistical design, were heated for 5, 10, 15 or 20 min in a bath of boiling water. Finally, they were stored at 20ºC and darkness for 24 hours and 90 days and after that, the correspondent analyses were performed.

2.3. Analytical determinations

All analytical determinations were performed in triplicate after 24h and 90 days of storage.

2.3.1. Volatile profile characterization

Following the same methodology as Peinado et al. (2013), volatile compounds were extracted by purge and trap thermal desorption using 2-pentanol as an internal standard. GC–MS analyses were performed using a Finnigan TRACETM MS (TermoQuest, Austin, USA) equipped with a BP-20 capillary column (SGE, Australia) (60 m x 0.32 mm i.d. x 1.0 mm film thickness). Helium at 1 ml·min^{-1} was used as a carrier gas. The ramp temperature was from 40ºC (2 min hold time) to 190ºC at 4ºC ·min^{-1} and finally to 230ºC at 10ºC min^{-1}.

Relative retention indices were determined by injection of a standard solution of normal alkanes (C_8–C_{20}; by Fluka Buchs, Schwiez, Switzerland). The volatile compounds were tentatively identified and semi-quantitative analyses were carried out (Peinado et al., 2013; Soria et al., 2008). The data (µg/100 g) were expressed using the amount of internal standard and the relative area of each compound with respect to that of the internal standard, assuming a response factor equal to one.

2.3.2.Physicochemical determinations

All the physicochemical parameters were analysed following the methods explained with more detail by Peinado et al. (2015). Basically, moisture content was determined gravimetrically by drying to constant weight in a vacuum oven at 60ºC (AOAC method 20.103, 2000). Soluble solids content (Brix) was measured, in previously homogenized samples, with a refractometer at 20ºC (ATAGO 3 T). Water activity (a_w) was determined with a dew point hygrometer (FA-st lab, GBX). pH was determined with a pH-meter (SevenEasy, Mettler Toledo). Texture properties of the spread-products were performed by a back-extrusion test using a texturometer TA/XT/PLUS Texture Analyser (García-Martínez et al., 2002; Sesmero et al., 2007). This assay provides a typical curve with two characteristic areas. The positive area of the curve is taken as an indication of consistency (N·s), while the negative area gives an indication of the adhesiveness (N·s) but also of the consistency/viscosity of the sample. The optical properties were conducted in a Minolta spectrophotometer (model CM-3600d), using a black background, at room temperature and visible absorption spectra were recorded between 380 and 770 nm by reflectance to obtain tristimulus values of CIEL*a*b*, considering standard light source D_{65} and standard observer 10° as references.

2.3.3. Antioxidant activity

Antioxidant activity was estimated by means of the DPPH method (Castelló et al., 2011). As the aim of the present work was to correlate the evolution of the aromatic profile with some quality parameters, antioxidant activity results were taking into account, however, the detailed methodology as well as individual results for all treatments can be found at (Peinado et al., 2015).

2.3.4. Total anthocyanin content

Finally, total anthocyanin content was measured at 520 nm using the spectrophotometric method described by Alarcão-E-Silva et al. (2001) and results were expressed as mg of pelargonidin-(Pgd)-3-glucoside in 100 g of spreadable product, on the basis of the molar extinction coefficient (E_{molar}=36,000 M^{-1} cm^{-1}) (Vicente, et al., 2002) and taking the molecular weight (433 g/mol) reported by Skrede et al. (1992) for pelargonidin-(Pgd)- 3-glucoside. In the same way that for antioxidant activity, the total anthocyanin content was correlated with the aromatic profile, but, the detailed methodology as well as individual results for all treatments can be found at (Peinado et al., 2015).

2.4. Statistical analysis

As previously mentioned, the number of samples was set by means of a central composite design taking into account four independent variables: *X1* (% of isomaltulose), *X2* (% of pectin), *X3* (% of citric acid) and *X4* (time of thermal treatment), at five levels (table I).

Principal Component Analysis, (PCA) and Partial Least Squares regression (PLS regression) (Unscrambler version 10.X; CAMO Process AS, Oslo, Norway) were applied to describe the relation between the volatile compounds with the physicochemical and antioxidant parameters as well as with the process variables (wt.% of isomaltulose, wt.% of pectin, wt.% of citric acid and time of heat treatment.

PCA was used an orthogonal transformation to convert the obtained data of possibly correlated variables (volatile compounds and different spread products) into a set of values of linearly uncorrelated variables (called principal components). This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. PLS was used used to find the correlations between two matrices of data (X: volatiles and Y: physicochemical paramenters as well as antioxidant values) (Martens & Næs, 1989).

3. Results and discussion

3.1. Volatile profile of spreadable strawberry products after storage.

Table II shows the relative retention index (RI), the odour threshold values as well as the odour descriptors for the volatile compounds identified in the raw strawberries as well as the volatile compound generated 24 hours after processing. The volatile profile of the samples changed as a consequence of storage time. In general terms, the concentration of the majority of the volatile compounds was modified compared to their concentration in the products after processing. Table III illustrates the relative retention index (RI) calculated for each volatile compound identified as well as the maximum and minimum net variations for the volatile compounds respect to the products after 24 hours of processing. Results are expressed as the ratio (C_{90}–C_0)/C_0), C_{90} being the concentration of the volatile compound in the spreadable products stored during 90 days, and C_0 the initial concentration of this compound in its correspondent spreadable product 24 hours after processing (µg of volatile compound /100 g of spreadable product). The general trend for most of the volatile compounds was a decreased in their concentration (table III illustrates just the lowest and highest value of the 26 products formulated with fructose-isomaltulose and 26 products formulated with sucrose-isomaltulose, therefore some increase can be observed as the maximum value), whereas some compounds present after processing such as octanal, nonanal, decanal, mesifurane, butyl butyrate, hexyl butyrate and octyl acetate, were not detected after 90 days of storage. Nevertheless, 11 new compounds were identified for the fructose-isomaltulose products and 13 for the sucrose-isomaltulose ones, within the volatile fraction of the strawberry spreadable products after storage. These compounds may be classified in: three esters (for the sucrose-isomaltulose samples) and one ester (fructose-isomaltulose samples), two aldehydes, three alcohols, one ketone and four acids, as it can be seen in table III which also illustrates the concentration of these new compounds expressed as µg of volatile compound /100 g of spread (net variation cannot be calculated as the initial concentration in the processed products after 24 hours would be equal to 0). It is important to point out that some compounds as isopropyl acetate and some of the alcohols (propan-2-ol, 3-methyl-butanol, 1-pentanol and 1-hexanol) were already detected in some of the samples after processing, however, they were not found in all 52 samples, meaning that there was also a generation of them after storage in some of the samples.

Esters decreased their concentration during storage, but three new esters were found, isopropyl acetate, ethenyl acetate and methyl-2-methyl butyrate. Some authors have also found a decrease in esters after storage of fruit jams at temperatures above refrigeration. Esters, might in fact, potentially serve as precursor compounds for synthesis of secondary volatile aroma compounds such as terpens, alcohols or aldehydes (Ayala-Zavala et al., 2004; Lamikanra & Richard, 2002; Touati et al., 2014). However, Aguiló-Aguayo et al. (2009), observed an increase in butyl acetate concentration in strawberry juices after 35 days of storage at 4ºC and in the same way, Ayala-Zavala et al. (2004), reported higher concentration of most of the esters of strawberry stored at 0, 5 and 10ºC. These authors established a relation between storage temperature and volatile profile development; the higher the storage temperature, the higher the increase in the concentration of the esters. It has to be mentioned, that in the present study, products were stored at 20ºC, which is above the refrigeration temperatures (0-10ºC) that seem to have a positive effect on the stability and even increase of typical strawberry esters. The results obtained in our study suggest that higher temperatures might contribute to a decrease or loss of esters in strawberry spreads, but also on the availability of other compounds such as acids and alcohols required for their formation as well as the presence of some enzymes responsible of their catalysis (Azodanlou et al., 2003; Bood & Zabetakis, 2002; Lamikanra & Richard, 2002; Touati et al., 2014).

Most of the alcohols increased their concentration after storage with the exception of propan-2-ol that decreased, and linalool that disappeared. Alcohols have been identified as constituents of the characteristic strawberry aroma (Pino et al., 2001), and some authors detected an increase in this compounds after the storage of strawberries at refrigeration temperatures; this increase might produce an undesirable aroma in the product due to their strong taste and odour (Aguiló-Aguayo et al., 2009; Ayala-Zavala et al., 2004). Furthermore, in the same way as in the present study, Von Sydow & Karlsson (1971), observed a decrease in linalool concentration during storage of samples after thermal treatment, which could be related to the conversion of linalool in other terpens, by different mechanisms as hydration, restructuration or cyclation of the double bounds.

Besides that the concentration of most of the aldehydes decreased and 1-penten-3-one disappeared, two new aldehydes and one ketone appeared after storage. These compounds are easily reduced or oxidized, leading to the formation of some other derivate compounds. Specifically, hexanal can be produced by an oxidation catalysed by LOX-lyase; therefore, the inactivation of this enzyme, that might occurred due to the heat treatment, would lead to a decrease of this compound during storage (Hamilton-Kemp et al., 1996).

For the furans presents in the strawberry products, mesifurane was not detected after 90 days of storage, while in general furfural, 2-acetilfurane and 5-methyl furfural experimented an increase in their concentrations. This fact is coincident with that observed by other authors with the similar type of compounds. For instance Touati et al. (2014) reported a significant increase of HMF content for fruit nectars after 8 months storage, at 25, 35 and 45 ºC and Orruño et al. (2001), observed an increase of DMHF (2,5-di-(hydroxyl-methyl)-furan) in strawberry juices thermally treated. The increase of those compounds might be related to the increase of some enzymatic activity responsible for the formation of compounds as β-glycosidase or also to sugar degradation in acidic medium (Orruño et al., 2001; Touati et al., 2014).

A PCA was conducted to evaluate the global effect of the storage on the volatile fraction of the spreadable products, from a descriptive point of view. Figure 1 illustrates the loadings for the different aromatic compounds as well as the sample scores of the different strawberry samples after 24 hours of processing ($S_0$1–$S_0$26, and $F_0$1–$F_0$26), and the samples after 90 days of storage (S_{90}-1–S_{90}-26, and F_{90}-1–F_{90}-26). The first two principal components of the analyses explain 50% of the total variance of the concentrations of the different volatile compounds among the different samples (PC1: 41 % & PC2: 9%). In the score plot, proximity between samples indicates similar behaviour in terms of the volatile profile. PC1 (41%) clearly differentiates between products after processing, located at the right side of the plot, and products after storage, located at the left side. PC2 (9%), differentiates between those treatments that had higher percentages of pectin and citric acid (treatments F-19, S-19, F20, S-20, F22, S-22), being the differences clearly more noticeable after storage when the gel has become stronger.

3.2. Influence of formulation on the physicochemical parameters of spreadable strawberry products.

A PLS was conducted to analyse the relation between the aromatic profile of the spreadable products and their physicochemical and antioxidant values. Figure 2 illustrates the sample loadings for the different aromatic compounds as well as physicochemical and antioxidant parameters analysed within the strawberry spreadable products after storage. In the plot, proximity between aromas demonstrates some similarity in their concentration levels, while the parameters allocated inside the ring are those that can be correlated with the volatile compounds. Figure 2 summarizes the significant correlation coefficients and the r^2 obtained for the analysed parameters. Antioxidant activity and anthocyanin content as well as texture values where highly correlated with the aromatic profile, while concerning colour, only chrome (*C) seemed to be correlated.

<u>3.2.1. Stability of stored products in terms of a_w and pH</u>

Table IV gathers the punctual data for the pH values and water activity (a_w) for every single spreadable product 24 hours after processing as well as after 90 days of storage.

Their pH values ranged between 3.410, for the spreads formulated with the lowest percentage of citric acid, and 2.703 for those with the highest percentage of citric acid, after 90 days of storage, (regardless the sugar used in their formulations sucrose-isomaltulose or fructose-isomaltulose). These values were in most of the samples slightly lower when compared to their correspondent values for the products after 24 hours of processing; however, the differences were not statistically significant (P_{value}> 0.005). It is important to mention that, contrary to what might have been expected, no correlation was found between pH or a_w and the volatile profile of the spreadable products after storage; nevertheless, the differences in pH and a_w between the different products should be taken into account because they could have a direct influence on the stability and acceptation of the product even when they are not reflected on the volatile profile.

3.2.2. Optical and mechanical properties

As reported in a previous study (Peinado et al., 2015), processing induced, in general, a reduction of L*, a* and b* parameters in all the spreadable products 24 hours after processing compared to raw strawberries (lower Chroma ($C^* = (a^{*2}+b^{*2})^{1/2}$), and hue ($h^* = \text{arctg}\ (b^*/a^*)$) were observed as well). As an example, Figure 3 illustrates the colorimetric maps (L*- a* and b*- a*) for the spreadable products formulated with the higher and lower levels of the formulation variables (Tables I and IV) after 24 hours of processing as well as after 90 days of storage. The higher the percentages of citric acid and pectin, the lower the values of these coordinates. However, the influence of pectin and citric acid disappeared after storage only for the spreadable formulated with the blend fructose-isomaltulose, leading to products with darker colour, and a major homogeneity regardless the process variables, so the type of sugar influenced the reactions involved in colour changes such as anthocyanin degradation.

Chrome showed a negative correlation with the volatile compounds characteristics of the spreads after processing (and so it did the anthocyanin content). Storage led to a change from bright red colour to dark pink. These colour changes may be mainly attributed to anthocyanin degradation, which are known to be very sensitive to different factors such as light, oxygen, temperature, pH, sugar content, ascorbic acid or metals (Golaszewski, et al., 1998; Garcia-Viguera et al., 1999; Renard et al., 2006). However, there are other compounds that also suffer browning reactions, for instance, sugar and ascorbic acid degradation during storage have been related to colour loss in strawberry products as well as formation of aromatic compounds such as acetic acid and some furans.

Regarding mechanical properties, an increase in consistency and adhesiveness after 90 days of storage was observed for all the spreadable products. Figure 4 illustrates the consistency values obtained for the spreadable products formulated with the higher and lower level of the formulation variables (Tables I and IV) after 24 hours of processing as ell as after 90 days of storage. This increase was higher as citric acid and pectin levels augmented, while sugar became also significant at high levels of pectin. The PLS plot, illustrates a positive correlation for the texture parameters with the volatile compounds characteristics of storage such as acids and aldehydes (butanoic acid, propanoic acid, benzaldehyde…), which are developed due to changes in the food matrix as the gel becomes more rigid along the storage time. Nevertheless, the intensity of aroma release in the samples stored will also depend on the amounts of pectin and citric acid, determining the final consistency and rigidity of the gel, (Boland et al., 2006; Golaszewski et al., 1998; Piccone et al., 2011).

3.2.3. Antioxidant activity and total anthocyanin content.

As it can be found in Peinado et al., (2015), the antioxidant activity (% DPPH inhibition) of the different spreadable products showed a considerable increase after 90 days of storage for most products compared to their antioxidant values immediately after processing, from 18 to 94 % DPPH (100 μM trolox = 50 % DPPH, reference value). Once again, citric acid and pectin levels were the variables that most influenced the antioxidant activity. A high antioxidant capacity was associated with a high level of pectin and citric acid in the samples after 24 hours of processing, while the antioxidant activity became similar among all samples after storage, regardless the sugar used or the amounts of pectin or citric acid.

On the contrary, there was a decrease in the anthocyanin content during storage, from 10.9 to 3.9, and from 10.0 to 1.7 mg pelargonidin-3-glucoside /100 g for sucrose-isomaltulose and fructose-isomaltulose respectively, (individual values after 24 houres and 90 days can be found at Peinado et al., 2015). Despite of this decrease, other compounds with high antioxidant activity such for instance those derived form degradation of phenolic, gallic or ellagic acid might result in an increase of antioxidant activity during storage (Aaby et al., 2007; Lamikanra & Richard, 2002). Along the storage time, the tri-dimensional network of the gel acquires more strength, becoming a key-factor for the retention and protection of the antioxidant components against oxidative agents (light, oxygen, etc.). In fact, the PLS correlated antioxidant activity with some of the new compounds identified after storage such as propanoic and butanoic acids.

4. Conclusions.

Storage influenced the colour, texture and antioxidant activity as well as the volatile profile of the spreadable products. The percentages of pectin and citric acid were a key factor on the retention of the aroma, especially in the fructose-isomaltulose products, contrary to that happening after processing (Peinado et al., 2013). Most volatile compounds in the spreads after storage decreased their concentration, whereas some compounds disappeared, and some new compounds were identified after storage.

The PLS established good correlations between the aromatic profile of the products after storage and some of their physicochemical parameters such as texture, colour and antioxidant content. Mechanical properties and antioxidant activity were positively correlated with some of the volatiles compounds after storage while anthocyanin content and chrome where negatively correlated. It can be concluded then, that a healthier spreadable strawberry product could be formulated replacing sucrose by fructose-isomaltulose with high percentages of citric acid and pectin. Further work in terms of which specific volatiles could be correlated with those parameters might be required as a future field of research.

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'Conflict of Interest Statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other people who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

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References

Aaby, K., Wrolstad, R. E., Ekeberg, D., & Skrede, G. (2007). Polyphenol composition and antioxidant activity in strawberry purees; impact of achene level and storage. *Journal of Agricultural and Food Chemistry*, *55*(13), 5156–66. doi:10.1021/jf070467u

Aguiló-Aguayo, I., Oms-Oliu, G., Soliva-Fortuny, R., & Martín-Belloso, O. (2009). Flavour retention and related enzyme activities during storage of strawberry juices processed by high-intensity pulsed electric fields or heat. *Food Chemistry*, *116*(1), 59–65. doi:10.1016/j.foodchem.2009.02.007

Alarcão-E-Silva, M. L. C. M. M., Leitão, A. E. B., Azinheira, H. G., & Leitão, M. C. A. (2001). The Arbutus Berry: Studies on its Color and Chemical Characteristics at Two Mature Stages. *Journal of Food Composition and Analysis*, *14*(1), 27–35. doi:10.1006/jfca.2000.0962

AOAC (2000). Association of official analytical chemists. Official methods of analysis (Washington, DC, USA)

Ayala-Zavala, J. F., Wang, S. Y., Wang, C. Y., & González-Aguilar, G. A. (2004). Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. *LWT - Food Science and Technology*, *37*(7), 687–695. doi:10.1016/j.lwt.2004.03.002

Ayalazavala, J., Wang, S., Wang, C., & Gonzalezaguilar, G. (2004). Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit. *Lebensmittel-Wissenschaft Und-Technologie*, *37*(7), 687–695. doi:10.1016/j.lwt.2004.03.002

Azodanlou, R., Darbellay, C., Luisier, J.-L., Villettaz, J.-C., & Amadò, R. (2003). Development of a model for quality assessment of tomatoes and apricots. *LWT - Food Science and Technology*, *36*(2), 223–233. doi:10.1016/S0023-6438(02)00204-9

Barron, D., & Etiévant, P. X. (1990). The volatile constituents of strawberry jam Zusammenfassung. *Zeitschrift Für Lebensmittel-Untersuchung Und Forschung*, *191*(4), 486–488. doi:10.1007/BF01202426

Berna, A. Z., Geysen, S., Li, S., Verlinden, B. E., Lammertyn, J., & Nicolaï, B. M. (2007). Headspace fingerprint mass spectrometry to characterize strawberry aroma at super-atmospheric oxygen conditions. *Postharvest Biology and Technology*, *46*(3), 230–236. doi:10.1016/j.postharvbio.2007.05.011

Blanda, G., Cerretani, L., Cardinali, A., Barbieri, S., Bendini, A., & Lercker, G. (2009). Osmotic dehydrofreezing of strawberries: Polyphenolic content, volatile profile and consumer acceptance. *LWT - Food Science and Technology*, *42*(1), 30–36. doi:10.1016/j.lwt.2008.07.002

Boland, A., Delahunty, C., & Vanruth, S. (2006). Influence of the texture of gelatin gels and pectin gels on strawberry flavour release and perception. *Food Chemistry*, *96*(3), 452–460. doi:10.1016/j.foodchem.2005.02.027

Bood, K. G., & Zabetakis, I. (2002). The Biosynthesis of Strawberry Flavor (II): Biosynthetic and Molecular Biology Studies. *Concise Reviews in Food Science*, *67*(1), 2–8. doi:10.1111/j.1365-2621.2002.tb11349.x

Castelló, M. L., Heredia, A., Domínguez, E., Ortolá, M. D., & Tarrazó, J. (2011). Influence of thermal treatment and storage on astringency and quality of a spreadable product from persimmon fruit. *Food Chemistry*, *128*(2), 323–329. doi:10.1016/j.foodchem.2011.03.023

Druaux, C., & Voilley, A. (1997). Effect of food composition and microstructure on volatile flavour release. *Trends in Food Science & Technology*, *8*(11), 364–368. doi:10.1016/S0924-2244(97)01095-9

Escriche, I., Chiralt, A., Moreno, J., & Serra, J. A. (2000). Influence of Blanching-osmotic Dehydration Treatments on Volatile Fraction of Strawberries. *Food Chemistry and Toxicology*, *65*(7), 1107–1111. doi:10.1111/j.1365-2621.2000.tb10247.x

Ganeko, N., Shoda, M., Hirohara, I., Bhadra, A., Ishida, T., Matsuda, H., … Matoba, T. (2008a). Analysis of volatile flavor compounds of sardine (Sardinops melanostica) by solid phase microextraction. *Journal of Food Science*, *73*(1), S83–8. doi:10.1111/j.1750-3841.2007.00608.x

Garcia-Viguera, C., Zafrilla, P., Romero, F., Abellan, P., Artes, F., & Tomas-Barberan, F. a. (1999). Color Stability of Strawberry Jam as Affected by Cultivar and Storage Temperature. *Journal of Food Science*, *64*(2), 243–247. doi:10.1111/j.1365-2621.1999.tb15874.x

García-Martínez, E., Ruiz-Diaz, G., Martínez-Monzó, J., Camacho, M. ., Martínez-Navarrete, N., & Chiralt, A. (2002). Jam manufacture with osmodehydrated fruit. *Food Research International*, *35*(2-3), 301–306. doi:10.1016/S0963-9969(01)00200-9

Giri, A., Osako, K., & Ohshima, T. (2010). Identification and characterisation of headspace volatiles of fish miso, a Japanese fish meat based fermented paste, with special emphasis on effect of fish species and meat washing. *Food Chemistry*, *120*(2), 621–631. doi:10.1016/j.foodchem.2009.10.036

Hamilton-Kemp, T. R., Archbold, D. D., Loughrin, J. H., Collins, R. W., & Byers, M. E. (1996). Metabolism of natural volatile compounds by strawberry fruit. *J. Agric. Food Chem.*, *44*, 2802–2805. doi:10.1021/jf9601980

http://pherobase.org (Accessed 10.10.2014)

http://www.leffingwell.com/odorthre.htm (Accessed 10.10.2014)

Kopjar, M., Piližota, V., Hribar, J., Simčič, M., Zlatič, E., & Tiban, N. N. (2008). Influence of trehalose addition and storage conditions on the quality of strawberry cream filling. *Journal of Food Engineering*, *87*(3), 341–350. doi:10.1016/j.jfoodeng.2007.12.011

Lamikanra, O., & Richard, O. A. (2002). Effect of Storage on Some Volatile Aroma Compounds in Fresh-cut Cantaloupe Melon. *J. Agric. Food Chem.*, *50*, 4043–4047. doi:10.1021/jf011470v

Martens, H., & Næs, T. (1989). *Multivariate calibration*. the University of Michigan: John Wiley & Sons Canada, Limited.

Mo, E. K., & Sung, C. K. (2007). Phenylethyl alcohol (PEA) application slows fungal growth and maintains aroma in strawberry. *Postharvest Biology and Technology*, *45*(2), 234–239. doi:10.1016/j.postharvbio.2007.02.005

Nielsen, T., & Leufven, A. (2008). The effect of modified atmosphere packaging on the quality of Honeoye and Korona strawberries. *Food Chemistry*, *107*(3), 1053–1063. doi:10.1016/j.foodchem.2007.09.025

Olías, J. ., Pérez, A. ., Sanz, C., & Ríos, J. J. (1993). Estudio comparativo de los perfiles aromáticos de manzana, plátano y fresa. *Revista Española de Ciencia Y Tecnología de Alimentos*, *33*(6), 665–667. doi:1131-799X

Orruño, E., Apenten, R. O., & Zabetakis, I. (2001). The role of b -glucosidase in the biosynthesis of 2 , 5-dimethyl-4-hydroxy-3 (2 H) -furanone in strawberry (Fragaria × ananassa cv . Elsanta). *Flavour and Fragance Journal*, *16*, 81–84.

Peinado, I., Rosa, E., Heredia, A., & Andrés, A. (2015). Use of isomaltulose to formulate healthy spreadable strawberry products. Application of response surface methodology. *Food Bioscience*, *9*, 47–59. doi:10.1016/j.fbio.2014.08.002

Peinado, I., Rosa, E., Heredia, A., Escriche, I., & Andrés, A. (2013). Influence of processing on the volatile profile of strawberry spreads made with isomaltulose. *Food Chemistry*, *138*(1), 621–9. doi:10.1016/j.foodchem.2012.09.104

Pelayo, C., Ebeler, S. ., & Kader, A. . (2003). Postharvest life and flavor quality of three strawberry cultivars kept at 5°C in air or air+20 kPa CO2. *Postharvest Biology and Technology*, *27*(2), 171–183. doi:10.1016/S0925-5214(02)00059-5

Piccone, P., Rastelli, S. L., & Pittia, P. (2011). Aroma release and sensory perception of fruit candies model systems. *Procedia Food Science*, *1*, 1509–1515. doi:10.1016/j.profoo.2011.09.223

Pino, J. A., Marbot, R., & Vázquez, C. (2001). Characterization of volatiles in strawberry guava (Psidium cattleianum Sabine) fruit. *Journal of Agricultural and Food Chemistry*, *49*, 5883–5887. doi:10.1021/jf010414r

Renard, D., van de Velde, F., & Visschers, R. W. (2006). The gap between food gel structure, texture and perception. *Food Hydrocolloids*, *20*(4), 423–431. doi:10.1016/j.foodhyd.2005.10.014

Rizzolo, a, Gerli, F., Prinzivalli, C., Buratti, S., & Torreggiani, D. (2007). Headspace volatile compounds during osmotic dehydration of strawberries (cv Camarosa): Influence of osmotic solution composition and processing time. *LWT - Food Science and Technology*, *40*(3), 529–535. doi:10.1016/j.lwt.2006.02.002

Rosa, E., Peinado, I., Heredia, A., Andrés, A. (2008). Deshidratación osmótica de frutas por vía seca. Una alternativa al uso de disoluciones. Póster-Artículo, Congreso Iberoamericano sobre Seguridad Alimentaria. V Congreso Español de Ingeniería de Alimentos (CESIA) (5–7/11/2008), Barcelona, Spain. Book of Abstracts, p. 168.

Sesmero, R., Quesada, M. A., & Mercado, J. A. (2007). Antisense inhibition of pectate lyase gene expression in strawberry fruit: Characteristics of fruits processed into jam. *Journal of Food Engineering*, *79*(1), 194–199. doi:10.1016/j.jfoodeng.2006.01.044

Soria, A. C., Martínez-Castro, I., & Sanz, J. (2008). Some aspects of dynamic headspace analysis of volatile components in honey. *Food Research International*, *41*(8), 838–848. doi:10.1016/j.foodres.2008.07.010

Torres, J. D., Chiralt, A., & Escriche, I. (2012). Development of volatile fraction of fresh cut osmotically treated mango during cold storage. *Food Chemistry*, *130*(4), 921–927. doi:10.1016/j.foodchem.2011.08.012

Touati, N., Tarazona-Díaz, M. P., Aguayo, E., & Louaileche, H. (2014). Effect of storage time and temperature on the physicochemical and sensory characteristics of commercial apricot jam. *Food Chemistry*, *145*, 23–27. doi:10.1016/j.foodchem.2013.08.037

Van Boekel, M. a J. S. (2006). Formation of flavour compounds in the Maillard reaction. *Biotechnology Advances*, *24*(2), 230–233. doi:10.1016/j.biotechadv.2005.11.004

Vandendriessche, T., Vermeir, S., Mayayo Martinez, C., Hendrickx, Y., Lammertyn, J., Nicolaï, B. M., & Hertog, M. L. A. T. M. (2013). Effect of ripening and intercultivar differences on strawberry quality. *LWT - Food Science and Technology*, *52*(2), 62–70. doi:10.1016/j.lwt.2011.12.037

Varlet, V., Prost, C., & Serot, T. (2007). Volatile aldehydes in smoked fish: Analysis methods, occurence and mechanisms of formation. *Food Chemistry*, *105*(4), 1536–1556. doi:10.1016/j.foodchem.2007.03.041

Yilmaz, E. (2001). Oxylipin pathway in the biosynthesis of fresh tomato volatiles. *Turk. J. Biol*, *25*, 351–360.

Zabetakis, I., & Holden, M. A. (1997). Strawberr y Flavour: Analysis and Biosynthesis. *J. Sci Food Agric*, *74*(February), 421–434. doi:10.1002/(SICI)1097-0010(199708)74:4<421::AID-JSFA817>3.0.CO;2-6

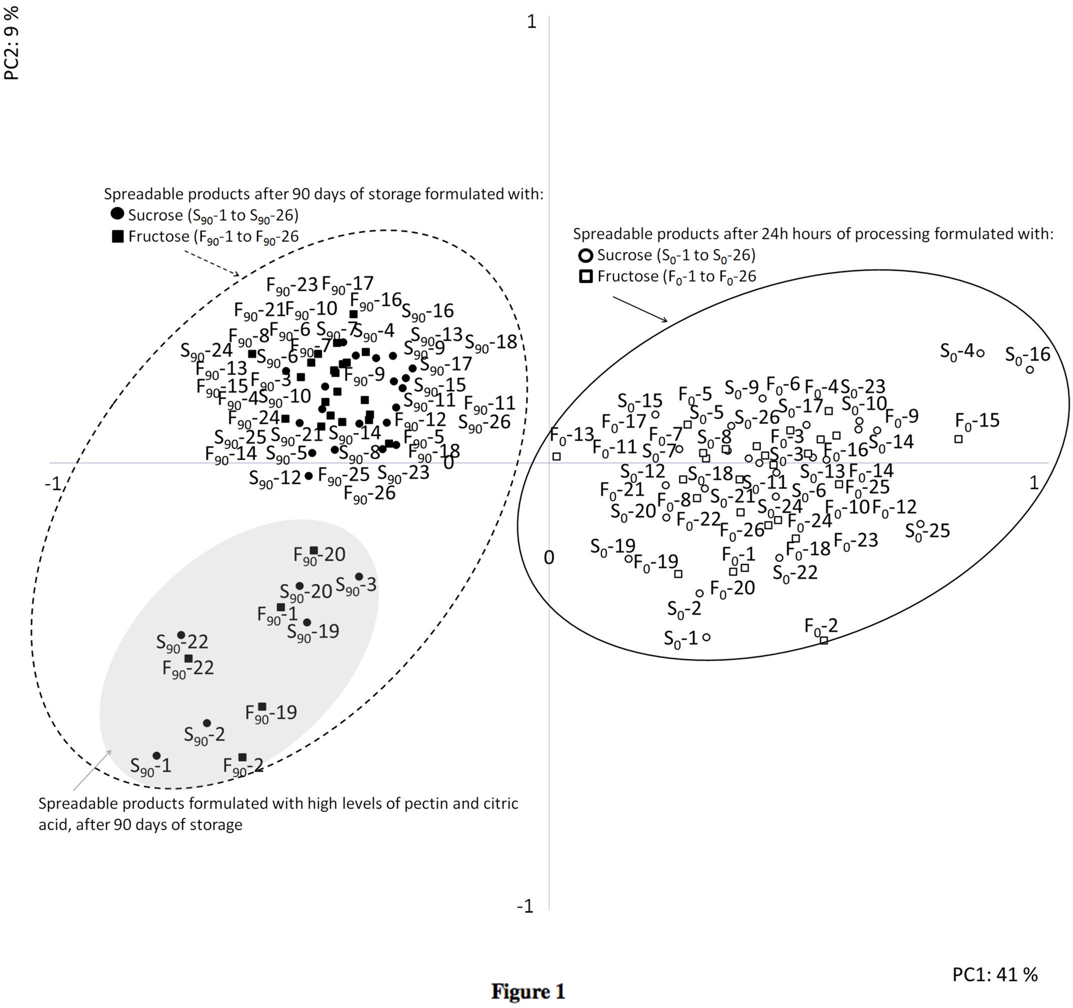

Figure 1

Fig 1. Biplot for the different volatile compounds and their relation with the different strawberry spreadable samples after 24 hours of processing ($S_0$1–$S_0$26, and $F_0$1–$F_0$26), and the samples after 90 days of storage (S_{90}-1–S_{90}-26, and F_{90}-1–F_{90}-26) (PC1: 41% and PC2: 9%) obtained by means of the PCA.

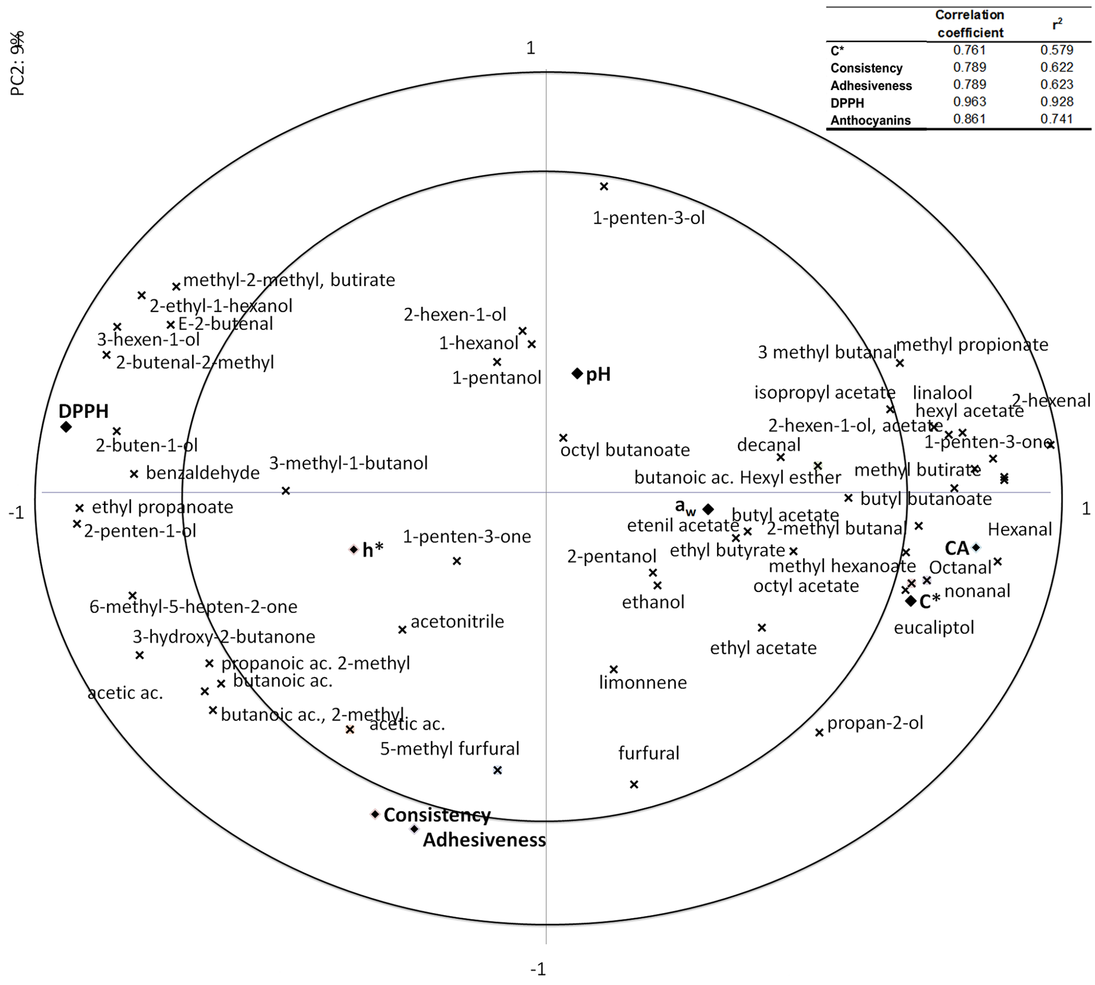

Figure 2

Fig 2. Biplot for the different volatile compounds and their relation with the physicochemical parameters (a_w, pH, colour [h*: hue; C*: chrome] and texture [Consistency & Adhesiveness]), antioxidant activity (DPPH) and anthocyanin concentration (CA). Correlation coefficients and the r^2 obtained by means of PLS. DPPH and total anthocyanin content results of all treatments can be found at Peinado et al., (2015).

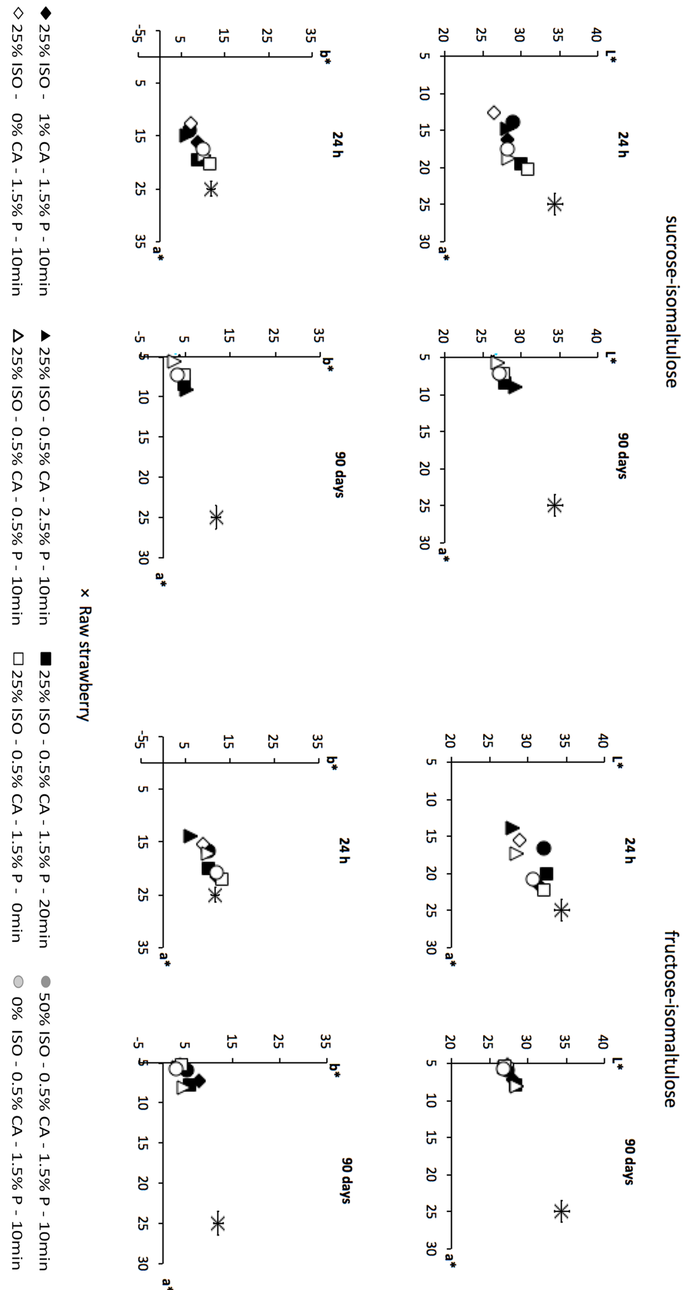

Fig 3. Colorimetric parameters L*, a* and b* of the raw material and strawberry spreadable products. Illustrated values correspond with the higher and lower level of each formulation variable (Table 1: 0-50% isomaltulose; 0-1% citric acid; 0.5-2.5% pectin and 0-20 minutes of thermal treatment) after 24 hours of processing as well as after 90 days of storage.

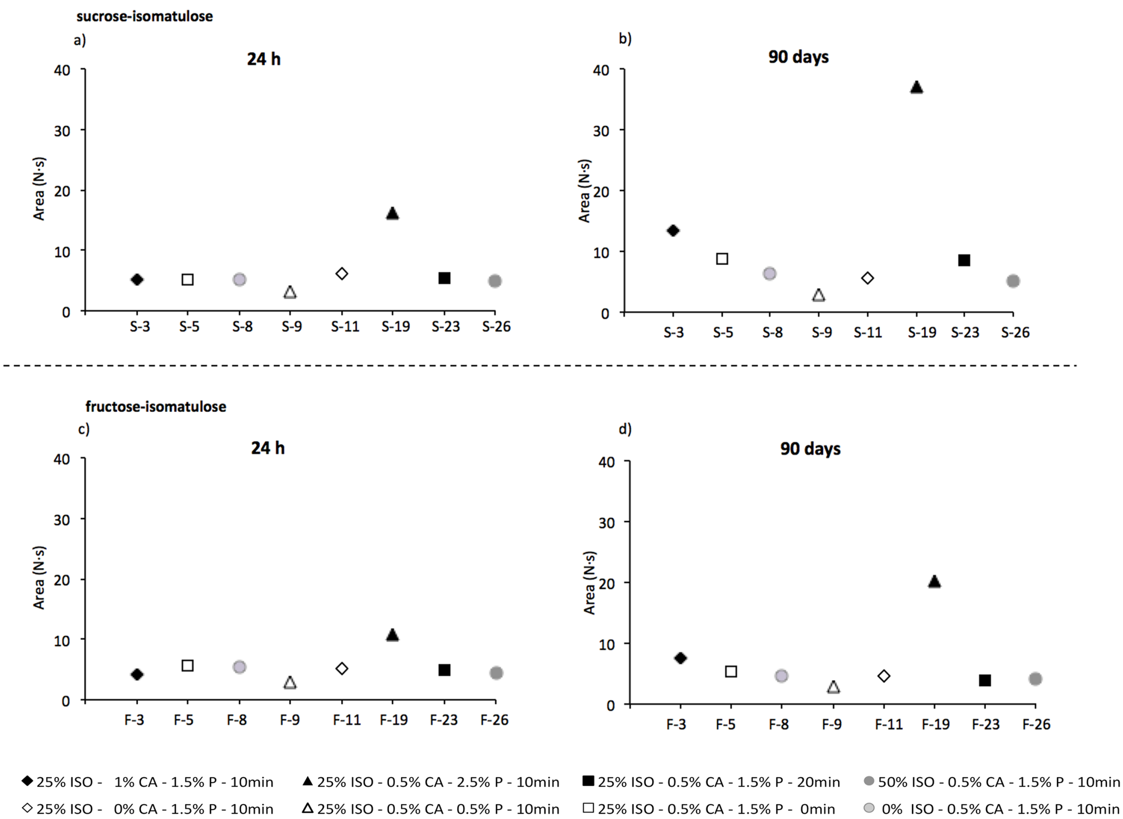

Fig 4. Consistency values (Ns) of strawberry spreadable products. Illustrated values correspond with the higher and lower level of each formulation variable (Table 1: 0-50% isomaltulose; 0-1% citric acid; 0.5-2.5% pectin and 0-20 minutes of thermal treatment) after 24 hours of processing as well as after 90 days of storage.

Table I. Independent variables and their level used for central composite design.

Independent variables	Symbol[c]	Coded variable levels				
		-2	**-1**	**0**	**1**	**2**
Isomaltulose (%)[a]	X_1	0	12.5	25	37.5	50
Pectin (%)[b]	X_2	0.5	1	1.5	2	2.5
Citric acid (%)[b]	X_3	0	0.25	0.5	0.75	1
Heat treatment time (min)	X_4	0	5	10	15	20

a: % of isomaltulose in the total amount of sugar mix (sucrose-isomaltulose or fructose-isomaltulose).

b: in final product.

c: Symbol with which each independent variable is cited in the text.

Table II. Retention index, odour thresholds and odour descriptors of volatile compounds identified in raw strawberries and generated after processing; (n=3).

	RI	Odour threshold	Identification	Odour description
In Raw strawberries				
Esters				
ethyl acetate	904	5-5,000 [D]	MS, RI Std	Caramel, Sweet, Solvent, Fruity, Acid, Buttery, Pungent, Orange[C]
isopropyl acetate	911	-	MS, RI Std	Ethereal, Fruity, Sweet, Banana, Chemical
methyl propionate	926	-	MS, RI Std	Ethereal, Rum, Fruity[C]
ethyl propionate	972	10 [D]	MS, RI Std	Fruity, Solvent, Acetone[C]
methyl butyrate	1005	60-76[D]	MS, RI Std	Fruity, Sweet, Ester, Green[C]
ethyl butyrate	1054	1[D]	MS, RI Std	Fruity, Banana, Strawberry, Sweet, Bubblegum, Pin Acetone, Caramel [C]
butyl acetate	1093	66[D]	MS, RI Std	Bitter, Green, Sweaty, Strong, Sweet
methyl hexanoate	1205	70-80[D]	MS, RI Std	Fruity, Thinner, Acetone[c]
butyl butyrate	1217	100[D]	MS, RI Std	Fresh, Sweet, Fruity[C]
ethyl hexanoate	1226	1[D]	MS, RI Std	Fruity, Strawberry, Anise, Wine gum, Sweet[C]
hexyl acetate	1248	2[D]	MS, RI Std	Fruity, Spicy, Herbal, Sweet wine, Rubbery, Tobacco, Acid, Citrus, Green[C]
3-hexen-1-yl, acetate	1266	-		-
2-hexen-1-yl, acetate	1277	-		-
hexyl butyrate	1432	250 [D]		Fruity[C]
octyl acetate	1494	12[D]		Waxy, Floral, Apple[C]
butyl octanoate	1634	1[D]	MS, RI Std	Fruity, Green, Oily, Floral[C]
Aldehydes				
hexanal	1106	4.5-5 [D]	MS, RI Std	Fishy, grass[A,B,C]
2-hexenal	1224	2-17 [D]	MS, RI Std	Apple, Fruity, Strawberry, Cherry, Green, Almond, Herbal, Leafy[C]
Alcohols				
propan-2-ol	943	-	MS, RI Std	Ethereal, Alcohol[C]
ethanol	953	100,000[D]	MS, RI	Ethanol, Pungent, Sweet[C]
1-butanol	1169	500 [A,D]	MS, RI Std	Fruity, Medicinal, Cheesy
1-penten-3-ol	1182	350-400 [A,D]	MS, RI Std	Burnt, meaty[A,] paint like chemical like[B] grassy-green[C]
3-methyl-1-butanol	1210	250-300 [D]	MS, RI, Std	Pungent, Balsamic, Alcohol, Fruity, Malty, Ripe o Cheesy, Bitter, Harsh[,C]
1-pentanol	1236	4,000 [D]	MS, RI, Std	Fruity, Green, Sweet, Pungent
1-hexanol	1286	2,500 [D]	MS, RI, Std	Flowery, Toasty, Dry, Fruity, Herbal, Mild, Woody, Sweet, Green, Leafy[C]
3-hexen-1-yl	1302	70 [D]	MS, RI, Std	Fresh, Green, Grassy, Leafy[C]
2-hexen-1-yl	1425	-	MS, RI, Std	Walnut, Medicinal, Cooked butter, Green, Leafy
linalool	1564	6 [D]	MS, RI Std	Muscat, Sweet, Green, Floral, Lemon, Parsley, Lavender, Fruity [C]

Ketones				
1-penten-3-one	1042	1-1.3[D]	MS, RI, Std	Pungent, fish-like, rotten, fruity, plastic, leather[A,B,C]
<u>Generated</u>				
Aldehydes				
2-methyl butanal	930	1[D]	MS, RI Std	Green, Almond, Strong burnt, Malty, Cocoa[C]
3-methyl butanal	934	0.2-2[D]	MS, RI Std	Cashew, apple[A] , almond-like, toasted, malty, green
Octanal	1256	0.7[D]	MS, RI Std	Lemon, stew-like, boiled meat-like, rancid, soapy, citrus, green, flower, fruit, orange[A,B,C]
Nonanal	1418	1[D]	MS, RI Std	Gravy, green, fruity, gas, chlorine, floral, waxy, sweet, melon, soapy, fatty, citrus fruit[A,B,C]
Decanal	1524	0.1-2[D]	MS, RI	Stewed, Burnt, Green, Waxy, Floral, Lemon, Fatty, Herbal, Soapy [C]
Benzaldehyde	1571	350-3,500[D]	MS, RI	Bitter almond[A,B] ,Burnt sugar, Woody[C]
Alcohols				
Eucalyptol	1215	12[D]	MS, RI, Std	Camphor, Minty, Sweet, Liquorices, Mentholic, Pine[C]
Furans				
Furfural	1503	3,000-23,000[A,D]	MS, RI	Woody, Almond, Sweet, Fruity, Flowery[C]
2-Acetilfurane	1539	10,000-15,000 [A,D]	MS, RI	Tobacco, Smoky[A],Balsamic, Cinnamon, Sweet[C]
5-Methyl furfural	1617	10,000[D]	MS, RI, Std	Sweet, caramellic, bready, brown, coffee-like [C]
Mesifurane	1632	0.03[D]	MS, RI,	Caramel, Cotton, Candy[C]
Terpens				
Limonene	1208	10[D]	MS, RI, Std	Green, Citrus, Ethereal, Fruit[C]

[A] Giri et al., 2010; [B] Ganeko et al., 2008; [C] pherobase.org; [D] http://www.leffingwell.com/odorthre.htm

Odour tresholds in water (µg/L)

Table III: Changes of volatile compounds in the strawberry spreadable products after 90 days of storage at 20ºC. (n=3)

		Detected after 90 days of storage compared to spreadable products after 24 h of processing: $\Delta C=(C_{90}-C_0)/C_0$				Detected after 90 days of storage C_{90}			
		sucrose-isomaltulose (S)		fructose-isomaltulose (F)		sucrose-isomaltulose (S)		fructose-isomaltulo (F)	
	RI	Min	Max	Min	Max	Min	Max	Min	Ma
Esters									
›propyl acetate	911	G	G	-0.59	-0.01	1.45	5.67	1.78	7.37
›nyl acetate	1000	G	G	-0.73	41.99	7.54	23.15	8.26	13.78
›thyl-2-methyl butyrate	1028	G	G	G	G	0.00	1.74	0.26	1.50
Aldehydes									
methyl butanal	930	-0.80	0.30	-0.73	0.86	0.86	5.31	0.43	6.86
methyl butanal	934	ND	ND	-1.00	23.13	ND	ND	0.00	29.87
2-butenal	1072	G	G	G	G	0.55	3.02	0.06	4.56
butenal-2-methyl	1126	G	G	G	G	0.51	1.41	0.04	1.74
nzaldehyde	1571	1.09	7.83	0.91	5.59	0.49	3.78	1.2	3.10
Alcohols									
opan-2-ol	943	-0.68	1.01	-0.69	-0.11	45.53	121.76	21.46	87.00
caliptol	1215	-1.00	1.62	-1.00	-0.56	0.00	2.12	0.00	0.65
methyl butanol	1210	-0.31	54.54	-0.28	25.15	0.92	3.33	0.92	3.19
pentanol	1236	-0.49	1.16	-0.49	0.97	0.78	1.72	0.59	1.58
hexanol	1286	-0.74	1.65	-0.69	1.22	1.96	14.15	2.26	14.61
buten-1-ol	1222	G	G	G	G	0.09	0.64	0.00	0.61
penten-1-ol	1272	G	G	G	G	0.71	1.76	0.84	2.43
›til-1-hexanol	1506	G	G	G	G	0.43	13.40	0.00	11.91
Ketones									
methyl-5-hepten-2-one	1283	G	G	G	G	0.09	0.93	0.12	0.54
Acids									
etic ac.	1478	G	G	G	G	0.54	16.43	0.17	25.74
opanoic-2-methyl ac.	1591	G	G	G	G	0.00	3.15	0.18	2.18
tyric ac.	1653	G	G	G	G	0.00	2.73	0.03	1.69
tyric -2-methyl ac.	1696	G	G	G	G	0.00	4.15	0.23	2.61
Furans									
rfural	1503	-0.70	0.72	-0.61	0.06	4.94	130.01	11.42	157.96
acetylfurane	1617	-0.68	52.15	0.40	4.12	0.32	6.17	0.75	16.90
methyl furfural	1632	-0.61	2.44	-0.43	3.02	0.07	5.28	0.15	10.96
Terpens	1208								
nonene		-0.78	2.51	-0.88	1.90	0.16	0.97	0.11	0.85
Nitriles									
etonitrile	1031	-0.81	30.33	-0.75	6.52	0.36	6.81	0.20	4.78

RI: Retention Index (Kovats Index) obtained for the volatile compounds.

($[C_{90}-C_0]/C_0$): Minimum and maximum concentration ratio for the volatile compounds that were present in the spreadable products after 24 hours of processing, and increased or decreased during storage.

G: volatile compounds generated after 90 days of storage at 20ºC (concentration cannot be expressed as the ratio ($\Delta \boldsymbol{C}$).

ND: not detected

C_0: concentration of volatile compound in the strawberry spreadable product after 24 hours of processing expressed as μg / 100 g of spreadable product.

C_{90}: concentration of volatile compound in the strawberry spreadable product after 90 days of storage at 20ºC expressed as μg / 100 g of spreadable product.