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# INFLUENCE OF HEALTHY SWEETENERS (TAGATOSE AND OLIGOFRUCTOSE) ON THE PHYSICOCHEMICAL CHARACTERISTICS OF ORANGE MARMALADE

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## ABSTRACT

Today's society shows a growing interest in healthy, safe and high nutritional quality food. Thus, in this paper sweet orange marmalades have been developed using healthy sweeteners (tagatose and oligofructose) in different proportions. Analyses of Brix, pH, moisture, water activity, antioxidant capacity, optical and rheological properties have been carried out, initially and after 45 days of storage. Microbiological analyses have also been performed to determine their stability. Furthermore, a sensorial assessment has been conducted to find out acceptance of these new orange marmalades by consumers. The results showed that the highest proportion of oligofructose contributed to improve the initial antioxidant capacity of marmalades. The marmalade with the same proportions of oligofructose and tagatose was more consistent and showed a further increase in the elastic component over time. All marmalades had a similar appearance, but oligofructose reduced L*. Finally, orange marmalades made with healthy sweeteners were better scored.

**KEYWORDS:** marmalade, tagatose, oligofructose, rheology, color, sensory analysis.

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## PRACTICAL APPLICATIONS

The development of new healthier marmalades offer new alternatives to the conventional ones not only to prevent caries and obesity but also to provide functional features associated with the use of tagatose and oligofructose as sweeteners. However, not always it is possible to replace traditional components by others and that is why is so important to assess their technological influence. In this study, the viability of the use of both sweeteners to prepare orange marmalades has been checked.

## INTRODUCTION

Nowadays, owing to the current lifestyle of society, there is an increasing demand for healthy food products such as fruit and vegetables. However, these products are highly perishable with the consequent problems of distribution and shelf life. As an alternative, processing makes it possible to extend their marketability, whilst maintaining some of the characteristics of the fresh products to a certain extent. In this regard, marmalades are a typical example of more stable fruit-derived products. Among the diverse variety of fruits and the requirements for manufacturing marmalades, oranges may be a good choice in the Mediterranean area as they are readily available at an affordable price, and also because of their high nutritional content.

In the case of marmalades, as in many other cases, sugars/sweeteners are crucial for these kind of products to achieve the right texture. In addition, they are responsible for the high concentration of Brix, the reduction of $a_w$ and consequently the control of the microbial growth in the product. Traditionally, sucrose has been used as the main sugar to manufacture marmalades. However, because of the negative connotations associated with sugar consumption (cariogenesis, high caloric intake, increase in the glycemic index, etc…) it has been replaced by bulk sweeteners (polyols) or high-potency sweeteners

(saccharine, aspartame…) depending on the properties required in the product (Edwards 2002; O'Donnell and Kearsley 2012). Nevertheless, these sweeteners also present some drawbacks. Concretely, most of the polyalcohols have a laxative effect. In the case of high-potency sweeteners, there is a lot of controversy since their relation with the development of different cancers and other diseases is being questioned (Weihrauch and Diehl 2004; Soffritti *et al*. 2006; Renwick and Nordmann 2007).

On the other hand, the World Health Organization (2014) considers reducing the excessive consumption of sugars and other carbohydrates of fast absorption, such as sucrose an urgent matter, whilst increasing daily physical activity in order to stop the trend towards obesity and diabetes type 2. A fast absorption of sugar may cause glycemic peaks and the excess sugar may be quickly converted into fat in the organism (Lu *et al*. 2008; Lina *et al*. 2002). In fact, most of the sugars (sucrose, fructose and glucose) have around 4 kcal/g, although their glycemic index (GI) changes. Thus, glucose has the highest GI, with a value of 100, followed by sucrose with 65 and fructose with a GI of 25. Factors such as obesity, diabetes, and the increasing awareness of the need to improve diet, increase the demand for alternative sweeteners to those previously mentioned. Fortunately, the food industry currently offers healthy alternatives, such as tagatose, oligofructose, stevia, isomaltulose, etc… The challenge is to check their viability to reformulate traditional products in order to keep or even improve their technological properties.

One of the alternatives to the traditional sweeteners is D-Tagatose (D-tag) that is a ketohexose bulk sweetener, a stereoisomer of D-fructose, with a texture very similar to sucrose, almost as sweet as sucrose, since its sweetening power is 92% (Oh 2007; Taylor *et al.* 2008; Calzada-León *et al.* 2013) but with only 1.5 kcal/g and it does not cause dental caries (Levin 2002). D-tagatose received Generally Recognized as Safe status by the Food

and Drug Administration in 2001 and entered the US market as a sweetener in 2003 (Donner *et al.* 2010). It is found naturally in several foods, including cheese and yoghurt. It can also be produced from D-galactose by means of a chemical method using calcium as a catalyst (Oh 2007). Tagatose is very suitable for confectionary products, ice creams, soft drinks and breakfast cereals (Vastenavond *et al*. 2011). It is considered a functional food because it is partially metabolized and the part that is not absorbed (80% of the intake) ferments in the colon, where it performs functions as soluble fiber (Taylor *et al*. 2008) favouring lactic acid bacteria and *Lactobacillus* specie bacteria (Petersen-Skytte 2006).

On the other hand, oligofructose is an oligosaccharide derived from sucrose, which acts as dietary fibre regulating intestinal transit. It improves calcium absorption (van den Heuvel *et al.* 1996) and reduces cholesterol and blood sugar levels (Chacón-Villalobos 2006). Moreover, it presents a prebiotic effect because it favours the selective growth of lactic bacteria and bifidobacteria (Ledur *et al.* 2013). Oligofructose has approximately between 30% and 60% of the sweetness of sucrose and it is easily hydrolysed by the action of acids or enzymes (Coussement 1999). It is highly soluble and possesses technological properties that are closely related to those of sucrose and glucose syrups (sweet taste, stability…) because it has free sugars (Pimentel *et al*., 2014). It is often used in combination with high intensity sweeteners. The replacement of carbohydrates by oligofructose offers the advantage of not compromising on taste and texture, while delivering nutritionally enhanced products (Franck 2002).

The aim of this paper focuses on characterising sweet orange marmalades formulated with different combinations of tagatose and oligofructose analysing their moisture content, Brix, pH and antioxidant capacity initially and after 45 days of storage. Besides,

their rheological and optical properties have been also registered. Finally, a sensorial analysis has been carried out to assess their acceptability by potential consumers.

## MATERIALS AND METHODS

### Formulations and Manufacturing Processes of Orange Marmalades

Marmalades were produced using 60% orange pulp (*Navelate* variety), 40% sucrose (Azucarera Española, Spain) or healthy sweeteners (tagatose or oligofructose) and 1% agar-agar (Roko Agar$^{(R)}$, Spain) on the percentage of sucrose or sweeteners. Tagatose was obtained from Damhert Nutrition (Tagatesse $^{(R)}$, Belgium) and according to the information of the label it was composed by 39.9% of tagatose, 39.9% of isomalt, 0.02% of sucralose and 20% of dietary fiber (inulin and oligosaccharides). Oligofructose was obtained from Sensus (Frutalose OFP$^{(R)}$, Netherlands).

The following notation was used depending on the combination of sweeteners used: Control marmalade: 100% sucrose, Marmalade A: 50% oligofructose and 50% tagatose, Marmalade B: 30% oligofructose and 70% tagatose, and Marmalade C: 70% oligofructose and 30% tagatose.

Oranges collected directly from crop were peeled and mixed with sucrose or the corresponding combination of healthy sweeteners and the agar-agar in a thermal blender (Thermomix, TM31, Vorwerk, Germany). After that, the mixture was cooked at 100 ºC for 20 min at 350 rpm. Then, glass jars previously sterilized in an autoclave at 121 ºC for 15 min, were filled with the marmalade. These jars were turned over to ensure proper sealing for 1 hour. Finally, the marmalade was allowed to cool for 24 hours and in that time jellification took place. Three batches of oranges were used to prepare the marmalades. Triplicated analyses were performed for each batch on the first day of storage and after 45 days of storage.

## Analytical Determinations

**Moisture Content, Brix, pH and Water Activity.** Moisture content ($x^w$), was determined gravimetrically by drying approximately 1 g of marmalade to a constant weight in a vacuum oven at 60 ºC (method 20.103 AOAC 2000). Water activity ($a_w$) was determined with a dew point water activity meter Decagon Devices, Inc. (Aqua Lab 4TE, Pullman, Washington, USA). Soluble solid content (Brix) was measured with a refractometer at 20 ºC (Atago 3T, Tokyo, Japan) and pH was registered with a pH-meter (Seven Easy, Mettler Toledo, Barcelona, Spain).

**Antioxidant Capacity.** The antioxidant activity of marmalades was analyzed on the basis of the scavenging activities of the stable 2,2-diphenyl-1-picrylhydrazyl free radical (Brand-Williams *et al.* 1995; Shahidi *et al*. 2006). 1 g of marmalade was mixed with 6 mL of pure methanol for 5 min in a vortex, keeping the supernatant. This mixture was centrifuged at 13,000 rpm for 10 min. The absorbance of 3.9 mL of the DPPH solution (0.025 mg/mL, prepared in methanol: water (80:20)) was read at 515 nm in a spectrocolorimeter Thermo Fisher Scientific, Inc. (Helios Zeta UV-VIS, Waltham, Massachusetts, USA). Then, 0.1 mL of the supernatant was mixed with the methanolic solution of DPPH and absorbance was read again after 30 min. Quantification was performed considering a standard curve of Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) and the results were expressed as mg of Trolox equivalent per 100 g of marmalade.

## Optical Properties

149 The colour of orange marmalades placed in 20 mm-wide cuvettes was measured using a
150 spectrocolorimeter Konica Minolta, Inc. (CM-3600d, Tokyo, Japan). CIE-L*a*b*
151 coordinates were obtained using D65 illuminant and 10º observer as reference system.
152
153 **Rheological Analysis**
154 Rheological properties of studied orange marmalades were obtained using a controlled
155 stress rheometer Thermo Fisher Scientific, Inc. (Haake RheoStress 1, Waltham,
156 Massachusetts, USA), at 25 ºC. Measurements were carried out with plate–plate geometry
157 and a 2.0 mm gap for steady state and oscillatory tests (Sato and Cunha 2009), by means
158 of steady state essays or oscillatory essays to study the pseudoplastic or viscoelastic
159 behavior of marmalades respectively.
160 Firstly, steady state measurements were performed with a shear rate linearly ranging from
161 0 to 100 $s^{-1}$, in 3 sweeps (up, down and up-cycles), in order to eliminate thixotropy. The
162 data obtained in the third sweep were fitted to the Herschel–Bulkley model (equation 1)
163 (Peinado *et al.* 2012). This model can describe Newtonian and a large group of time
164 independent non-Newtonian fluids. There are three parameters: $\tau$ is the shear stress (Pa),
165 $\tau_0$ is the yield stress above which the fluid starts flowing (Pa), $\gamma$ is the shear rate ($s^{-1}$), $k$ is
166 the index of consistency ($Pa \cdot s^n$) and $n$ is the index of fluidity (Skelland 1967).

167 $$\tau = \tau_0 + \kappa \cdot \gamma^n \quad (1)$$

168 In second place, an oscillatory assay was carried out following the power-law that
169 described the mechanical spectrum within the linear viscoelastic region in terms of
170 storage (*G'*) and loss (*G"*) modulus as a function of frequency (equations 2 and 3)
171 (Subramanian *et al.* 2006; Basua *et al*. 2011):

172 $$G' = a \cdot \omega^b \quad (2)$$

173 $$G'' = c \cdot \omega^d \quad (3)$$

Where, $\omega$ x is the angular speed (rad·s$^{-1}$), $a$ is the low frequency storage modulus (Pa$^{b}$); $b$ is the power-law index for the storage modulus (dimensionless); $c$ is the low frequency loss modulus (Pa$^{d}$); and, $d$ is the power-law index for the loss modulus (dimensionless). The value of the shear stress to fulfill the linearity of *G'* and *G"* was obtained in a preliminary trial. In order to do so, an interval of shear $\tau$ = 0.1-10 Pa was studied and three fixed frequencies were marked in the range of 0.1-10 Hz. Once these 3 curves were represented, the lineal zone of viscosity was obtained. Having chosen the value of $\tau$ in the linear zone for all the frequencies, the oscillatory assay was performed between 0.1-10 Hz (Peinado *et al.* 2012).

**Microbiological Analysis**

Serial dilutions were prepared by homogenising 10 g of marmalade with 90 mL of 1% sterile peptone water in a stomacher bag, using sterile techniques. Mesophilic aerobic populations were analysed in Plate Count Agar (Scharlau Chemie, 1-329, Barcelona, Spain) incubating samples for 72 hours at 31 ºC. Yeast and moulds were determined in Sabouraud Chloramphenicol Agar (Scharlau Chemie, 1-166, Barcelona, Spain) plates for 5 days at 31 ºC. Samples were analysed at 45 days of storage.

**Sensorial Analysis**

An acceptance test using a 9-point hedonic scale (ISO 4121:2003) was used to evaluate the following attributes: colour, aroma, texture, consistency, spreadable capacity, palatability, flavor, sweetness, bitterness, and global preference (ISO 5492:2008) in the three formulations with different combinations of healthy sugars (A, B and C) along with the control marmalade. The possible appearance of sineresis was also assessed. Moreover, the intention of buying was considered. The panel consisted of 30 trained panelists, in the

age range of 20-50 years old, who are regular consumers of this kind of marmalades. Samples were presented in jars of 25 mL presented one after another. Three testing sessions were conducted in a sensory evaluation laboratory built according to the international standards for test rooms (ISO 8589: 2007).

### Statistical Analysis

Statgraphics plus (version 5.1) software was used to perform the statistical analyses. Analyses of variance (multifactor ANOVA) were carried out to discern whether the effect of the formulation or the time of storage on the studied marmalades was significant. The interactions between factors were considered.

## RESULTS AND DISCUSSION

### Compositional Characterization of Marmalades

Table 1 shows the results of moisture content ($x^w$), Brix, water activity ($a_w$), pH and antioxidant capacity. In all cases the sugar concentration reached in marmalades was 50 Brix and it remained during the storage period considered. Moreover, marmalades B and C showed higher water content than the control and marmalade A. With time, the moisture content of samples B and C reduced, while in marmalade A it increased though in all cases there were slight differences. Regarding water activity, storage time was the factor which implied the most significant influence, showing a small decrease in water activity at 45 days of storage, except for sample A. Focusing on the pH, all marmalades showed values below 3.8, which would ensure proper microbiological stability. For all analyzed products, pH ranged between 3 and 4, in the same magnitude of order as the pH of other jams made using strawberry, peach, plum and apricot (Carbonell *et al.* 1991; García-Martínez *et al*. 2002). Furthermore, in the control marmalade and sample A pH

decreased after storage as was also observed by Rababah *et al*. (2011) in strawberry jams with sucrose. However in the same paper the pH value of orange fruit after processing to obtain jam was decreased significantly, and only after 5 months of storage there was again a significant decrease in pH. In terms of antioxidant capacity, initially formulation C showed the highest value probably due to the greater amount of oligofructose in its composition, in contrast with the results of Ścibisz and Mitek (2009) who observed that high bush blueberry jams had the lowest levels of anthocyanins and total phenolics when oligofructose was included in their formulation. In our research, both formulation A and B reported lower antioxidant content than the control, showing that tagatose reacts less than table sugar with free radicals. These results differ from those reported by Zeng *et al*. (2012) who observed that via the Maillard reaction, rare sugars (especially D-tagatose) induced a more remarkable improvement than D-fructose in the radical scavenging activity and oxidation–reduction potential of the hydrolysates of tune backbone. Moreover, in our study, the antioxidant capacity of marmalades increased over time, showing possible combinations of components which would imply the appearance of new antioxidants. However, Rababah *et al.* (2011) observed that antioxidant activity of orange marmalades prepared with sucrose decreased significantly after 3 and 4 months, and 5 months, respectively.

**Rheological Properties**

The rheological properties of the studied marmalades were determined by two tests: steady and oscillatory obtaining the parameters of the models considered in each case. The results obtained in the stationary test are presented in Figure 1. Rheograms indicate that initially there were no differences between samples, except for formulation B which scored slightly higher than the rest. After the storage period, the shear stress exceeded

249 was reduced in all cases although to a lesser extent in marmalade A. Furthermore, in Table
250 2 the parameters of the Herschel-Bulkley model are shown. As expected, all marmalades
251 showed a shear thinning behavior ($n$ <1). However, the yield stress ($\tau_0$) was similar in
252 marmalade control and formulation A initially and after 45 days of storage whereas in
253 formulations B and C the values of this parameter were significantly lower especially
254 after storage in B. Besides, marmalade A showed the highest level of consistency after
255 storage, giving evidences that the combination of oligofructose and tagatose in same
256 proportions would improve consistency of marmalades during the storage. With respect
257 to the index of fluidity ($n$), no significant differences were found considering the
258 formulation studied but the time implied a reduction of this index in all cases. In studies
259 carried out by other authors (Peinado *et al*. 2012; Rosa *et al*. 2009) where sugars were
260 also replaced by other sweeteners (in this case isomaltulose) a decrease in consistency
261 and cohesiveness of strawberry jams was observed respect to the sucrose-jams. In our
262 study, only an increase of consistency was observed in the combination of 50%
263 oligofructose and tagatose, but not for the other blends.
264 Figure 2 shows the rheological results of the oscillatory assay where the frequency
265 dependence on storage (*G'*) and loss (*G"*) moduli of the orange marmalades formulated
266 with healthy sweeteners are represented. This type of test determines the ratio between
267 the elastic and viscous component of a material and it is useful to quantify to what extent
268 it behaves as a solid or liquid. Since in all cases *G'* was greater than *G"*, marmalades
269 showed a semi-solid behavior. This is a typical gel characteristic being more elastic than
270 viscous (Peinado *et al*. 2012).
271 Concerning the formulations studied, at the beginning of storage there were no differences
272 between the control marmalade and the marmalade with the same amount of tagatose and
273 oligofructose (formulation A), for both moduli (*G'* and *G"*). Moreover, marmalades B

and C were similar in terms of viscous level, whereas the most elastic character was for marmalade with more oligofructose (C). At the end of storage, the increase in the elastic component of formulation A was noteworthy, unlike what was observed in the other marmalades, giving evidence of the interaction between the analyzed factors as a function of the sweeteners used. Besides in this assay, marmalade B had more similar elastic characteristics to the control marmalade.

In order to quantify in depth the differences between the oscillatory test of the analyzed samples, the values of both the storage (*G'*) and the loss (*G"*) moduli were fitted with respect to the angular speed ($\omega$) with the power-law model as described in materials and methods. The parameters of this model are shown in Table 2. As can be observed, initially there were no significant differences between samples in *a* and *b* parameters of the power-law model for the storage modulus. However, in marmalade A *a* increased significantly after 45 days of storage, while the time factor did not affect the other formulations. This behavior would be consistent with that observed in Fig. 2, reflecting a more elastic nature of marmalade A at the end of storage. Regarding the terms related to the loss modulus (*c* and *d*) it should also be mentioned that marmalade A had a significantly greater value of *c* in coherence with the position of its curve *G"* versus frequency ($\omega$) above the rest of the samples (Fig. 2). However, these differences were much lower than in the case of the parameters related to the storage modulus. In addition, parameter *d* fluctuated more between the cases studied. In fact lower values were only observed in the formulation A with regard to the initial control and at the end of storage and higher values in marmalade B after 45 days. In contrast to the few differences found in this study, Peinado *et al.* (2012) observed that by replacing sucrose for isomaltulose in the formulation of different strawberry spreadable products resulted in a decrease in parameters *a* and *c* of the power-law model. This decrease was associated with how sugar type influences the availability

of water in the mixture of pectin-sugar-acid and therefore in the formation of hydrogen bonds and the possible association of water in the pectin polymer chain. In this study, the gelling agent used was agar-agar instead of pectin and it could have homogenized the rheological properties of the marmalade regardless of the type of sugar used, except in the case of marmalade A.

**Optical Properties**

Colorimetric coordinates *b** and *a** of the different studied sweet orange marmalades initially and at the end of storage placed in the chromatic plane are shown in Figure 3A. The new marmalades, especially for A and B formulations, increased *b** and *a** coordinates in comparison with the values of the control marmalade. Consequently the chrome ($C^*=(a^{*2}+b^{*2})^{1/2}$) followed the same trend, while the hue ($h^*=arctg(b^*/a^*)$) remained very similar to the control giving place to a similar appearance in all cases. Furthermore, values of initial and final luminosity (*L**) of the studied marmalades are also presented. According to these results, initially, *L** of samples A and especially B was much higher than in the control marmalade unlike what happened to marmalade C. Therefore, high concentrations of oligofructose significantly reduced *L** of marmalades. Considering the time factor in *L**, the most stable formulations were A and C, while *L** in the control and B changed oppositely, increasing in the case of control and decreasing for B.

In other studies, Peinado *et al*. 2015 showed that strawberry jams formulated with the healthier sugar isomaltulose and different concentrations of citric acid and pectin, darkened with time. Besides that, the colorimetric coordinates of the products containing the sucrose-isomaltulose blend seemed to be influenced by the percentages of pectin and citric acid while the colour of the samples containing the fructose-isomaltulose blend, did

not seem to be affected by the different variables. Therefore the influence of the different ingredients on the food system does not only depend on their concentration or distribution within the different system phases but also on the different component interactions during the studied period (Dervisi *et al.* 2001; Renard *et al.* 2006; Peinado *et al*. 2015).

**Microbiological Analysis**

There were no colonies of molds and yeast or aerobic mesophillic found in any of the marmalades in this study during the storage period considered.

**Sensory Analysis**

Figure 4 shows a radial chart of the average scores for each attribute evaluated (color, aroma, texture, consistency, spreadable capacity, palatability, flavor, sweetness and bitterness) besides the global preference and intention of buying of the studied marmalades. As can be seen, A and B formulations showed the highest scores in all attributes, although no significant differences were found in color, aroma, texture and consistency among the samples. Furthermore, A and B, which had higher proportions of tagatose, showed the highest sweetness. This would be consistent with the recommendations given by the manufacturer of the commercial tagatose (two tablespoons of sucrose provides the same sweetness as one tablespoon of tagatose), although as was mentioned in the introduction, tagatose should have similar sweetening power to sucrose (Oh 2007; Taylor et al. 2008; Calzada-León et al. 2013). However, the commercial tagatose used in this study was composed also by oligosaccharides, isomalt and sucralose. The higher sweetening power of this combination could be due to the synergic influence between these sweeteners. In fact, according to the Patent EP0946112 B1 (Dörr and Jager 2002), oligosaccharides increase the sweetness and improve the taste of an acesulfame-

k/aspartame mixture. Moreover, although the level of bitterness in the marmalades evaluated in this study was expected to be very low, analyzing the possible interference of the combination of sweeteners used in this property was deemed relevant. Thus, the control and formulation C had the highest bitterness, showing the great ability of tagatose to hide this taste. Furthermore, no marmalade developed syneresis. In relation to the rheological properties, the results obtained in the sensorial analysis were in accordance with those registered instrumentally. Finally, attention should be brought to the fact that both the global preference and buying intention of all marmalades formulated with healthy sweeteners were higher than those containing only sucrose.

## CONCLUSIONS

The reformulation of orange marmalade with healthy sweeteners such as tagatose and oligofructose is feasible. Only oligofructose improved the antioxidant capacity compared to marmalade prepared with sucrose and also reduced its luminosity. In general, all marmalades had the same appearance. In terms of rheology, formulation with the same proportion of tagatose and oligofructose improved consistency and elastic component of marmalades over time. Moreover, all of them reported microbiological stability in storage during the storage period considered. Finally, global acceptance and intention of buying of marmalades with healthy sweeteners were higher than for marmalade containing only sucrose.

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## FIGURE CAPTIONS

**FIG. 1.** MEAN FLOW CURVES (RHEOGRAMS) OBTAINED FROM THE STEADY ASSAY OF ORANGE MARMALADES AT THE BEGINNING AND AT THE END OF STORAGE. SAMPLES WERE CODED RESPECT TO THE AMOUNT OF SUGARS AS: CONTROL (100% SUCROSE); A (50% OLIGOFRUCTOSE AND 50% TAGATOSE); B (30% OLIGOFRUCTOSE AND 70% TAGATOSE), AND C (70% OLIGOFRUCTOSE AND 30% TAGATOSE).

**FIG. 2.** AVERAGE FREQUENCY CURVES OBTAINED IN THE OSCILLATORY TEST OF ORANGE MARMALADES AT THE BEGINNING AND END OF STORAGE. SAMPLES WERE CODED RESPECT TO THE AMOUNT OF SUGARS

AS: CONTROL (100% SUCROSE); A (50% OLIGOFRUCTOSE AND 50% TAGATOSE); B (30% OLIGOFRUCTOSE AND 70% TAGATOSE), AND C (70% OLIGOFRUCTOSE AND 30% TAGATOSE). EMPTY SYMBOLS REFER TO VALUES OF STORAGE MODULUS (G') AND FILLED SYMBOLS REFER TO VALUES OF LOSS MODULUS (G").

**FIG. 3.** A) CHROMATIC PLANE REPRESENTATION (b*-a*) OF THE STUDIED MARMALADES INITIALLY AND AFTER 45 DAYS OF STORAGE. Straight line represents the hue of control orange marmalade for day 1 from (0,0). B) LUMINOSITY (L*) OF THE DIFFERENT FORMULATIONS OF MARMALADE INITIALLY AND AFTER 45 DAYS OF STORAGE. SAMPLES WERE CODED RESPECT TO THE AMOUNT OF SUGARS AS: CONTROL (100% SUCROSE); A (50% OLIGOFRUCTOSE AND 50% TAGATOSE); B (30% OLIGOFRUCTOSE AND 70% TAGATOSE), AND C (70% OLIGOFRUCTOSE AND 30% TAGATOSE). Equal letters indicate homogeneous groups.

**FIG. 4**. RESULTS OF THE SENSORY ANALYSIS IN THE EVALUATION OF THE SAMPLES CODED RESPECT TO THE AMOUNT OF SUGARS AS: CONTROL (100% SUCROSE); A (50% OLIGOFRUCTOSE AND 50% TAGATOSE); B (30% OLIGOFRUCTOSE AND 70% TAGATOSE), AND C (70% OLIGOFRUCTOSE AND 30% TAGATOSE). * p-value <0.05, ** p-value <0.01

**TABLE 1**. VALUES FOR MOISTURE CONTENT ($x^W$), Brix, WATER ACTIVITY ($a_W$), pH AND ANTIOXIDANT CAPACITY OF ORANGE MARMALADES INITIALLY AND AFTER 45 DAYS OF STORAGE.

**TABLE 2.** RHEOLOGICAL PARAMETERS OF THE HERSCHEL-BULKLEY MODEL AND PARAMETERS OF THE POWER-LAW MODEL FOR MARMALADES INITIALLY AND AT THE END OF STORAGE.