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Jam processing and storage effects on β-carotene and flavonoids content in grapefruit.

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Abstract

Grapefruit phytochemicals (β-carotene and flavonoids) stability after different jam processing was evaluated. Osmotic dehydration, microwave energy and conventional heating techiques have been used to obtain jam. β-carotene and individual flavonoids were analyzed by HPLC technique. The results showed that jam obtained from osmodehydrated fruit (ODJ) is the only that preserved completely the β-carotene content. All processes of production of jam significantly decreased the content of narirutin (NAT), poncirin (PON), naringenin (NAG) and quercetin (QUER), while naringin (NAR) remained stable. Jams obtained by applying a heat treatment showed significant lower values of NAG and QUER in comparison with ODJ. The jam obtained from osmodehydrated fruit, without being submitted to any heat treatment, showed at the end of storage the highest contents of naringin, hesperidin, neohesperidin, didymin, quercetin, poncirin and the total sum of analysed flavonoids. In general, the phytochemical loss in jams as a consequence of processing was lower than those provoked by storage effect.

Keywords: grapefruit jam, osmotic dehydration, microwaves, flavonoids, β-carotene, phytochemicals

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25 **1. Introduction**

26 Numerous epidemiological studies suggest that diets rich in phytochemicals and
27 antioxidants perform a protective role on health and diseases. Frequent consumption of
28 fruits and vegetables is associated with a lowered risk of cancer, heart disease,
29 hypertension and stroke (Marco et al., 1997; Vinson et al., 2001; Wolfe & Liu, 2003).
30 Phytochemicals are some of the bioactive non-nutrient compounds present in fruits,
31 vegetables, grains and other plant foods that have been associated with the protection of
32 human health against chronic degenerative diseases (Kalt, 2001; Martínez-Navarrete et
33 al., 2008; Shahidi & Naczk , 1995).

34 Cells in humans are constantly exposed to a variety of oxidizing agents. These agents
35 may be present in air, food and water, or they may be produced by metabolic activities
36 within cells. The key factor is to maintain a balance between oxidants and antioxidants to
37 sustain optimal physiologic conditions in the body. Overproduction of oxidants can cause
38 an imbalance, leading to oxidative stress, especially in chronic bacterial, viral and parasitic
39 infections (Liu & Hotchkiss, 1995). Moreover, oxidative stress can cause oxidative damage
40 to large biomolecules such as proteins, DNA and lipids, resulting in an increased risk of
41 cancer and cardiovascular disease (Ames, & Gold, 1991; Ames et al., 1993). To prevent or
42 slow down the oxidative stress induced by free radicals, sufficient amounts of antioxidants
43 need to be consumed. Fruits and vegetables contain a wide variety of phytochemicals
44 compounds, such as phenolics and carotenoids, that may help to protect the cellular
45 systems from oxidative damage and to decrease the risk of chronic diseases (Liu, 2003).

46 Citrus fruits are especially valued for their antioxidant capacity, which has been linked to
47 the presence in them of vitamin C, phenols (mainly flavonoids and some phenolic acids)
48 and terpenes (carotenoids). Flavones are phenolic compounds that exist almost
49 exclusively in citrus plants and they have been of particular interest due to their
50 documented broad spectrum of biological activity, including anti-inflammatory, anti-

51 carcinogenic, and anti-atherogenic properties, among others (Shiming et al., 2009). Citrus
52 fruits are also particularly rich in pectin, implicated in colon cancer prevention and
53 regulation of glucose and cholesterol level (Wang et al., 2007), and in minerals. The
54 amount of each of these compounds found is specific to the citrus fruit and the variety
55 considered. Among them, the orange is the most consumed and therefore has been the
56 most studied. However, the grapefruit is a citrus fruit also of interest, with important health
57 benefits. According to some authors (Peterson et al., 2006a, b; Xu et al., 2008), grapefruit
58 is an excellent source of phytochemicals, more than orange, tangerine, lemon or lime,
59 emphasis in the presence of naringin (which owes its bitter taste) and neohesperidin and,
60 in pink varieties, also β-carotene (pro-vitamin A) and lycopene, responsible for its colour.
61 Despite the high functional value of the grapefruit, it is not widespread consumed, probably
62 because of its strong bitter taste. In this sense processed products that mask this flavour in
63 some extent, such as jams, could be even more acceptable than the fresh fruit.
64 In traditional jam manufacture, all the ingredients are mixed in adequate rates and the mix
65 is concentrated by applying an intense thermal treatment to reach the required final
66 soluble solid content. This process also implies an undesirable impact in colour, flavour
67 and nutritional and functional value of the fruit due to the long time and high temperature
68 reached in the cooking process. An alternative for jam formulation is to use dehydrated
69 fruit obtained by osmotic dehydration (OD) at mild temperature. This technique has been
70 proposed to obtain fruit products without being so aggressive to the antioxidant
71 compounds in the fruit (García-Martínez et al., 2002; Igual et al., 2010; Shi et al., 1996).
72 OD consists of immersing the fruit in a highly concentrated solution in order to promote the
73 water loss of the fruit cells (Lazarides, 2001). The high concentration of solutes reached on
74 the surface of the product contributes to obtain a product with good taste, flavour and
75 colour, to improve the cellular structure and to prevent the pigments and aromatic
76 compounds loss also as the browning of the products (Moraga et al., 2000; Moreno et al.,

2000; Shi et al., 1996). Another proposed alternative for jam cooking has been the employ of a faster heating method as it is the application of microwave energy (Igual et al., 2010). Microwave absorption provokes internal water heating and evaporation, greatly increasing the internal pressure and concentration gradients and thus the effective water diffusion. As a consequence, shorter processing time is required and higher product quality may be achieved. The different processing technique may affect in a different way to their bioactive compounds. For this reason, the most suitable method to process each product should be selected depending on the type of compounds considered to be the most important (Siriamornpuna et al.,, 2012). In this sense, the aim of this work was to evaluate the influence of processing (osmotic dehydration, microwave energy and conventional heating) and storage on flavonoids and β-carotene content of grapefruit jam.

2. Materials and methods

2.1. Raw materials

Grapefruits (*Citrus paradise* var. Star Ruby) from the city of Murcia (Spain) were purchased from a local supermarket. Fruit pieces were peeled and cut perpendicularly to the fruit axis into 10 mm thick half-slices. Food grade commercial sucrose was used to prepare conventional and microwave (MW) jams. In the case of the jam obtained by osmotic dehydration, an osmotic solution (OS) was prepared by mixing sucrose with distilled water until it was completely dissolved, forming a 65 ºBrix syrup. In this case, citrus peel pectin (60% degree of esterification, Fluka Biochemika, Switzerland) was used as a gelling agent.

2.2. Jams preparation procedures

102 The following procedures were applied to obtain a 40-60 ºBrix product, as described by the
103 Spanish quality norm for fruit jam (BOE, 1990). In all the cases, the obtained jams were
104 placed in sterile glass jars and stored at room temperature for 24 h till analysis. Water
105 activity (a_w) and pH of the jams were analysed by means of a dew point hygrometer FA-st
106 Lab, GBX (Bourg de Peage, France) and a CRISON pH-meter (Barcelona, Spain),
107 respectively. Each analysis was carried out in triplicate.
108
109 2.2.1. Conventional process
110 Fresh fruit (FG) (67 g grapefruit/100 g mixture) was pre-cooked at 85 ºC for 10 min, added
111 to the sugar and potassium sorbate (32.99 and 0.01 g/100 g mixture, respectively) and
112 cooked at 95-100 ºC for 20 min longer. An electrical food processor (Thermomix TM 21,
113 Vorwerk, Spain) was used for the process. The conventional jam obtained with this
114 procedure was named CJ.
115
116 2.2.2. Microwave process
117 FG (67 g grapefruit/100 g mixture) was pre-cooked (900 W, 5 min), added to the sugar and
118 potassium sorbate (32.99 and 0.01 g/100 g mixture, respectively) and cooked at 900 W for
119 10 min longer. A household microwave-air oven (Moulinex 5141 AFW2, Barcelona, Spain)
120 was used to obtain this jam, named MWJ.
121
122 2.2.3. Osmotic process
123 Half slices of peeled grapefruit were placed in a 65 ºBrix OS (ratio OS:fruit 5:1) for 10 min
124 at room temperature and 50 mbar pressure and then maintained for 10 min longer at
125 atmospheric pressure. After that, the fruit pieces and the OS were heated to 40 °C (water
126 bath P-Selecta Precisterm, Barcelona, Spain) with continuous stirring of the OS(200 rpm,
127 Heidolph Instruments, RZR 2020, Schwabach, Germany) for 3 h, to reach grapefruit with

about 30 ºBrix according (Igual et al., 2010). Osmo-dehydrated grapefruit pieces (ODG), potassium sorbate (0.01 g/100 g jam) and pectin (1 g/100 g jam) were ground with the required part of the OS to obtain jam with 60 g fresh fruit/100 g jam, taking into account ºBrix of ODG and ºBrix of the OS. The jam thus obtained was referred as ODJ.

2.2.4. Combined osmotic-microwave process

Jams obtained from osmo-dehydrated grapefruit, as described in Section 2.2.3, were cooked in the microwave-air oven at 900 W for 5 min to obtain OD+MWJ samples.

2.3 Storage conditions

Jams were stored for 3 months at room temperature, except ODJ which was stored at 4 °C (García-Martínez et al., 2002; Igual et al., 2011a). Analyses were carried out after 1, 7, 15, 30, 45, 60, 75 and 90 days of storage.

2.4. Analysis

2.4.1. β-carotene

Samples were homogenized. Ethanol (4 mL) was added to 2 g homogenate paste and the mixture was centrifuged (Selecta Medifriger-BL, Barcelona, Spain) at 2000 rpm for 3 min at 4 ºC. The supernatant was filtered through a Whatman No.1 paper and 0.5 mL of n-hexane were added to the filtrate and mixed. β-carotene was extracted twice in the hexane phase and the collected extract was dried under a stream of liquid nitrogen. Dried extract was solubilized in 0.2 mL methanol. β-carotene content was determined and quantified by HPLC. The HPLC (Jasco, Cremella, Italy) equipment consisted of a ternary pump (Jasco PU- 1580 HPLC pump), a gradient generator (LG-1580-02 Ternary Gradient Unit), Ultrabase-C18 column (5 µm, 4.6 x 250 mm) and a UV–visible detector (MD-1510) with a range of measurement wavelength of 190 to 650 nm. The mobile phase was composed

154 methanol: acetonitrile: chloroform (47:42:11, v/v/v), volume injection 20 μL and flow rate 1
155 mL/min. The β-carotene detection was at 436 nm and 25 ºC (Munzuroglu et al., 2003).
156 Standard curve of this reference compound (Fluka-Biochemika, Milwaukee, WI, USA) was
157 used to quantify. The results were expressed as mg of β-carotene per 100 grams of fresh
158 sample, considering the percentage of fresh grapefruit in the sample. Changes in this
159 compound along storage were expressed as the compound variation (ΔM_i) referred to the
160 fresh grapefruit content, according to equation (1):

161 $$\Delta M_i = \frac{(M_i^t - M_i^0)}{M_i^{FG}} \quad (1)$$

162 where: M_i^t: mass of compound i in the sample / g fresh grapefruit at storage time t, M_i^0:
163 mass of compound i in the sample / g fresh grapefruit at storage time 0 and M_i^{FG}: mass of
164 compound i / g fresh grapefruit.
165
166 2.4.2. Flavonoids
167 The extraction of flavonoids was carried out following the procedure proposed by Tomás-
168 Barberán et al. (2001). It consisted of homogenizing 35 g of the sample (T25 Janke and
169 Kunkel turrax) for 5 min with 40 mL of methanol, 10 mL of double distilled water and NaF
170 to inactivate polyphenol oxidases and to prevent phenolic degradation. The homogenate
171 was centrifuged (Selecta Medifriger-BL, 10,000 rpm, 10 min, 4 °C) to obtain the
172 supernatant that was filtered through a 0.45 μm membrane filter. HPLC method and
173 instrumentation was: Ultrabase-C18, 5 μm (4.6x250 mm) column (Análisis Vínicos,
174 Tomelloso, Spain); mobile phase was composed of methanol and water and a linear
175 gradient elution was performed starting at 30:70 to reach 100:0 at 70 min, volume injection
176 25 μL and flow rate 1 mL/min. Chromatograms were recorded at 286, 284 and 254 nm and
177 at 25 °C. The standard curves of the reference flavonoids, narirutin (NAT), naringin (NAR),
178 hesperidin (HES), neohesperidin (NEOH), didymin (DID), poncirin (PON), naringenin

179 (NAG) and quercetin (QUER) (Extrasynthese, France) were used to quantify the
180 flavonoids. Naphthalene was used as internal standard (Peiró, 2007; Igual et al., 2011b).
181 The results were expressed as mg of each flavonoid per 100 grams of fresh sample,
182 considering the percentage of fresh grapefruit in the sample. Changes in each compound
183 along storage were expressed as the compound variation (ΔM_i) referred to the fresh
184 grapefruit content, according to equation (1).
185
186 *2.5. Statistical analysis*
187 Significant differences among treatments and storage time were evaluated by means of
188 the corresponding analysis of variance (ANOVA) performed by using Statgraphics Plus
189 5.1. Values of $p<0.05$ were considered to represent a significant effect. A Principal
190 Component Analysis (PCA) with varimax rotation was applied to the values of the
191 flavonoid content, using SPSS program version 16.0.
192
193 **3. Results and Discussion**
194 Significant differences were found among water activity of all the jams, the values being
195 0.945, 0.942, 0.924 and 0.922 (standard deviation 0.003 in all the cases) for ODJ,
196 OD+MWJ, MWJ and CJ, respectively. As regards pH (standard deviation 0.02 in all the
197 cases), no significant differences were found between ODJ, OD+MWJ (3.39 and 3.40,
198 respectively) while it was significantly different from that of MWJ (3.27) and CJ (3.25).
199 Some authors have indicated that freezing, pasteurization, boiling and microwave cooking
200 generally reduce the antioxidant capacity of fruits (Aziz et al., 1998; Gil-Izquierdo et al.,
201 2002; Guyot et al., 2003). Phenolics and carotenoids have been described as antioxidant
202 compounds. Processing of fruits normally leads to a decrease in the concentration and a
203 change in the composition of phytochemicals including flavonoids (Tsao et al., 2006).
204 Carotenoids are lost between 5 and 40%, depending on the conditions of food preparation

205 and preservation (Belitz & Grosch, 1997, Eitenmiller & Laden, 1999). The impact of the
206 different processes carried out in the present work to obtain jam on these compounds is
207 shown in Table 1, where the mean values of β-carotene and flavonoids content of FG,
208 ODG and jams, all of them referred to 100 g of fresh grapefruit, appear. Table 2 shows the
209 loss of each analyzed compound, compared to the content present in the fresh fruit, due to
210 processing and storage.
211 The β-carotene is the major dietary precursor of vitamin A (Xu et al., 2006), becoming
212 retinol inside the human body (Belitz & Grosch, 1997). Besides its function as pro-vitamin
213 A, the functional significance of this carotenoid is also due to its antioxidant action
214 (Bushway, 1986). As is shown in Table 1, in this study FG showed values in the same
215 order to those obtained in previous studies for red grapefruit of the same variety (0.2-1.3
216 mg/100 g; Ladaniya, 2008; Rojas, 2004; Rouseff et al., 1992). After osmotic-dehydration,
217 the sample retained the β-carotene content. When comparing the jams, ODJ was the only
218 one that completely preserved the β-carotene content showing only 4.19% loss of this
219 compound. Nevertheless the sample subjected to combined treatment (OD+MWJ)
220 presented the greatest loss (29 g β-carotene loss/100 g β-carotene present in the fresh
221 fruit, Table 2). The jams obtained by applying an intense thermal treatment (CJ and MWJ)
222 showed similar values of this compound, with about 17.5 g β-carotene loss/100 g β-
223 carotene present in the fresh fruit (Tables 1 and 2). In general, β-carotene is sensitive to
224 oxygen and light, oxidation losses occurring especially at high temperatures (Lesková et
225 al., 2006). On the other hand, in the absence of these two factors, β-carotene is quite
226 stable at elevated temperatures (cooking), producing in this case isomerization and
227 fragmentation.
228 Figure 1 shows the β-carotene change in the jams during storage period, referred to the
229 content in the fresh sample. β-carotene losses were faster during the first week in the case
230 of ODJ and during the first 15 days in the rest of the jams. From that moment onwards, the

β-carotene content remained constant until the end of storage in all the jams. After 3 months, the samples that were subjected to more intense heat treatments during jam preparation presented a loss between 33 and 38% (Table 2); lower values than these were observed for jams made from osmodehydrated fruit (55-56%). Although the OD treatment maintained the β-carotene content of the fresh grapefruit, greater losses during storage were observed in OD and OD+MWJ samples. This could be related to the greater a_w and pH of the jams obtained from OD fruit. As it can be observed in Table 1, the most abundant flavonoid in the fresh grapefruit was NAR followed by NAT, QUER and NAG, results that closely agree with other studies (Gorinstein et al., 2006; Igual et al., 2011b; Peterson et al., 2006a, Ross et al., 2000; Vanamala et al., 2006). In general, osmotic dehydration of the fruit caused no changes in the concentration of the studied flavonoids. Only a significant HES decrease was detected. All the processes carried out to obtain jams significantly ($p<0.05$) decreased the content of NAT, PON, NAG and QUER. NAR remained stable during all treatments without showing significant ($p>0.05$) differences with the fresh grapefruit. Jams obtained by heating (CJ, MWJ and OD+MWJ) showed significant ($p<0.05$) lower values of NAG, DID and QUER as compared to ODJ while NAT, HES and NEOH were worse preserved in ODJ. The loss of each compound due to the jam elaboration process appears in Table 2. As regards the total flavonoids in the samples, calculated as the sum of the individual analysed flavonoids, fresh and OD grapefruit contained about 140 mg/100g fresh fruit and all the jams presented a significant ($p<0.05$) lower content, ODJ followed by MWJ being the ones with more flavonoids (about 124 mg/100g fresh fruit). A total flavonoids loss caused by processing of 9-18 g/100g total flavonoids present in the fresh fruit was quantified (Table 2).

The change in content of flavonoids in the obtained jams during storage appears in Figures 2 and 3. In general, losses of all the studied flavonoids, except in the case of PON, could be observed. In all the jams, PON remained stable during the first month of storage

257 and thereafter, it increased. This increase can be attributed to a chemical transformation of
258 NAG and NAR (Igual et al., 2011b). During the first 45 days of storage, NAT and NAG
259 remained stable and from that moment onwards, its content decreased until the end of
260 storage. The greatest loss of HES, NEOH and DID occurred in all the samples during the
261 first 15 days. From that moment, the content of these flavonoids remained stable until the
262 end of storage. Intensive thermal treatments (CJ and MWJ) lead to greater losses in NAR,
263 HES and NEOH during storage, while jams made from osmodehydrated fruit lost more
264 QUER and NAG in this period (Table 2). Figure 4 shows the variation in the sum of all the
265 flavonoids considered referred to the content in the fresh fruit, during 3 months of storage.
266 Jams presented losses during the storage period in the range of 21.5-29.3 g total
267 flavonoids/100g total flavonoids present in the fresh fruit (Table 2). These losses were
268 more marked from day 45 (Figures 2 and 3). The more intensively treated samples (CJ
269 and MWJ) showed the greatest loss during the studied period.
270 The evolution of flavonoids content can be easily observed by means of the PCA carried
271 out with the values corresponding to all the jams at different storage times (Figure 5). The
272 first two factors showed eigenvalues higher than 1. The consideration of both factors
273 accounted for 83.79 % of the total variability. The first factor (F1), explaining 51.14% of the
274 variability, was associated with DID (r=0.94), NEOH (r=0.93), NAR (r=0.93), HES (r=0.90),
275 QUER (r=0.75) and NAG (r=0.74) values. The second factor (F2) accounted for 26.65% of
276 the variability and it was mainly associated with PON (r=0.94) and NAT (r=0.91) values. All
277 the grapefruit jams newly processed showed a higher content of the flavonoids associated
278 with F1 and of NAT but low of PON. During the first month of storage, PON and NAT
279 remained stable while the rest of the flavonoids decreased. From this moment onwards,
280 NAT decreased and PON increased while the other flavonoids did not showed additional
281 changes. Applying a multifactor ANOVA to the values of F1 and F2, it can be observed
282 that both factors are affected by the interaction of the progress of time and the treatment

283 applied to obtain jams. F1 decreased more sharply during the first month in CJ and MWJ
284 as compared to ODJ and OD+MWJ while F2 decreases faster during the last two months
285 in the samples ODJ and OD+MWJ when compared to CJ and MWJ.
286 As can be observed in Table 2, in general the losses of the analyzed compounds in jams
287 caused by processing were lower than those provoked by storage period. As regards the
288 total losses occurred due to both processing and storage, the β-carotene loss when
289 compared to its content in the fresh fruit was between 53 and 86 %, being the combined
290 treatment (OD+MWJ) especially less recommendable to preserve this compound. In the
291 case of flavonoids, these loosses were between 33 and 47 %, the greatest ones being
292 showed by the more intense thermally treated jams, especially the one obtained by using
293 the conventional procedure.
294
295 **4. Conclusion**
296 Flavonoids of grapefruit are better retained than β-carotene in jams. The greatest losses of
297 the analyzed compounds occurred during jam's storage and not during the production
298 processing. Taking into account the obtained results, microwave heating may be proposed
299 as a good process, better than osmotic dehydration or conventional heating, to obtain a
300 stable jam. This procedure can best fulfill the commitment process time-functional quality
301 of the stored obtained product. Osmotic dehydration would only be recommended if a
302 ready to eat jam is wanted to be obtained.
303
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307

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473 **FIGURE CAPTIONS**
474 **Figure 1.** β-carotene variations of studied jams along 3 month of storage.
475 **Figure 2.** Narirutin (NAT), naringin (NAR), naringenin (NAG) and quercetin (QUER)
476 variations of studied jams along 3 month of storage.
477 **Figure 3.** Hesperidin (HES), neohesperidin (NEOH), didymin (DID) and poncirin (PON)
478 variations of studied jams along 3 month of storage.
479 **Figure 4.** Principal Component Analysis (PCA) with varimax rotation of the values of
480 flavonoid content corresponding to all the grapefruit jam samples. D0, D30, D60 and D90
481 indicate storage days.
482 **Figure 5.** Total flavonoids variations of studied jams along 3 month of storage.

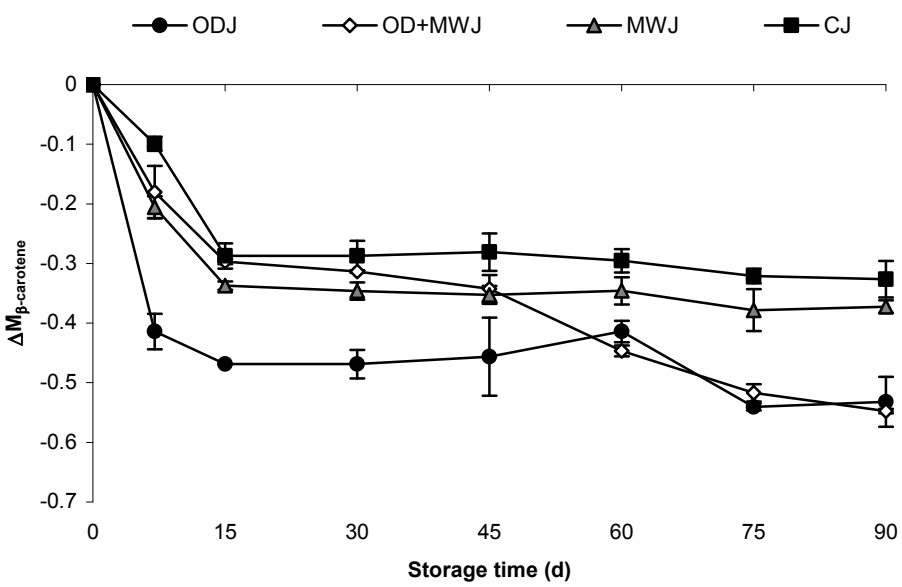
ODJ
OD+MWJ
MWJ
CJ
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
ΔMβ-carotene
0
15
30
45
60
75
90
Storage time (d)

Figure 1

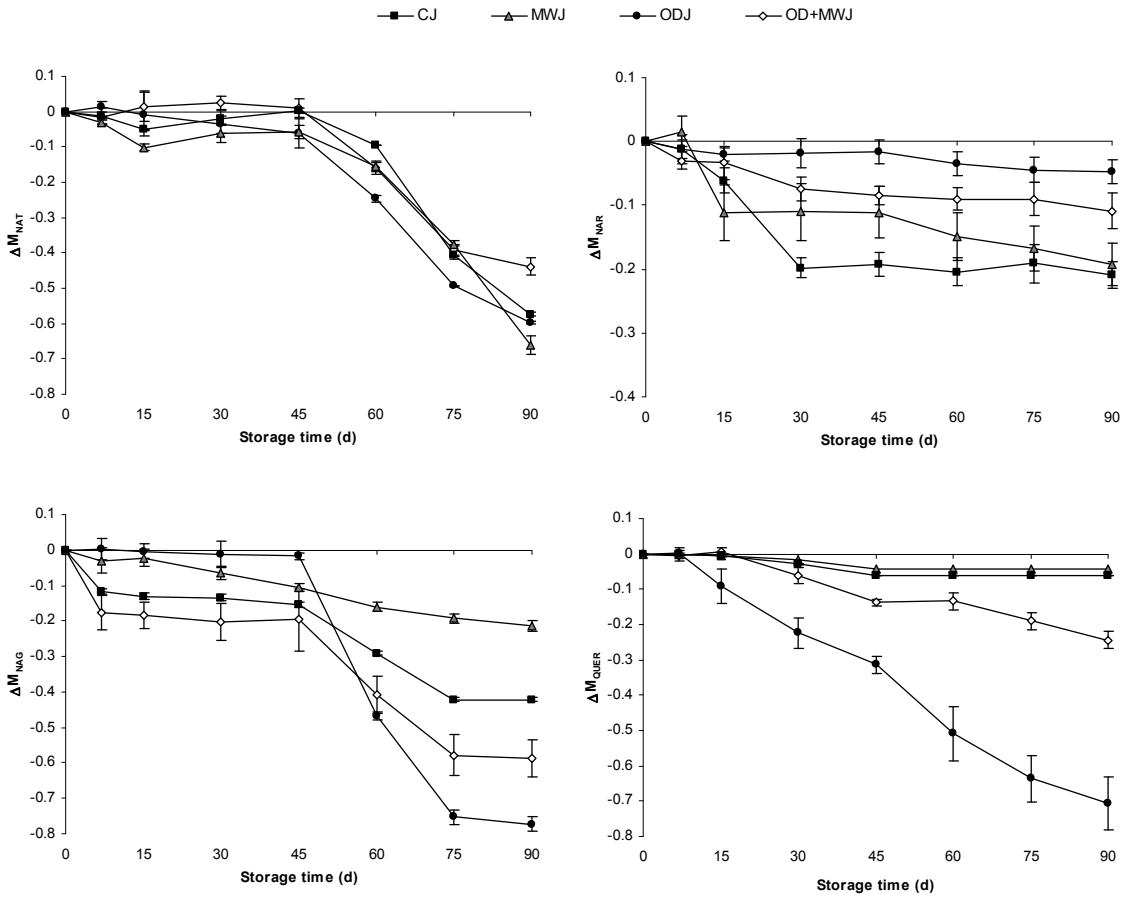

Figure 2

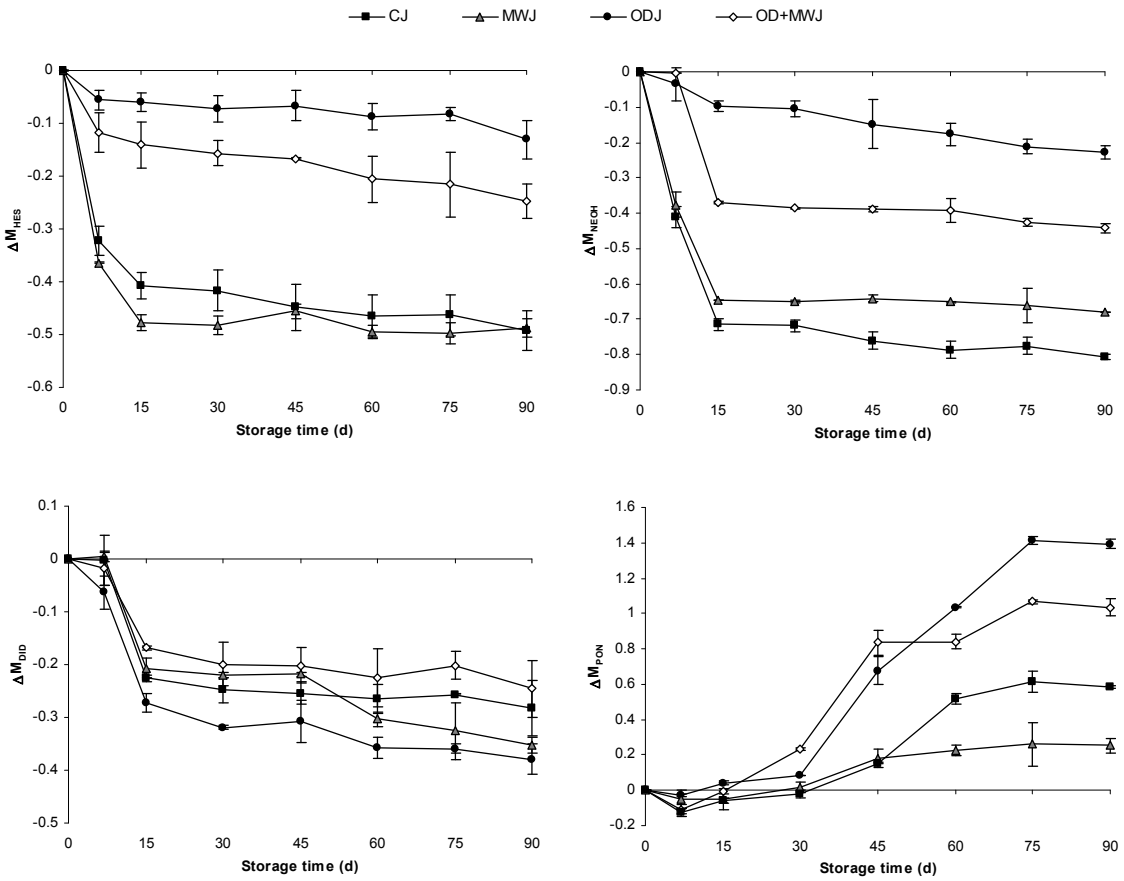

Figure 3

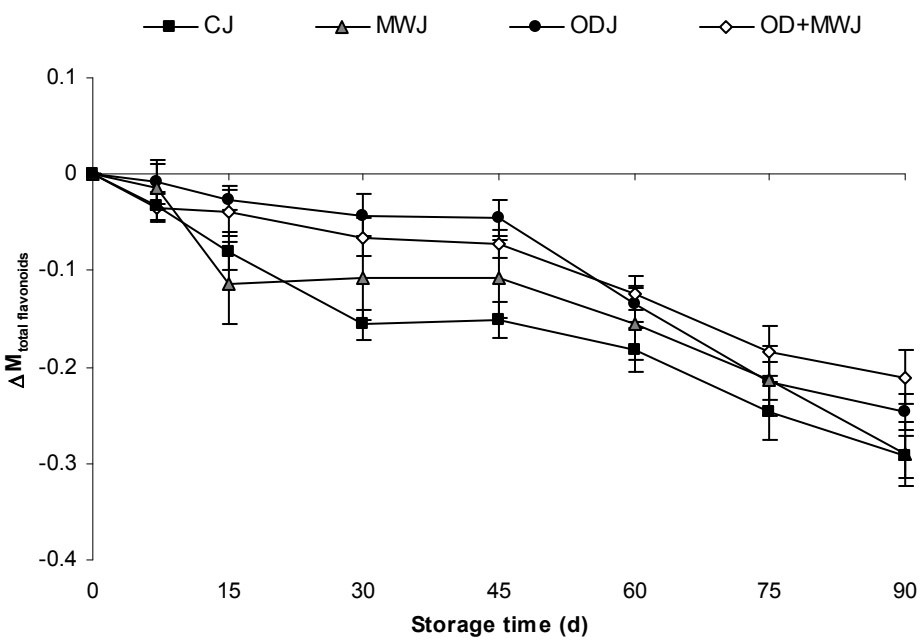
CJ
MWJ
ODJ
OD+MWJ
0.1
0
-0.1
-0.2
-0.3
-0.4
ΔM total flavonoids
0
15
30
45
60
75
90
Storage time (d)

Figure 4

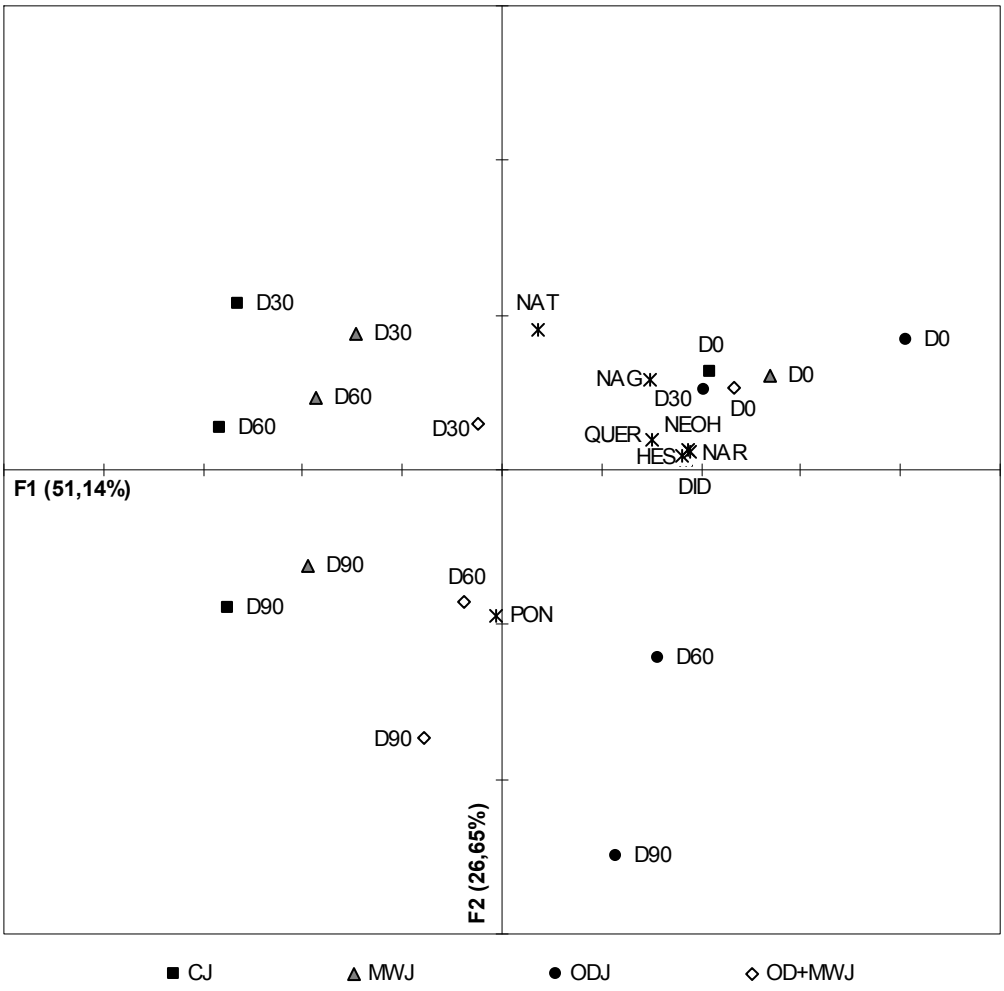
D30
D30
D60
D60
D30
NAT
D0
D0
NAG
D0
D30
D0
NEOH
QUER
HES
NAR
DID
F1 (51,14%)
D90
D60
D90
PON
D60
D90
D90
F2 (26,65%)
CJ
MWJ
ODJ
OD+MWJ

Figure 5

Table 1. Mean values (with standard deviation) of β-carotene and flavonoids content (mg / 100 g fresh fruit) in fresh grapefruit (FG), osmodehydrated grapefruit (ODG) and jams obtained by convencional processing (CJ), microwave (MWJ), from osmodehydrated grapefruit (ODJ) and by combined treatment (OD+MWJ).

Compound	FG	ODG	CJ	MWJ	ODJ	OD+MWJ
β-carotene	2.58 (0.11)^{a}	2.60 (0.14)^{a}	2.05 (0.02)^{b}	2.22 (0.06)^{b}	2.48 (0.05)^{a}	1.83 (0.02)^{c}
NAT	29.4 (0.4)^{a}	28.7 (0.2)^{a}	24.2 (0.3)^{b}	25.3 (0.6)^{b}	22.2 (0.5)^{c}	20.0 (0.8)^{d}
NAR	84 (3)^{a}	82 (2)^{a}	81 (5)^{a}	85 (3)^{a}	81 (2)^{a}	84 (6)^{a}
HES	2.40 (0.06)^{a}	1.98 (0.09)^{b}	2.09 (0.05)^{b}	2.24 (0.04)^{a}	1.76 (0.05)^{c}	1.72 (0.07)^{c}
NEOH	2.92 (0.07)^{ab}	2.94(0.2)^{a}	3.13 (0.05)^{a}	3.09 (0.09)^{a}	2.6 (0.2)^{c}	2.64 (0.07)^{bc}
DID	1.42 (0.03)^{a}	1.5 (0.2)^{a}	0.95 (0.03)^{c}	1.10 (0.02)^{bc}	1.46 (0.02)^{a}	1.16 (0.05)^{b}
PON	1.921 (0.010)^{a}	2.06 (0.12)^{a}	0.47 (0.02)^{b}	0.47 (0.09)^{b}	0.52 (0.02)^{b}	0.60 (0.03)^{b}
NAG	8.3 (0.2)^{a}	8.5 (0.4)^{a}	3.49 (0.04)^{d}	3.55 (0.04)^{d}	6.8 (0.4)^{b}	4.9 (0.5)^{c}
QUER	11.4 (0.2)^{a}	11.34 (0.03)^{a}	0.70 (0.02)^{d}	0.50 (0.04)^{d}	8.6 (0.8)^{b}	3.1 (0.2)^{c}
Total Flavonoids	141 (3)^{a}	139.4 (0.8)^{ab}	116 (5)^{d}	119 (7)^{cd}	129 (4)^{bc}	115 (3)^{d}

The same letter in superscript within rows indicates homogeneous groups established by the ANOVA ($p<0.05$).
NAT: narirutin, NAR: naringin, HES: hesperidin, NEOH: neohesperidin, DID: didymin, PON: poncirin, NAG: naringenin y QUER: quercetin

Table 2. Loss of each analyzed compound, compared to the content of the correponding compounds present in the fresh fruit, due to the process and also to the storage in jams obtained by convencional processing (CJ), microwave (MWJ), from osmodehydrated grapefruit (ODJ) and by combined treatment (OD+MWJ).

Compound	g component lost during processing / 100g component present in fresh grapefruit				g component lost during storage / 100g component present in fresh grapefruit				g component lost during processing and storage / 100g component present in fresh grapefruit			
	CJ	MWJ	ODJ	OD+MWJ	CJ	MWJ	ODJ	OD+MWJ	CJ	MWJ	ODJ	OD+MWJ
β-carotene	20.83	14.13	4.19	29.19	33.63	38.36	54.82	56.42	54.46	52.49	59.01	85.61
NAT	17.75	14.20	24.42	31.92	57.47	66.08	59.79	44.27	75.21	80.28	84.21	76.19
NAR	3.11	0.009	-1.87	3.03	20.98	19.31	4.80	11.20	24.09	19.32	2.93	14.23
HES	13.04	6.50	26.61	28.16	49.25	48.63	12.97	25.25	62.29	55.13	39.57	53.42
NEOH	-7.45	-6.01	12.01	9.60	80.57	67.89	22.90	44.98	73.12	61.89	34.91	54.58
DID	33.32	22.75	-2.90	18.19	28.18	35.30	37.89	24.98	61.50	58.05	34.98	43.17
PON	75.38	75.38	73.13	68.98	-58.39	-25.47	-139.33	-103.15	16.99	49.91	-66.19	-34.16
NAG	57.78	57.04	18.20	39.72	42.22	21.37	77.26	59.67	100.00	78.41	95.45	99.39
QUER	93.85	95.58	24.53	73.36	6.15	4.42	70.67	24.13	100.00	100.00	95.20	97.48
Total Flavonoids	17.87	15.21	8.67	18.45	29.33	29.02	24.66	21.47	47.20	44.23	33.33	39.92

NAT: narirutin, NAR: naringin, HES: hesperidin, NEOH: neohesperidin, DID: didymin, PON: poncirin, NAG: naringenin y QUER: quercetin