THE SYNERGISTIC EFFECTS OF A HARVESTING AND CONSERVATION METHOD DESIGNED FOR SMALL PRODUCERS ON THE QUALITY OF THE PRODUCED OLIVE OIL.

Small-scale harvesting and storage effects on oil quality (short running title)

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ACKNOWLEDGMENTS

This work was funded by the Spanish Ministry of Science and Innovation (research project AGL2015-71585-R). We thank the Del Cetino Olive Farm and their personnel for their collaboration and Carmen Martínez for her technical assistance.

ABSTRACT

The production of ‘Premium’ olive oil depends in a large part on the quality of the fruit. Small producers see themselves confronted with vast investments and logistic snags when they intend to optimize the harvesting. Today, manual harvesting devices promise less damaged fruit when compared to the traditional methods with nets while the use of a cooling room on the farm is suggested as a solution when the harvesting needs to be stretched out over several days. The use of a manual inverted umbrella during the harvest, together with a storage up to 14 days at 5 °C at a family farm, was studied for three cultivars, ‘Arbequina’, ‘Picual’, and ‘Verdial’. Ten quality parameters of the produced oil were examined in two consecutive years together with an extended sensory analysis in the first year. The results underline the importance of the used harvesting and conservation method on the quality of the extracted oil. The strength of each factor varied in time and according to the cultivar. The ‘Arbequina’ c.v. showed a rapid increase in the importance of the conservation factor, while ‘Picual’ c.v. was the most resistant to deterioration, presenting a lower explanatory value of the conservation factor as compared to the harvesting one. The results indicate that small producers with financial and logistic restrictions can obtain a high-quality product. Either by combining both methods or by choosing the one that guarantees the best results given the cultivar and the specific storage time they need to consider.

KEYWORDS

cold storage, manual inverted umbrella, omega square, quality parameters, sensory analysis, virgin olive oil

1. INTRODUCTION

The extension of the Andalusian olive fruit production is with more than 1.500.000 ha not only the core agricultural activity for that region but also the main source of income for more than 250 villages (Junta de Andalucía, 2015; Ley Del Olivar, 2011). Lesser-known characteristics are that 60 % of the 170.000 exploitations are smaller than 5 ha and 80 % less than 10 ha and that more than 50 % of the Agricultural Work Units is done in a strictly family context, in particular as non-salary-compensated work (Junta de Andalucía, 2015).

These structural factors have a direct impact on the used harvesting methods as they limit the financial possibilities of the small producers. Many of them, already of advanced age (70 % are older than 45 years) of which only 60 % define agriculture as their prime activity, are not inclined to do big investments (Serrano *et al.*, 2012; Colombo and Villanueva, 2017). There are several methods available for harvesting olives trees that target the tree in different ways (Sola-Guirado *et al.,* 2014). The impossibility to amortize sophisticated but expensive machinery on the one hand, or to contract specialized services on the other, explains why many small farmers continue to harvest their olives traditionally, beating the olive tree with sticks with nets put on the ground around it.

This traditional method implies that once the fruit is detached, the nets are dragged to the next tree, where they are spread out again until their weight is too heavy to be lugged any further. At that time the fruit is collected in containers or a truckload. The method is speedy and implies low costs but has several inconveniences that may jeopardize the intactness of the fruit. Dragging the fruit on the nets over the ground damage them inevitably, while the harvesters cannot avoid stepping on the fallen fruit while beating the branches. The relation between the quality of the fruit and the extracted oil has been the object of many studies and proven to be primordial to obtain an excellent end product (Garcia and Yousfi, 2006; Yousfi *et al.*, 2012; Rallo *et al.*, 2018; Faminiani *et al.*, 2020). However, when one decides to maximize the yield of

71 the production, the quality of the fruit becomes less important compared to the applied
72 extraction techniques.

73 During the last decade, a growing number of Spanish mills started to produce so-called
74 EVOO Premium's, instead of the common one-sided attention on maximizing the quantity. The
75 choice for quality instead of quantity goes along with the necessity to evaluate rigorously the
76 quality of the fruit in the reception yard, and an adjusted reimbursement to the producer. More
77 recently, preliminary studies to automatize this evaluation are preceding more stringent quality
78 controls soon (Puerto *et al.*, 2015; Navarro Soto *et al*. 2018; Aguilera Puerto *et al.*, 2019).

79 Meanwhile, a new kind of olive oil producer came to the foreground. Smaller-scale and
80 with a clear focus on the production of high quality. However, these producers do not only face
81 the challenge to optimize their harvesting but also confront an additional problem if they do not
82 extract the oil themselves, such as the restrictions that are imposed by the mill that processes
83 their fruit. The necessity to bring in at least several tons of olives to process them as a single
84 batch implies several days of harvesting when working on a family scale. While it is common
85 knowledge that the olives are ideally processed as soon as possible, the conservation of the
86 picked fruits becomes thus a core problem for these small producers.

87 The need to produce good quality oils is emphasized when olive production is
88 approached from a small producer's point of view, not only for them but also for the member of
89 the local cooperative who will be reimbursed not only on the yield but also on the quality of the
90 fruit. A growing amount of economic harvesting devices is coming on the market that
91 specifically addresses these small producers. One promising method for this purpose is the
92 Manual Inverted Umbrella (MIU) which consists of a foldable umbrella that is mounted on the
93 movable structure to collect the fallen fruit harvested using manual aids methods such as
94 branch shakers or shaker rakes. The use of such a MIU turned out to be competitive when

compared with the traditional method while the quality of the picked fruit was significantly better (Plasquy *et al.*, 2019, 2021).

To maintain the fruit at its best, conservation at 5°C is extensively studied and proven for more than 25 years (García and Streif, 1991; García *et al.*, 1994; Canet and García, 1999; Pereira *et al.*, 2002). These studies were mainly focused on prolonging the use of the extraction lines and thus envisioned conservation up to one month or more (García *et al*., 1996). The benefits of adequate conservation at a shorter time have not been yet studied, especially when the aim is to produce premium quality virgin olive oil and not just avoiding a significant deterioration of its initial quality (Kalua *et al.*, 2008). Nevertheless, it might offer a solution for the individual farmer who seeks to keep his harvested olives during a limited time on the farm before their transport to the mill. It makes it possible to plan the harvesting according to the available workforce, to anticipate bad weather, and to organize in advance a convenient transport and time slot in the mill.

Knowing that both methods (harvesting and conservation) contribute in a significant way to a better result does not answer the question which one has a major impact on the quality parameters of the produced olive oil, especially when the storage time is taken into account as a complementary factor. This work aims to study the effect of MIU harvesting and cold storage on the quality of olive oils. This study becomes vital when the economic resources of the farmer are viewed as a limiting factor in the decision process.

2. MATERIAL AND METHODS

2.1. Location

The experiment took place in the olive groove of 'Del Cetino', situated in Bollullos par del Condado (Huelva). It covers 8 ha and includes 1700 trees, mainly of the varieties

119 'Arbequina', 'Picual', and 'Verdial', planted between 2005 and 2007 at distances of 6 x 7 m
120 and irrigated on a deficient regimen at 50 % of the estimated crop evapotranspiration.

121

122 **2.2. Harvesting method and conservation facilities**

123 The farm disposes of a MIU and a cooling room with a storage capacity of 5000 kg. The
124 harvesting was performed with a prototype of a MIU and with nets as the control group
125 (Plasquy *et al.*, 2019). The device has an inverted umbrella structure with a width of 6.85 m
126 and is formed by 14 aluminum bars covered with a resistant canvas mounted on a chassis with
127 4 wheels (Fig. 1). Through an opening in the canvas, the harvested fruit is collected into a
128 plastic and perforated box of 20 kg capacity. This box is introduced and extracted by a system
129 of pulleys and ropes. Two branch shakers (Stihl SP471) were used to detach the fruit.

130 Two types of harvesting were performed: one using the MIU system (R1) and another
131 using a traditional one, collecting the fruit detached on nets on the ground (R2), both storing the
132 caught fruit in the same perforated boxes. Then the boxes were stored in a pile in a cooling
133 room with a size of 4.3 x 4.4 m and 2.45 m in height isolated with 10 cm thick extruded
134 polystyrene insulating panels on the walls, floor, and roof. (Fig. 2). In the upper part the cold
135 group was placed, formed by a compressor (EMBRACO, UNJ 9232) and an evaporator (LU-
136 VE, SHDN 25-80). The temperature was set at 5 °C (± 1 °C). The boxes of the control group
137 were stored outside under a protected roof at ambient temperature. The mean temperatures in
138 October 2017 were 15.4 °C (min) and 29.3 °C (max) and in October 2018, 14.2 °C (min) and
139 24.7 °C (max). Two types of conservation were performed: one using the cooling room (C1)
140 and another storing the boxes outside at ambient temperature (C2).

141

142 **2.3. Experimental material**

143 The trials took place between the end of September and the beginning of November
144 during two consecutive years (2017-2018) when the majority of the olives were still green (in
145 all cases the Maturity Index of the fruit samples was situated between 1,5 and 2,5). To assess
146 the effects of the harvesting and conservation method on the produced oil, an equal amount of
147 fruit from the 'Arbequina', 'Picual', and 'Verdial' cultivars were taken at the same moments
148 and under the same conditions as those intended for industrial extraction. Also, it was evaluated
149 the conservation time of 0, 4, 8, and 14 days. To evaluate each factor (harvesting method,
150 conservation method, and conservation time), triplicates of olive samples of both harvesting
151 methods were kept during the distinct periods each one in 6 boxes of 20 kg, which were
152 previously distributed in the cooling room at 5 °C and outside at ambient temperature. The two
153 harvesting methods (R1 and R2), two types of conservation (C1 and C2), and four distinct
154 conservation periods (T0, T4, T8, and T14), gave rise to 18 different combinations of factors
155 for each variety and each year.

156

157 **2.4. Preparation of the samples**

158 The extraction of the oil was performed in the laboratory using an "Abencor" system
159 (Martinez *et al.*, 1975). Individual samples of 1.500 g olives were crushed in the hammer mill
160 and the resulting paste was distributed in two subsamples of 700 g, which were weighed in two
161 stainless steel casserole pots. Then the paste was malaxated in the thermoblender for 30 min at
162 30 ºC. Afterward, the malaxated paste of each pot was centrifuged at 1.000 G for 1 min. The
163 resulting solid phase of the paste was discarded and the liquid obtained was placed in a
164 graduated 500 mL test tube for separating the aqueous phase of the lipid phase. The Virgin
165 Olive Oil (VOO) extracted from both subsamples was taken from the lipid phases using a
166 Pasteur pipette, filtered with filter paper, and placed in a glass bottle of 250 mL, which was

167 filled with nitrogen and kept at -20 ºC until further examination. The experiment was carried
168 out in triplicate.

169

170 **2.5. Physico-chemical analysis**

171 Free fatty acidity (FFA), Peroxide value, absorbency at 232 and 270 nm were
172 determined according to the official analytical methods as described in EEC guidelines (EEC,
173 1991).

174 The oxidative stability was evaluated using the Rancimat method. The stability was
175 expressed as the oxidation induction time (h) measured with the Rancimat apparatus (Metrohm
176 AG, Herison, Switzerland) at a temperature of 120 °C and an airflow rate of 20 L/h.

177 The chlorophyll and carotenoid pigment profile was obtained by measuring the
178 spectrophotometric absorbency in the ultraviolet, respectively at 470 nm for the carotenoids
179 and 670 nm for the chlorophyll fraction.

180 The bitterness index used to estimate the presence of the attribute 'bitterness', was
181 calculated using the formula: $IA = 13{,}33 \times K_{225} - 0{,}837$ (21).

182 An estimation of the total polyphenols was obtained by the sum of the calculated
183 amount of polyphenols obtained by measuring the spectrophotometric absorbency at 280 and
184 335 nm using p-hidroxifenil acetic acid and orto-cumaric acid as calibrating patron
185 respectively. Prior measurements revealed a calibration function for p-hidroxifenil acetic acid
186 of $y = 0{,}0585x - 0{,}0007$ and for orto-cumaric acid of $y = 0{,}0218x + 0{,}0001$.

187 The content of α-tocopherols was determined through high-performance liquid
188 chromatography (HPLC) using the IUPAC method (IUPAC, 1992).

189

190 **2.6. Sensory analysis**

191 A sensory evaluation of the oils was performed to reveal significant differences between
192 the treatments in the first year. The analytical panel was formed by 8 approved tasters of the
193 Instituto de la Grasa (CSIC, Sevilla) and applied the method as described in the EC regulation
194 640/2008. The procedure permits the classification of the EOV's according to the presence of
195 negative attributes (Muddy, Musty, Winey, Frostbitten, Rancid, others) as well as a
196 measurement of the intensity of positive attributes (Fruity, Bitter, Pungent). The panel members
197 were also asked to classify the presented samples in order of preference to examine whether
198 there were significant differences noticeable between the different treatments at each storage
199 day. To reduce the number of unnecessary tastings the selection started with the samples of day
200 0 and day 14. If no significant difference between them was detected, no further analysis was
201 performed on the oils extracted from the same cultivar on days 4 and 8.

202

203 **2.7. Statistical data analysis**

204 Statistical data analysis of the physicochemical parameters was performed using PASW
205 Statistics 18.0 (SPSS). For each cultivar, one-way ANOVA determined the effect of the storage
206 time, considering independently each combination of the other factors (harvesting and
207 conservation method), as well the effect of these four combinations for each separately.
208 Similarly, for each period, the effect of harvesting was studied independently for each
209 conservation method and vice versa. The effect of the storage time and the treatments, defined
210 as the four possible combinations of, on the one hand, R1, R2, and on the other S1, S2, was
211 tested with two-way ANOVA. Finally, the effect of three factors (storage time, harvesting
212 method, and conservation method) was studied by three-way ANOVA. If a significant effect of
213 one of the factors was detected in a parameter, the Tuckey test was applied to discriminate
214 mean values ($P < 0.05$) in each variable.

For each time, the effect size of the different factors and their interaction was determined by calculating the $\hat{\omega}^2$ value. The effect size is a descriptive statistic indicating the proportion of variability in the observed data that is accounted for by the treatments (Maxwell *et al*., 2018). The effect size can be estimated in various ways, but the calculation of the Omega-Square ($\hat{\omega}^2$) was preferred because this estimation resulted to be less biased when dealing with small samples as compared to Eta and Partial Eta-Squared (Maxwell *et al*., 2018; Yigit and Mendes, 2018).

The calculation was performed in MS Excell, using the data from the SPSS analysis in the following formula (equation 1):

$$\hat{\omega}^2 = \frac{SS_{Effect} - df_{Effect} MS_{Error}}{SS_{Total} + MS_{Error}} \quad (1)$$

with

SS_{Effect} = the Sum of Squares of each effect (R, C, or R × C)

df_{Effect} = the degrees of freedom of each effect (R, C, or R × C)

MS_{Error} = the mean square error

SS_{Total} = Sum of Squares total.

Negative values were set to zero. Omega squared measures become positive when the observed F value exceeds 1,0. Only in these cases, the effect accounts for variance in the population.

To estimate the tendency of the overall effect of the methods on the produced olive oil over time, the average of the $\hat{\omega}^2$-values for all the parameters and both years for each ST were

calculated. The selection of these parameters was not predetermined because to date there is no theoretical model that integrates the various parameters and their weights.

The Friedman test was used to detect differences in treatments in the sensory evaluation (Sprent and Smeeton, 2001; Fernández, 2018). This non-parametric statistical test involves ranking each taster's judgment together, then considering the values of the ranks by columns. The null hypothesis expects that there are no differences between the treatments. When the calculated probability is significant ($P < 0.05$) it can be concluded that at least 2 of the treatments are significantly different from each other.

Once a significant difference was identified within a tasting cluster, the preference of the panel for the treatments was further deciphered through a new statistic: the Panel Preference ($\overline{P}$¿. $\overline{P}$ permit a qualitative positioning of the judgments of a panel, composed of *n*-members who individually ranked *t*-different treatments. The procedure consists of two steps. In the first one, the value of each $\overline{P}_i$ (equation 2) is calculated as a ratio with as the numerator the sum of the rank given to treatment *i* by each member, subtracted by the minimum sum of ranks of a treatment, which equals *n*, to afford comparison of $\overline{P}_i$ -values from panels with a different size. The denominator is formed by the corrected maximum sum of ranks, being the product of *t* and (*n*-1). In a second step, the $\overline{P}$ values of the different treatments, each with a value between 0 and 1, are ranked in descending order, with the highest-ranked treatment having the highest ratio and the lowest-ranked one the lowest.

$$\overline{P}_i = 1 - \frac{\sum_{j=1}^{n} R_{ij} - n}{t(n-1)} \quad (2)$$

with

$\overline{P}_i$ = Panel preference ratio of a specific treatment *i* ($0 < \overline{P}_i < 1$)

257 R_{ij} = Ranking giving by panel member *j* on treatment *i*

258 *n* = number of members in the tasting panel

259 *t* = total number of treatments to be compared in conjunction

260

261 **3. RESULTS**

262 **3.1. Free Fatty Acidity**

263 In all of the three varieties, the storage time showed to be highly significant in year 1
264 and 2, although the 'Arbequina' variety turned out to be much more vulnerable when compared
265 to 'Picual' and 'Verdial', since in both years 'Arbequina' showed a highly significant effect of
266 the factors R and S (Supl. Mat. Table 1). After 4 days there was a clear difference between the
267 oils extracted from fruits harvested with nets and stored at room temperature (R2S2) and the
268 other three possible combinations. In year 1, the FAA of these samples even exceeded the limit
269 of 0,80 % of oleic acid, and as a consequence could not be classified as 'extra'. In year 2, the
270 effect of the cooling was more prominent when compared with year 1 and led to a clear
271 differentiation between the oils on day 14, with the lowest values for treatment R1S1: 0,12 ±
272 0,00, and the highest for R2S2: 0,53 ± 0,03. The values of the $\widehat{\omega}^2$ presented for both years a
273 similar profile over 14 days. On the day of the harvest, day 0, the method of harvesting turned
274 out to explain the variance slightly above 30 % (Table 1). From day 4 on, the effect of the
275 conservation method was always greater than the harvesting method. However, in year 1, the
276 interaction between both methods gained importance from day 4 on, indicating that the effects
277 of the storage method depended in large part on the intactness of the fruit. In year 2, the role of
278 this interaction was downplayed with an obvious effect of S from day 4, and explaining more
279 than 80 % of the variance on day 14.

The ‘Picual’ variety showed to be more resistant toward an increase in the FFA, with similar tendencies on day 14, although without exceeding the official limits. In both years, the R2S2 treatment presented the highest values at day 14. In year 1, no significant effect of the harvesting method was detected (Suppl. Mat. Table 1). Measurement of the effect revealed two different profiles (Table 1). In year 1, a steep increase in the importance of the interaction between both methods became visible from day 4. The same happened for the effect of the conservation method from day 8 on. Both balanced each other in importance at day 14, explaining almost 80 % of the variance. In year 2, 76 % of the variance was explained by the storage method on day 4 which implies a downplaying of the role of the harvesting method. On day 14, the effect of the latter, as well as it is interaction with the storage method, gained importance in explaining the obtained results.

Over the 2 years, the ‘Verdial’ variety presented a confusing image. While the storage time and the treatment were significant in both years, the conservation method showed to be highly significant and the harvesting method not in year 1, while in the following it was exactly the inverse (Supl. Mat. Table 1). This profile was reflected in the calculated effect, which showed in year 1 an increasing importance of the conservation method from day 4 up to almost 60 % on day 14. In year 2, this effect was absent while the importance of the harvesting method fluctuated between 30 and 60 % (Table 1).

3.2. Peroxides

The degree of initial oxidation of the three studied cultivars was similar two years but showed a clear difference between ‘Arbequina’ and ‘Picual’ on one side, and ‘Verdial’ on the other. While oils of the former presented values that were always far below the official maximum of 20 mEq O_2/kg oil, the extracted oils of the latter came close to that threshold in

304 the second year. The Storage time and the harvesting method stood out as a significant factor in
305 all of the 6 different cases, while the conservation method and the interaction between the R
306 and S-factors were only significant in three cases, namely both years in 'Arbequina' and the
307 first year in 'Verdial'. (Suppl. Mat. Table 2).

308 The magnitude of the effect of the different methods showed a similar profile (Table 1).
309 In all the cases, the harvesting method stood out as the most influential factor in all cases on
310 day 14. In 'Arbequina' an increase from day 4 was present in both years. The effect of the
311 harvesting method was at the most during the first 4 days, in which it explained the variance for
312 more than 60 % (year 1) and more than 40 % (year 2). From then on it descended below 5 % on
313 day 14. An effect of the interaction was also involved, although not in the same matter in both
314 years. In year 1, it becomes visible from day 8 where it attained more than 30 % on day 14,
315 while in year 2, the effect is at its most 16 % on day 8. For the 'Picual' variety the effect of the
316 conservation method was neglectable over the whole period while the effect of the recollection
317 method differed in both years. The profile for 'Verdial' was consistent, although the effect of
318 the harvesting method fluctuated between 60 and 80 % during year 1 and between 15 and 30 %
319 in year 2.

320

321 **3.3. K 232 and K 270**

322 The calculated values of the absorbance at 232 nm were only affected by the different
323 factors in one case out of six, namely in year 2 of the 'Verdial' cultivar. 'Arbequina' and
324 'Picual' did not showed a significant difference in the harvesting and conservation methods in
325 neither studied years. The storage time showed to be significant in 'Verdial' and year 2 in
326 'Arbequina' (Suppl. Mat. Table 3). Concerning the absorbance at 270 nm the storage time was
327 the only significant factor in all of the 6 cases. The 3 cultivars were comparable regarding the

328 significance of the harvesting and storage method. All showed a significant effect in the second
329 year for the factor R, while S was not a significant factor in the Arbequina and 'Picual' cases,
330 and only during year 2 in the 'Verdial' variety (Suppl. Mat. Table 4).

331 In year 2, the magnitude of the effect of the harvesting method was substantial in all the
332 3 varieties. In 'Arbequina', it was responsible for 35 % (day 8), in 'Picual' for 62 % (day 8),
333 and in 'Verdial' for 82 % (day 4) and 72 % (day 8) of the variance. A notable effect of the
334 conservation method in the 'Verdial' variety increased from day 8 (8 %) and attained 55 % on
335 day 14, at the cost of the importance of the harvesting method, which was reduced to 21 % at
336 that time (Table 1).

337

338 **3.4. Oxidative stability**

339 The levels of oxidative stability, expressed in hours, varied consistently in the three
340 studied cultivars over both years. The highest values were measured in 'Picual', within an
341 overall range between 90 and 145 h; 'Verdial' showed values between 60 and 80 h, and
342 Arbequina between 27 and 47 h. In 'Arbequina', there was a clear difference in the distinct
343 treatments and a significant effect of harvesting and storage methods. In both years there was a
344 significant effect of the interaction between the conservation method and the storage time,
345 however only in year 1, an interaction effect between the harvesting method and the storage
346 time was observable. In 'Picual', the harvesting method turned out to be a highly significant
347 factor, and this in both years, while this was not the case for the conservation method, except
348 when studied in interaction with the ST. The 'Verdial' cultivar showed a confusing profile
349 when comparing both years. In year 1, the storage time, harvesting method, and conservation
350 method were very significant, however, in year 2 neither one of these factors showed a
351 significant effect (Suppl. Mat. Table 5).

352 The impact of the different factors was consistent in the three varieties, characterized by
353 a superior impact of the harvesting method up to 4 days, followed by a decrease from then on.
354 In the course of the 14 days, the strength of the used conservation method increased, however,
355 its maximum and velocity varied along with the cultivars: In ‘Arbequina’ it attained almost 80
356 % on day 14, in ‘Verdial’ 40 %, and ‘Picual’ 20 %. The results over the 2 years also indicated
357 that the importance of the interaction varies between them. ‘Arbequina’ showed an importance
358 of 20 % at day 4 in year 2. In year 1 of ‘Picual’, 20 % was explained by the interaction on day 8
359 and increased up to 40 % on day 14, while in year 2, the highest impact was on day 8 with 12
360 %. In the case of ‘Verdial’, an increase of up to 20 % in both years was present on day 4.
361 However, in year 1, the impact from then on diminished, while in year 2, levels over 20 % were
362 present up to 8 days (Table 1).

363

364 **3.5. Photosynthetic pigments**

365 The amount of carotenoids and chlorophylls were similar over the two years. In both
366 cases, the three cultivars showed a significant effect on both the Storage time and the treatment
367 (Suppl. Mat. Tables 6 and 7). The three varieties diverted slightly on the effect of the used
368 recollection and harvesting methods over the two years. Overall a significant effect of these
369 factors was present for both photosynthetic pigments over the two years. In year 2, deviant
370 results were obtained in ‘Arbequina’ and ‘Verdial’ regarding the effect of the harvesting
371 method on the level of carotenoids. In that same year, the ‘Verdial’ cultivar did not demonstrate
372 an effect of the harvesting method on the amount of chlorophylls. Finally, the storage method
373 was significant in all cases except in one case, namely in year 1, with regard to the carotenoids
374 in the ‘Picual’ cultivar.

375 The measures of effect on both pigments were comparable although they varied
376 between the cultivar (Table 1). In ‘Arbequina’, both years demonstrated the impressive
377 importance of the storage method, attaining from day 4 up to day 14 values situated around 80
378 % of the explained variance. In ‘Picual’, the importance of the conservation method was only
379 visible in year 2, with a linear growth from day 0 (0 %) to day 14 (80 %). In year 1, the used
380 harvesting method explained the variance with values above 50 % from day 0, only to decent at
381 28 % on day 14. The ‘Verdial’ cultivar, showed to be highly sensitive to the storage method.
382 This was the clearest in year 2, where a steep increase was noticeable from day 4 to day 8,
383 explaining more than 90 % of the variance, up to day 14 with approximately 70 %. In year 1, a
384 linear increase started from day 0 to day 8, after which it descended beneath 10 %. This decline
385 from day 8, went together with a remarkable increase in the importance of the interaction of the
386 factors recollection and harvesting, explaining at day 14 more than 40 % of the variance.

387

388 **3.6. Bitterness Index**

389 The three cultivars presented distinct trends over the 14 days for the Bitterness Index. In
390 ‘Arbequina’, the storage time and the kind of treatment-induced significant effects in both
391 years, but the factor harvesting did not. The Factor conservation as well as its interaction with
392 the storage time came to the fore as very significant in both years. The ‘Picual’ oils did not
393 show a significant effect due to the storage time in year 1, however, the effect of the
394 interactions of this factor with the factors harvesting and conservation, respectively, turned out
395 to be very significant. Separately, the used harvesting and conservation methods exerted
396 significant effects on this parameter. In both years, the bitterness index of ‘Verdial’ oils
397 experimented significant effects due to the storage and treatment factor. In year 2, the effects of

398 the used recollection and conservation methods were significant, while in year 1 only the factor
399 conservation (Suppl. Mat. Table 8).

400 The magnitude of the effects also varied according to the cultivars. While in
401 'Arbequina' the effect of the harvesting method disappeared after day 4, the storage method
402 gained in importance from that moment on, in year 1, attaining its maximum at day 14 of 71 %,
403 and in year 2, even 83 % at day 8 (Table 3). 'Picual' maintained in year 1 a high explanatory
404 power for factor 'harvesting' with a value that fluctuated between 50 and 80 %. In year 2, a
405 value around 60 % was observable up to day 4, after which it sharply descended towards a
406 neglectable value. The factor 'conservation' on the other hand, presented only a slight increase
407 in day 14 up to 30 % in year 1, while in year 2, the values did not exceed 10 %. The 'Verdial'
408 cultivar expressed a steady increase in factor conservation method in year 1, attaining a
409 maximum above 60 % on day 14. In year 2, the same maximum was reached, although
410 interrupted with a slight decline at day 8. The difference between the two years was reflected in
411 reverse when comparing the values of factor harvesting, characterized in year 1 with the
412 disappearance of the effect on day 4 and rebounding at day 8 in year 2 (Table 1).

413

414 **3.7. Total polyphenols**

415 The way the amount of polyphenols was influenced by the harvesting method and
416 storage method varied markedly between the 2 years for the 'Arbequina' cultivar (Suppl. Mat.
417 Table 9). While in year 1 there was a clear effect of all the factors studied, in year 2 no effect
418 due to the factor was detected. The 'Picual' and the 'Verdial' variety showed consistent effects
419 due to storage time and the kind of treatment in both years but diverged in the effect of factors
420 harvesting and conservation. In 'Picual' oils, the used harvesting method induced significant
421 effects on polyphenol content in both years, while the conservation method only exerted a

422 significant effect during year 1. In year 2, the used harvesting and conservation methods
423 induced significant effects on the polyphenol content of 'Verdial' oil, however, the effect of the
424 factor harvesting was absent in year 1.

425 The three varieties expressed the strength of the various factors in different ways (Table
426 1). In year 1, the profile of the 'Arbequina' cultivar was marked by a steep increase of the
427 importance of the used conservation method from day 8, attaining a maximum of 40 % up to
428 day 14. Meanwhile, the impact of the used harvesting method decreased rapidly from day 4 to
429 20 % on day 8. In 'Picual', harvesting came to the fore as the main factor, responsible for
430 explaining between 60 and 80 % during the 14 days, while the impact of the conservation
431 method was with 7 % far less important in year 1. In year 2, the strength of the used harvesting
432 method stayed below 60 % (day 4) and even disappeared from day 8 on. The 'Verdial' variety
433 also presented a confusing result. In year 1, the magnitude of strength of the factor
434 'conservation' was characterized by an increase of almost 60 % at day 8 and followed by a
435 subsequent decrease, while at year 2, the effect at that moment was absent whilst the impact
436 was reduced to less than 40 % and brought forward to day 4. The factor 'harvesting', with no
437 significant effect in year 1, presented in year 2 a steep increase in day 8 (60 %), only to descent
438 rapidly to a neglectable level on day 14.

439

440 **3.8. α-tocopherols**

441 During the two assay years, the storage time and the used harvesting method induced a
442 significant effect on the amount of α-Tocopherols in the oils of the three varieties, as well as
443 the interaction of these factors (Suppl. Mat. Table 10). In contrast, the effect of the used
444 conservation method was absent in both years for the 'Arbequina' and 'Verdial' oils. In the

445 'Picual' cultivar the effect of this factor was only significant in year 1, while the second year
446 was detected a significant effect due to the interaction of this factor and the storage time.

447 The magnitude of the strength of the factor 'harvesting' varied clearly among the two
448 years and the distinct varieties (Table 1). In 'Arbequina' there was a clear difference at day 0
449 (both years 60 %), followed by a descent to 0 % at day 8 and a renewed increase up to almost
450 80 % in year 1 but only 14 % in year 2. In 'Picual', the same high values during day 0 were
451 present, although the profile was different when compared with 'Arbequina'. On day 4 the
452 effect faded away, only to rise to 75 % on day 8 after which it once again descended towards a
453 neglectable value on day 14. During both years, the 'Verdial' variety showed no effect of the
454 factor 'harvesting' at day 0 but expressed from day 4 a profile that was comparable with
455 'Picual' at year 1, with a steady increase in day 8 (60-80%) after which descent was set in
456 towards values below 10 %.

457

458 **3.9. Overall effect of the factors**

459 The means of the obtained $\hat{\omega}^2$-values for both years and all parameters, were used to
460 express the tendency of the magnitude of strength that characterized the different factors along
461 the storage time of the olives (Figure 3). In 'Arbequina' the profile of the three factors under
462 study, namely the harvesting and conservation methods, and the interaction between both, was
463 characterized by a rapid decrease of the initial importance of the factor 'harvesting' towards
464 day 4 (60 %) after which its explanatory share settled around 15 % for the rest of the studied
465 period. On day 4, the factor 'conservation' became responsible for more than 30 % and further
466 increased to almost 40 % on day 14. The interaction of both factors was situated at 15 % on day
467 4 after which it slightly fell around 10 %. The descending importance of the used harvesting
468 method and the increasing one of the used conservation methods became equal around day 3

after which the factor ‘conservation’ started to exert a major effect on the final result (Figure 1a). In ‘Picual’, the recollection method was the most important factor in explaining the variance. Despite a moderate decrease from day 1 (55%) to day 4, the value on this day and day 8, were situated around 30 %. From then on the value descended further to less than 15 %. The factor ‘conservation’ on the contrary did not attained a level above 15 % until day 14 where it surpassed the impact of the factor ‘harvesting’ and attained about 25 %. The effect of the interaction came only into play on day 8 with values slightly above 10 % (Figure 1b). The ‘Verdial’ cultivar presented a similar profile as ‘Picual’ concerning the used harvesting method, although with lesser present importance at day 0 (25 %) and overall lower values when compared to the latter. The same can be observed for the factor ‘conservation’, although its effect gained more importance from day 8 (25 %) up to day 14 (30%). The steeper inclination of both curves advanced the crossing point to an earlier moment in time (Figure 1c). When in ‘Picual’ this took place around day 13, it occurred in ‘Verdial’ around day 10. In a similar way as in ‘Arbequina’, the interaction factor exerted his influence at his maximum (15 %) around day 4, after which it decreased to values below 10 %.

3.10. Sensory Analysis

The research design foresaw that, if no significant differences were found between the samples of D0 and D14 or between those of D14, the samples of D4 and D8 would not be tasted. It turned out that only in the 'Arbequina' variety, the panel was able to significantly distinguish differences between the treatments after 14 days of storage. Therefore, only D4 and D8 oils of this variety were further examined. The official limit that disallows the use of the quality label of ‘Extra Virgin’ was only exceeded once: In the R2C2 treatment of the

'Arbequina' sample on day 14, the 'extra' category was lost due to a median of the 'Mold' defect above 0, namely 1.2.

The evolution of the positive attributes disclosed a clear difference between the ‘Arbequina’ cultivar on the one hand and the ‘Picual’ and ‘Verdial’ varieties on the other (Table 4). The bitterness and pungency levels of the ‘Arbequina’ oils were significantly affected by the storage time and the conservation method, while no significant effect was found due to the interaction between the factors ‘harvesting’ and ‘conservation’. The fruity attribute was not affected by the storage time, nor by the type of treatment. The 'Picual' variety presented no effect of the studied factors on the different attributes. In the ‘Verdial’ cultivar, the attributes 'fruitiness' and 'bitterness' were only significantly influenced by the type of harvesting, showing that the oils from olives collected with the MIU presented values significantly higher, while the storage time decreased the intensity of the attribute ' pungency’.

According to the official regulations, most of the samples analyzed did not receive the minimum amount of negative evaluations necessary to lower their quality. Nevertheless, these negative evaluations can be taken into account to detail the applied treatments that showed to be different, as was the case with the ‘Arbequina’ variety. Calculating the median of the maximum grouped defects of each sample revealed that the deterioration became first visible in the treatments that were kept at room temperature. On day 14, fruit harvested with the traditional method (R2) and cold stored (S1) presented the onset of deterioration. The oils from fruit picked with the MIU (R1) and kept at 5 °C (C1), did not show a median above 0 during the time under investigation (Table 3).

For each cultivar and each storage time, the tasters ranked the oils in order of preference. The two from day 0 and the four from day 14 were evaluated together. The Friedman’s test detected significant differences, with a $\chi^2 = 11.07$ ($p = 0.05$), between the six

516 presented samples in the three cultivars, with χ^2_R values of 13,43 for the 'Arbequina' c.v., 14,34
517 for the 'Picual' c.v. and 11,35 for the 'Verdial' c.v.. However, when the ranking was restricted
518 to the four samples on day 14, no significant difference could be detected by the panel between
519 the treatments of the 'Picual' and 'Verdial' varieties. As a consequence, no further sensory
520 analysis was performed on the samples of day 4 and day 8 of these varieties. The oil samples of
521 the 'Arbequina' cultivar not only showed a significant difference between the treatments at day
522 14 (χ^2R = 12.45**), but also on day 4 and day 8, with respectively a χ^2_R value of 12.64* and
523 13.07*.

524 The Panel Preference ($\overline{P}_i$), as calculated with the formula (2) used the obtained raking
525 results for the Arbequina oil samples from storage days 4, 8, and 14 (Fig. 4). The calculation
526 and the subsequent ranking of the obtained $\overline{P}_I$ values revealed a clear preference for the cold
527 stored olives from day 4 up to day 14. The impact of the harvesting method does not come to
528 the fore as a major factor. On day 0, the tasters almost split in giving preference over one of the
529 two methods (3 preferred R1 against 5 in favor of R2), while only on day 14 a consistent
530 pattern was observed in giving preference over a treatment that included the R1.

531

532 **4. DISCUSSION**

533 The positive correlation of the conservation temperature on the level of FAA as well as
534 the combined effect of a mechanized harvest and the conservation method was confirmed in the
535 three varieties, as well as the fact that the effect of these factors varied between the cultivars
536 tested.

537 The observed degree of oxidation (Peroxides, $K_{232,}$ and K_{270}) demonstrated no consistent
538 tendencies for the factors 'harvesting' and 'conservation' over the studied years. It is only in

539 year 2 that a significant effect was observed for the Peroxides and the K_{270} in all of the three
540 varieties, while only in the 'Arbequina' and 'Verdial' cultivar concerning the K_{232}. Yousfi *et al*.
541 (2012) mention values of Peroxides, $K_{232,}$ and K_{270} that were significantly higher when
542 'Arbequina' is recollected mechanically and relate this to the internal ruptures as a consequence
543 of the received blows during the harvesting. The results in year 2 supported this hypothesis,
544 indicating a slight difference between the oils from 'Arbequina' and 'Verdial' olives in front of
545 'Picual' oils.

546 For the oxidative stability, the total amount of polyphenols, and the Bitterness Index, a
547 clear distinction was present between the varieties. The results support the hypothesis that the
548 reduction of the oxidation time is not only related to the progress of ripening but also to the
549 aggressiveness of the harvesting method, especially when harvesting the 'Arbequina' variety.
550 In the same way, the presence and the evolution of the α-tocopherols are genetically related.
551 The hypothesis of Yousfi *et al.* (2012) that mechanized harvesting and conservation at 18 °C
552 favors the degradation of these compounds is not confirmed as the 'Arbequina' cultivar showed
553 an inverse relationship in both years.

554 The photosynthetic pigments (K_{470} and K_{670}) evolved consistently in the three varieties.
555 However, the calculated strength of the present factors underlines the increasing importance of
556 the factor 'conservation' in explaining the observed differences, especially for the 'Arbequina'
557 and 'Verdial' oils.

558 While various parameters indicated the importance of the genetic factor when
559 evaluating the effect of the harvesting and conservation method on the various parameters, it is
560 only when the magnitude of the strength of these factors are taken together and compared that
561 their full impact comes to the fore. The obtained results pointed to the critical interrelation that
562 exists between the two factors and their interaction, and demonstrate the differences between

563 the 3 cultivars as the storage time increases. The vulnerability of the ‘Arbequina’ towards
564 deterioration as compared to the ‘Picual’, and a lesser degree to the ‘Verdial’, is obvious when
565 taking the crossing point of the two curves (harvesting- and conservation-strength) as a point of
566 reference. The curious rebounding of the harvesting-strength in the ‘Picual’ and ‘Verdial’-
567 cultivars at day 8, may indicate that the effects of a produced damage due to a more detrimental
568 harvesting method, can be constrained during the first week due to the cooling of the fruit.
569 However, this initial compensating effect loses power over the following week.

570 The results of the tasting panel did follow the results based on the physicochemical
571 analysis. The outcome of the ‘Arbequina’ oil judging allowed to specify in detail how the
572 effects of the different treatments were reflected in the quality levels of the samples at each
573 storage time. The fine-tuning on the negative attributes revealed a striking parallel with the
574 measured levels of free fatty acidy and peroxide levels while the presence of positive attributes
575 was mirrored in the raking scores and the panel preference. The different strength profiles were
576 closely related to the results of the tasting panel, especially in the case of the ‘Arbequina’
577 cultivar where the increase of the storage factor from day 4 is matched with a clear panel
578 preference for cool stored oils.

579

580 **5. CONCLUSIONS**

581 The study underlines the importance of both harvesting method and conservation in the
582 quality of the oils extracted before their processing and confirms the presence of a genetic
583 predisposition of the different varieties studied. The use of the MIU and the consequent storage
584 of the picked olives at 5 °C does affect the majority of the parameters in a significant way when
585 compared with traditional harvesting and storage at ambient temperature. Especially in a more
586 sensible variety as ‘Arbequina’ as compared with ‘Picual’ or ‘Verdial’. The calculation of the

587 magnitude of strengths and the calculated panel preference made it possible to discern the
588 explanatory weight of each of the factors, to understand the differences between the varieties to
589 the factors, and to emphasize the need to take into account the days of storage when evaluating
590 their importance. This information is crucial whether to decide which solution fits the farmer
591 best given the specific constraints he has to deal with.

592

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594

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669 Table 1. Values of $\widehat{\omega}^2$ (omega square), as a measure of the effect of the factor harvesting (R), conservation (C), and the interaction between
670 both (R × C), for each of the 4 storage times during year 1 and 2. Negative values are set to .00.

671

672 Table 2. Initial values of positive attributes (Fruitiness, Bitterness, Pungency) and negative attributes

Storage Time (days)	0						4						8						14					
Factor	R		C		R x C		R		C		R x C		R		C		R x C		R		C		R x C	
Year	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
ARBEQUINA																								
FFA	.26	.40	.00	.00	.00	.00	.17	.17	.33	.64	.03	.08	.27	.17	.40	.66	.22	.10	.35	.14	.37	.82	.28	.02
PV	.00	.61	.00	.00	.00	.00	.06	.08	.71	.42	.02	.14	.31	.34	.46	.15	.00	.16	.44	.60	.05	.09	.32	.05
K232	.38	.59	.00	.00	.00	.00	.00	.00	.02	.09	.30	.42	.00	.24	.00	.11	.00	.23	.00	.09	.00	.37	.27	.00
K270	.62	.09	.00	.00	.00	.00	.07	.28	.00	.02	.00	.41	.00	.35	.14	.00	.00	.06	.00	.24	.26	.00	.57	.00
Oxidative Stability	.03	.25	.00	.00	.00	.00	.34	.13	.00	.41	.00	.30	.34	.01	.07	.76	.00	.07	.18	.00	.70	.69	.04	.00
K470	.75	.49	.00	.00	.00	.00	.05	.02	.88	.83	.00	.03	.04	.00	.86	.91	.02	.00	.00	.03	.89	.71	.01	.04
K670	.75	.56	.00	.00	.00	.00	.09	.15	.65	.49	.00	.18	.15	.00	.57	.89	.09	.00	.03	.20	.52	.57	.13	.00
Bitterness Index	1.00	.38	.00	.00	.00	.00	.00	.01	.00	.57	.00	.22	.14	.00	.21	.83	.00	.00	.04	.00	.71	.30	.00	.11
Total polyphenols	1.00	.42	.00	.00	.00	.00	.59	.36	.00	.00	.18	.34	.17	.00	.42	.00	.01	.00	.21	.00	.30	.04	.03	.01
α-tocopherols	.55	.55	.00	.00	.00	.00	.41	.30	.00	.16	.00	.02	.00	.02	.32	.00	.08	.00	.77	.14	.00	.01	.00	.24
PICUAL																								
FFA	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.76	.00	.00	.07	.00	.00	.72	.60	.00	.05	.27	,44	,54	,34	,09
PV	,51	,27	,00	,00	,00	,00	,00	,48	,00	,06	,00	,13	,59	,05	,08	,00	,06	,18	,28	,00	,00	,00	,05	,11
K232	,13	,08	,00	,00	,00	,00	,11	,21	,37	,09	,00	,00	,09	,00	,15	,00	,04	,12	,01	,00	,00	,00	,00	,13
K270	,00	,93	,00	,00	,00	,00	,80	,29	,03	,00	,09	,00	,73	,62	,14	,13	,05	,00	,15	,07	,00	,33	,07	,08
Oxidative Stability	,00	,87	,00	,00	,00	,00	,74	,00	,04	,00	,00	,00	,58	,43	,03	,00	,22	,12	,35	,05	,21	,26	,35	,07
K470	,79	,84	,00	,00	,00	,00	,48	,39	,00	,29	,07	,04	,87	,27	,08	,57	,03	,08	,28	,07	,00	,81	,00	,00
K670	,73	,83	,00	,00	,00	,00	,55	,44	,21	,27	,00	,01	,81	,22	,03	,54	,08	,06	,00	,01	,25	,78	,00	,00
Bitterness Index	,64	,62	,00	,00	,00	,00	,77	,59	,01	,08	,00	,05	,69	,00	,00	,13	,00	,08	,47	,06	,31	,15	,10	,35
Total polyphenols	,74	,29	,00	,00	,00	,00	,82	,60	,01	,00	,03	,20	,52	,00	,07	,15	,28	,17	,83	,56	,03	,00	,00	,12
α-tocopherols	,96	,83	,00	,00	,00	,00	,05	,00	,00	,27	,00	,11	,75	,17	,05	,02	,00	,08	,01	,19	,38	,15	,24	,21
VERDIAL																								
FFA	.17	.55	.00	.00	.00	.00	.43	.35	.00	.00	.51	.00	.07	.31	.22	.12	.43	.03	.06	.58	.54	.00	.00	.00
PV	.61	.33	.00	.00	.00	.00	.71	.10	.01	.00	.23	.11	.83	.29	.00	.00	.09	.00	.65	.00	.11	.00	.00	.0

gency) as noted by a sensory analysis panel in the 'Arbequina', 'Picual' and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8 and 14 days at 5 °C (C1) and at ambient temperature (C2)[a]. The panel was formed by 8 approved tasters.

Storage Time (days)	Treatment R (1,2); C (1,2)	Arbequina			Picual[b]			Verdial[b]		
		Fruitiness	Bitterness	Pungency	Fruitiness	Bitterness	Pungency	Fruitiness	Bitterness	Pungency
0	1,1	2.4 ± 1.0	3.9 ± 1.5	6.1 ± 1.1	4.3 ± 1.1	4.6 ± 0.7	5.3 ± 0.8	3.5 ± 0.6	4.1 ± 1.0	5.2 ± 0.8
	1,2	2.4 ± 1.0	3.9 ± 1.5	6.1 ± 1.1 **A**	4.3 ± 1.1	4.6 ± 0.7	5.3 ± 0.8	3.5 ± 0.6	4.1 ± 1.0	5.2 ± 0.8 **A**
	2,1	3.0 ± 1.3	4.5 ± 1.2	6.1 ± 1.4	4.6 ± 1.3	4.8 ± 1.1	5.2 ± 0.7	3.4 ± 0.6	3.7 ± 1.1	4.5 ± 0.6 **A**
	2,2	3.0 ± 1.3	4.5 ± 1.2 **A**[a]	6.1 ± 1.4 **A**	4.6 ± 1.3	4.8 ± 1.1	5.2 ± 0.7	3.4 ± 0.6	4.1 ± 1.0	4.5 ± 0.6
4	1,1	1.9 ± 1.2	3.6 ± 1.1	5.2 ± 1.1 α	-	-	-	-	-	-
	1,2	2.2 ± 1.2	3.6 ± 0.9	4.4 ± 1.5 **B** β	-	-	-	-	-	-
	2,1	2.4 ± 1.4	3.3 ± 1.6	5.5 ± 0.9 α	-	-	-	-	-	-
	2,2	1.9 ± 0.8	3.0 ± 1.1 **AB**	4.0 ± 1.5 **B** β	-	-	-	-	-	-
8	1,1	2.4 ± 1.3	3.3 ± 1.1 α	4.6 ± 17 a α	-	-	-	-	-	-
	1,2	1.8 ± 1.0	2.2 ± 0.9 β	2.7 ± 0.7 **C** b β	-	-	-	-	-	-
	2,1	2.6 ± 1.5	3.1 ± 1.3 α	5.0 ± 1.1 a α	-	-	-	-	-	-
	2,2	1.7 ± 1.1	2.1 ± 1.3 **B** β	3.3 ± 1.4 **B** ab β	-	-	-	-	-	-
14	1,1	2.8 ± 1.6	3.9 ± 1.5 a α	5.5 ± 1.2 a α	4.5 ± 1.2	4.3 ± 0.8	5.1 ± 0.8	3.0 ± 0.9	4.7 ± 0.7	5.2 ± 0.5
	1,2	2.4 ± 1.2	3.5 ± 1.4 ab β	4.2 ± 1.2 **BC** ab β	4.3 ± 1.2	4.1 ± 1.2	4.4 ± 1.3	2.9 ± 1.1	3.8 ± 1.0	4.7 ± 1.2 **B**
	2,1	2.7 ± 1.8	4.8 ± 1.1 a α	4.9 ± 1.1 ab α	4.2 ± 1.1	4.3 ± 1.0	4.9 ± 0.9	3.8 ± 0.8	3.1 ± 0.7	4.1 ± 0.8 **B**
	2,2	1.7 ± 0.8	2.0 ± 1.1 **B** c β	3.4 ± 1.4 **B** b β	4.4 ± 0.8	4.1 ± 1.0	4.7 ± 1.1	2.2 ± 0.8	3.6 ± 1.2	4.8 ± 1.0
Storage Time (ST)		0.217	0.000	0.000	0.059	0.055	0.900	0.718	0.568	0.000
Treatment (T)		0.203	0.010	0.000	0.952	0.749	0.965	0.031	0.150	0.340
ST × T		0.752	0.057	0.199	0.960	0.724	0.962	0.383	0.486	0.348
R		0.700	0.774	0.780	0.682	0.924	0.749	0.010	0.014	0.767
R × ST		0.421	0.311	0.366	0.720	0.733	0.728	0.677	0.814	0.324
C		0.062	0.002	0.000	0.980	0.613	0.707	0.171	0.126	0.130
C × ST		0.326	0.166	0.738	0.682	0.334	0.878	0.632	0.775	0.035

[a] In each variable the values of different treatments followed by different letters are significantly different according to the Tukey test ($P < 0.05$). Absence of letters means no significant effect due to treatment according to one-way ANOVA ($P < 0.05$). In each column, values at different storage times (ST) and the same harvesting method (R) and conservation method (C), followed by different upper bold case letters are significantly different; four values at each ST, followed by different lower case letters (a, b, c, d) are different; two values at the same ST and same harvesting method, but different conservation method, followed by different Greek letters are significantly different. Each value is the mean ± SD of 3 replicates.

[b] When the Friedman test detected that de panel was not able to differentiate significantly the overall quality of the olive oils at day 0 and day 14, the samples at day 4 and day 8 were not sensory evaluated.

690 Table 3. Number of defects and the median of their intensity as reported by the sensory panel,
691 in the oil extracted from the 'Arbequina' cultivar, harvested with a Manual Inverted Umbrella
692 (R1) or in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) or at am-
693 bient temperature (C2). The panel was formed by 8 approved tasters.

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Treatment	D0		D4		D8		D14	
	median	# defects	median	# defects	median	# defects	median	# defects
R1 C1	0.00	1	0.00	3	0.00	1	0.00	2
R1 C2	0.00	1	0.00	5	0.00	1	1.60	6
R2 C1	0.00	1	0.80	10	1.95	8	2.25	11
R2 C2	0.00	1	2.65	13	1.55	8	2.70*	11

*median for the attribute 'musty'=1.2

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Figure legends

Figure 1. Recollecting olive fruit with the Manual Inverted Umbrella (MUI), 4 operators and the use of 2 branch shakers (R1)

Figure 2. Cooling room situated in a barn on the farm with a capacity of 5.000 kg, and where the fruit can be kept at 5 °C. (C1)

Figure 3. Magnitude of strength of the factors recollection and conservation and their interaction for three different varieties (Arbequina, Picual, and Verdial), based on the mean of the calculated omega squared ($\widehat{\omega}^2$) values of 10 parameters (FFA, peroxides, K232, K270, oxidative stability, photosynthetic pigments, bitterness index, total polyphenols, α-tocopherols) over 14 days.

Figure 4. The Panel Preference ($\overline{P}_i$) for the oil extracted from the 'Arbequina' cultivar, recollected with a Manual Inverted Umbrella (R1) or in a traditional way (R2) and stored during 4, 8, and 14 days at 5 °C (C1) or at ambient temperature (C2). The panel was formed by 8 approved tasters. Data at day 0 are not showed as the Friedman test can not be performed on two treatments.

Supplementary material Table legend

Table 1. Free Fatty Acid (% oleic acid) noted in the 'Arbequina', 'Picual', and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 2. Peroxide Value (mEq O_2/ kg oil) noted in the 'Arbequina', 'Picual', and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 3. Absorbance at 232 nm (K232) noted in the 'Arbequina', 'Picual', and 'Verdial' olive oils extracted from fruit. picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 4. Absorbance at 270 nm (K270) noted in the 'Arbequina'. 'Picual' and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 5. Oxidative Stability (h) noted in the 'Arbequina'. 'Picual' and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 6. Absorbance at 470 nm (Carotenoids) noted in the 'Arbequina'. 'Picual' and 'Verdial' olive oils extracted from fruit picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 7. Absorbance at 670 nm (Chlorophyll) noted in the 'Arbequina'. 'Picual' and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 8. Bitterness Index noted in the 'Arbequina'. 'Picual' and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

Table 9. Total Polyphenols (mg/kg) noted in the 'Arbequina', 'Picual', and 'Verdial' olive oils extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).

767 Table 10. α-Tocopherols (mg/kg) noted in the ‘Arbequina’, ‘Picual’, and ‘Verdial’ olive oils
768 extracted from fruit, picked with a Manual Inverted Umbrella (R1) and in a traditional way
769 (R2) and stored during 0, 4, 8, and 14 days at 5 °C (C1) and ambient temperature (C2).