The impact of processing operations on oil quality

Introduction

Results obtained by the Wagga Wagga Research Institute show that the FFA and PV values of the oils analysed for Australian growers have been increasing since 2004, (Figures 1 & 2).

It is expected that sound fruit processed immediately after harvesting should produce oils with less than 0.35% FFA and 12 meq O2/kg PV. Being the case, it can be appreciated that if in 2007 we were just below those limits, in 2008 we have certainly left those boundaries below us.

The job of the processing plant manager is, apart from obtaining oil from olives in an efficient and cost-effective manner, to express the full quality potential of the oil contained in the olives by disturbing its chemical and organoleptic parameters as little as possible. Unfortunately, it is not possible to produce good olive oil from bad olives. We cannot blame the processing manager if oils with high FFA & PV are obtained from frosted or anthracnose-infected olives as these agronomical and climatic factors as well as others such as year, variety, irrigation and fertigation, can have an impact on the overall quality of the oil. However, the decisions made by the plant managers will inevitably have an impact on the quality of the resulting oil regardless of the quality of the olives they receive at the plant.

Factors affecting FFA

- **Harvesting - processing gap:** The top quality of oil can be found in the olives on the canopy of the tree. Once we have picked the olives the only thing we experience is the loss of the quality of that oil as time goes by so reducing the time of the harvesting-processing gap is essential if we want to maintain the maximum oil quality potential.

- **Storage of the olives pre-processing:** The piling of olives (so common in Spain) in order to store and process them days later usually produces oils with very high FFA levels as well as with a characteristic “fusty” defect on their organoleptic profile. The elevated temperature of the pile triggers anaerobic fermentations in the fruit and this is usually worsened when dealing with riper, mashy fruit that blocks the airflow within the pile and helps the growth of moulds. As a general rule, the temperature measured in a pile or container at 30-50cm depth should not be 10-15°C higher than the ambient temperature. It is important to point out that in the early stages these fermentations are not visible from the surface of the container and it is very easy to judge as good a batch that is actually fermented in its interior.

- **Travelling time between grove and plant:** In many cases growers need to travel long distances to reach the processing facility that will deal with their olives. The ambient temperature during transport as well as the depth of the load and the ripeness of the fruit will determine the temperature of the fruit and eventually the risk of fermentations affecting the FFA.

- **Washing machine operation:** The high levels of organic matter in dirty water and the decision of by-passing the washing of the olives at the wrong time can also impact considerably on the FFA of the oil. The water in the washing machine should be renewed every 12 hours minimum if working continuously, or daily if working in batching modality. The wash by-passing is an interesting tool to consider for improvement of the oil extractability of the paste as it reduces the level of moisture of the olives going into the crusher, but it can backfire on the oil quality if not managed properly. Wash by-passing is a technique to be used preferably after a rain event that has washed down the dust from the olives in the grove and a constant monitoring of the FFA during processing is required if this operation is adopted.

- **Clean fruit hoppers:** In several plants in Australia holding hoppers are used between washing machines and
crushers in order to have a buffer holding capacity that also allows a consistent feeding to the crushers. It is extremely important that these hoppers are emptied and inspected at least once a day if working continuously for it is common to see the build-up of fruit on the sides of the wall of the hopper. This fruit stays stacked to the walls for days, it ferments, and when it finally reaches the crusher the oil resulting has a very high FFA. Also in this case, riper, mashy fruit will worsen the situation.

- **Cleanliness of the processing equipment**: The presence of old, mouldy paste from the past season attached to paste and oil pipes as well as to hoppers and processing equipment will trigger fermentations resulting in high FFA in the oil. Needless to say, the post-season cleaning of the plant and its equipment is essential and will impact on the next season's oil quality. A safe processing practice is to put aside or isolate the first oil of the season coming out from each decanter of the plant so it can be assessed chemically and organoleptically and decide if a more effective cleaning of the equipment is required before resuming operations. The ‘batching’ modality of processing requires a very close monitoring of this issue as the continual starting and stopping of the equipment can lead in the ‘off-hours’ to fermentation of paste attached to the equipment.

- **Sediments removal**: The liberation of fatty acids from the triglycerides is a hydrolytic reaction that takes place in presence of enzymes acylhydrolases and H₂O in an anaerobic condition. Consequently, the removal of sediments and water from the bottom of the tanks is essential in order to keep low the FFA of the oils. A proper and consistent drainage of the tanks during processing and in storage conditions will guarantee a constant FFA level along the life of the oil.

**Factors affecting PV**

- **Cleanliness of the processing equipment**: The presence of organic matter (old paste, fermented leaves, etc.) will trigger oxidation reactions on the free fatty acids of the oil that will result in an elevated production of peroxide compounds. Same as in the case of the FFA, a proper cleaning of the processing equipment will reduce the risk of having these oxidations.

- **Crusher**: An excessive wearing of the hammers can lead to the presence of metal traces in the oil that will produce oxidation reactions eventually increasing the PV. Inspecting the crusher at least once a week if working continuously and replacing old hammers is essential in order to avoid this negative situation.

- **Malaxer**: The use of excessive malaxing temperatures in order to improve the oil extractability of the paste usually backfires on the PV level of the oil. Temperature (thermosiation), along with O₂, metals and light, is one of the strongest oxidation catalysts. It is important to point out that varieties such as Arbequina, Frantoio or Leccino do not have much capacity to stand excessive temperatures during malaxation and are exposed to important changes of their PV levels. On the other hand, varieties such as Barnea or Picual can handle much better high malaxing temperatures, due to their more stable chemical composition, though they are still affected to some extent.

- **Decanter**: The excessive temperature of the water added to the decanter can also trigger oxidation reactions in the oil. The temperature of addition of water to the decanter should never exceed 30°C.

- **Vertical centrifuge**: This is another point where thermostomax reactions can occur. The temperature of the water of addition in this case should be same as or 1-2°C higher than the temperature of the oil coming from the decanter (usually at 29-30°C).

- **Storage conditions**: Having mentioned temperature, light, oxygen and metals as the most important catalysts for oxidation of fatty acids it is obvious that oils stored in clean stainless steel tanks, properly drained, kept under Nitrogen blanket and in an atmosphere of 16-22°C will be better prepared to deal with the normal ageing process of olive oil. Extremely important is to understand that the final level of PV reached by the oil at the end
of its life will depend greatly on the initial level of PV immediately after production for the presence of peroxides triggers auto-oxidation reactions and more formation of peroxides. In other words, it is important to process the oil properly and supply the tank farm with low PV oils to ensure that at the end of their life they will still be within the IOOC limits for EVOO. Figure 3 shows the evolution of the PV at Boort in the year 2004 when the oil was under Nitrogen but with no room temperature control, in 2005 with no temperature control nor Nitrogen addition, and in 2006 with both temperature control and Nitrogen addition.

![Graphs showing PV evolution](image)

Fig. 3. Annual evolution of PV in Barnea oil at Boort Estate tank farm in 2004 (only N2), 2005 (no N2/T°C control), and 2006 (N2 & T°C control).

**Impact on other chemical parameters**

**Malaxing**

The processing decisions made at the malaxing step can impact on a large number of chemical parameters in the olive oil: PV, polyphenols, bitterness, ortodiphenols, oxidative stability, chlorophylls, carotenoids, trans-fatty acids, panel test, sterols composition and E+U.

Figures 4 & 5 show increasing the paste temperature in the malaxer produces an increase in the polyphenols, bitterness, ortodiphenols and chlorophylls content of the oil. This increase in polyphenols and bitterness when working with excessive temperatures in the malaxer usually translates into very unbalanced oils with an unpleasant harsh bitterness feeling that requires a corrective blending action in order to make them more consumer-friendly.

On the other hand, the increase of the malaxing time when working at 30°C or hotter produces a reduction in the levels of polyphenols, bitterness and ortodiphenols.

The thermoxidation of the oil that occurs when working with high temperatures in the malaxing step also reduces the oxidative stability of the oil measured in the Rancimat® test, as well as it reduces the intensity of the ‘fruitiness’ attribute in the organoleptic assessment showing in some cases a distinctive and undesirable ‘overcooked’ smell.

The excessive heat treatment of the paste provokes a change in the configuration of the fatty acid molecules of the oil going from the naturally existing cis-forms to the trans-forms. This tends to show up in the trans fatty acid profile of the oil with levels of trans fatty acids slightly lower than the limit set by the IOOC. The trans fatty acid profile is a chemical test carried out in order to determine the presence of refined oil in EVOO.

Recent research carried out by Modern Olives has demonstrated that the processing practices adopted can also modify the concentrations of some sterols, the total amount of sterols and the concentration of triterpene alcohols. According to this work, the increase of the time between harvesting and processing, as well as the increase of the malaxing time and temperature produced an increment in the concentration of Stigmasteryl (sterol) and Erythrodiol and Uvaol (triterpene alcohols), as it can be appreciated in Figure 6. Both Tripterpenes and Sterols are used to determine the adulteration of olive oil with seed oil and pomace oil.

![Graphs showing polyphenol content and bitterness](image)

Fig. 4. Polyphenols content and bitterness (K225) in the oil at different temperatures and malaxing times.
Olive washing

The washing of the olives prior to crushing is carried out in order to ensure the removal of any dust or foreign matter that those olives may carry along. As mentioned earlier, this will prevent undesirable fermentations that can impact on the FFA of the oil. However, the washing operation increases the olives' moisture content (adding up to 1-1.5% moisture) as well as it increases the

![Graphs showing moisture content, polyphenols, shelf life, and extractability for washed and unwashed olives.](image)

**Fig. 7.** Impact of the olive washing on moisture content, extractability, shelf life and polyphenols content of Picual fruit and the oil obtained. Marín Uceda, 2005.
It is important to point out that choosing to by-pass the washing at the wrong time can impact not only on the FFA but also on the organoleptic profile with the appearance of an unpleasant 'earthy' flavour in the oil if the olives bring mud, dust or earth from the grove. Likewise, a poor leaf removal at the washing step can lead to the presence of a 'leafy' aroma and taste that usually transfers an unpleasant bitterness and pungency that makes the oil unbalanced.

**Crushing**

The type of crusher used in the process will impact on the quality of the oil obtained, (Table 1). Double grid hammer mills tend to give oils with lower polyphenols content and with less organoleptic bitterness and pungency than the ones obtained using single grid hammer mills. The double grid mills are gentler on the olives due to the fact that they spin slower than the single grids and this affects the partitioning of the fruit's polyphenols that end up on the oil and in the water phase of the paste.

In the case of the size of the grids, the use of smaller grid sizes produces an increase of the friction between olives and...

<table>
<thead>
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<th>Variety</th>
<th>Crushing</th>
<th>Polyphenols (ppm)</th>
<th>Shelf life (days)</th>
<th>Fruitiness</th>
<th>Bitterness</th>
<th>Pungency</th>
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<tr>
<td>Barnea</td>
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<td>664</td>
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<td>3.7</td>
<td>2.9</td>
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<tr>
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<td>935</td>
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<td></td>
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<td>208</td>
<td>901</td>
<td>4.2</td>
<td>1.9</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Table 1. Polyphenols content, shelflife and organoleptic parameters of Picual and Barnea oils obtained with the use of single and double grids (BBE).

grid that also produces an increase of the temperature of the paste at crushing. As a consequence of this, there is an increase in the content of chlorophyll as well as an increase in the intensity of the green tones in the oil obtained. However, this green colour tends to disappear in the oil in the tanks as time goes by as part of a natural ageing process.

A very interesting work carried out by Lucioz et al. in Spain suggests that it is only the temperature of the olives when entering the crusher what defines the contents of chlorophyll and phaeophytins that are eventually transferred to the oil. The higher the temperature of the olives at crushing, the higher the chlorophyll content and the greener the oil. This also explains the fact that olives that have started fermenting in clean fruit hoppers produce greener than normal oils.

**Use of coadjuvants**

Processing aids are used in order to improve the oil extractability of the olive paste. However, their use also impacts on the quality of the oil obtained. Several research works have demonstrated the beneficial impact of the use of processing aids on some of the quality parameters of the olive oil.

Ranalli et al. (2003) have found that the use of enzymes enhanced the quality of the oil in varieties Dritta, Leccino and Coratina. The oils obtained with the enzyme treatment showed higher levels of phenolics, volatiles, tocopherols, carotenes and chlorophyll and lower levels of oxidised triglycerides and diglycerides, thus becoming less susceptible to oxidation, more stable and aromatic. On the other hand, the saponifiable fraction was not affected by the use of enzymes.

Studies carried out by the Fat Institute in Seville (1996) and the University of Jaen (2007), Spain have shown that the use of tale and microtale powder on varieties Arbequina, Hojiblanca and Picual generated an improvement of the FFA, PV, polyphenols, stability in Rancimat, moisture content, impurities and panel test score of the oils obtained. The use of tale powder reduces the impact of the water on the polar composition of the oil, which explains the higher...
stability and polyphenols contents found. No variations were found in the fatty acid profile of the oil by the use of talc powder.

Recent works carried out by Cruz et al. have demonstrated that the addition of common salt (NaCl) to the olive paste during malaxation produced an increase in the oil stability, the orthodiphenols content, the pigment content and the bitterness (K225), with no induction of any off-flavours in the oil obtained. The increase of polarity of the hydrophilic phase due to the presence of dissolved NaCl could facilitate the solubility of the phenol compounds in the oil, thus inducing an increase of both the oxidative stability and the bitter taste.

Pablo Canamasas finished his studies in Argentina as an agriculture engineer and has specialised in olive oil production and oil quality. Since moving to Australia in 2002, Pablo has been the manager of one of the largest olive oil processing plants in Australia being responsible for all matters related to olive oil chemical and organoleptic quality. Pablo has completed a post-graduate Superior Course of Specialisation in Oil Production and Table Olives in Jaen, Spain. During this course he has extensively studied and researched the areas of oil production techniques, oil quality (chemical and organoleptic) and table olives production. Since then, Pablo has maintained a permanent contact with researchers from Spain and Italy in order to update his technical knowledge.