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Evaluation of Processing Aids for Olive Oil Extraction and Quality Improvement

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Evaluation of Processing Aids for Olive Oil Extraction and Quality Improvement

by Pablo Canamasas and Leandro Ravetti

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Foreword

It has been estimated that the current industrial efficiency of the Australian olive oil industry ranges between 75 and 87 per cent. For the industry, each additional percentage point of improvement in this efficiency through the proper use of processing aids would represent approximately $1,000,000 worth of oil per year at current production levels, and up to $2 million per year for expected future production levels by 2025.

Treatment with a number of different processing aids can induce changes in the physical properties of olive paste; changes that facilitate the liberation of the oil contained in the cell tissues thus increasing the efficiency of the oil extraction process.

This work analysed the effect of the most commonly used processing aids on efficiency of extraction and oil quality. It provides information on the proper use of processing aids for the improvement of olive oil processing efficiency and product quality. Determining the influence of traditional and new processing aids on the industrial yield and quality of olive oil from some of the most important Australian olive varieties is essential in supporting the consistent production of high quality, healthy and safe olive oils that meet consumer expectations and in which those consumers have confidence.

By knowing the impact of proper processing-aid management on both industrial efficiency and oil quality when dealing with different olive varieties, Australian growers and processors will be better prepared to process their fruit in a more cost-effective manner, not compromising the quality and nutritional value of their product.

It has been determined that under numerous conditions, certain processing aids such as talc and/or enzymes in combination can offer a significantly better olive oil extraction result without a negative impact on the quality of the final product. As a consequence of this work, processors should consider the different processing-aid options available to determine those that suit their situation, and then evaluate the introduction of selected options within their normal processing practices.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our New Industries/Olives R&D program, which aims to:

- provide information which establishes the benefits of Australian olive products
- maintain the current high quality product while improving productivity, profitability and environmental management through all stages of the supply chain
- develop strategies for existing and new olive producers to reduce the effects of climate change and variability
- build an educated, collaborative, innovative and skilled industry workforce and a cost effective, well-funded RD&E program.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation

Publication Review

RIRDC publication No. 11/091 *Evaluation of processing aids for olive oil extraction and quality improvement* was reviewed and updated in November 2019 by one of the original authors, making the following amendments:

- Foreword (minor updating)
- About the authors (minor updating)
- Executive summary (significant updating)
- Introduction (minor updating)
- Implications (minor updating)
- Recommendations (significant updating)
- References (significant updating)

Most of the changes/additions suggested are based on new research evidence as well as on new industry findings regarding the use of processing aids for EVOO production.

Out of all processing aids studied on this report, talcum powder and enzymes are the ones that provided the most significant findings in the industry in recent years.

Talcum powder products with crystalline structure have proven to be more useful than the standard talcum powder of laminar structure.

More in-depth information is now available on the pectinase enzymes used for testing in this research work. The positive impact of the use of enzymes on both the paste viscosity and the extraction equipment's energy consumption should also be noted.

As a result, further recommendations should be provided to growers in Australia on the most cost-effective use of these aids.

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November 2019
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About the Authors

Pablo Canamasas has been involved in the olive oil industry for 23 years. In Argentina, he graduated as an Agricultural Engineer and has completed a Post Graduate Superior Course of Specialization in Oil Production and Table Olives in Jaen, Spain. In Australia, Pablo has been the Oil Production Technical Manager of the largest olive oil processor in the country, being responsible for all matters related to olive oil chemical and organoleptic quality. He has also provided technical advice to several oil processing plants Australia-wide and has been invited as a lecturer in Australian Olive Association (AOA) national conferences. Pablo was a member of the research team in the RIRDC-funded project PRJ-000385, "Technological and biological factors affecting sterols in Australian olive oils", as well as in the HAL-funded project "Use of ultrasound technology for olive oil processing".

Leandro Ravetti's involvement with modern olive production covers a period of 24 years. In Argentina, he graduated as an Agricultural Engineer and has worked for the National Institute of Agricultural Technology specialising in olives. He has also studied and worked as an invited researcher at the Olive Growing Research Institute of Perugia, Italy and other olive institutes in Andalusia, Spain. In Australia, Leandro has been providing technical advice to some of the largest olive projects, as well as conducting applied research in different areas of the industry. Leandro is the principal investigator of the RIRDC and HAL-funded projects mentioned above and a key collaborator of RIRDC project PRJ-000389.

Acknowledgments

Special thanks to the Rural Industries Research and Development Corporation (RIRDC) for their financial support of this project.

Abbreviations

AOA	Australian Olive Association
AOCS	American Oil Chemists' Society
HPLC	High-performance liquid chromatography
IOC	International Olive Council
NIR	Near infra-red
1,2-DAGs	1,2-diacylglicerides
PPP	Pyropheophytin
RIRDC	Rural Industries Research and Development Corporation (Now Agrifutures Australia)

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Executive Summary

What the report is about

This report analyses the impact of the use of traditional and new processing aids on olive oil extraction and oil quality.

The information generated by this project aims to provide new tools for improving olive oil processing that can increase both the extraction efficiency and profitability of the olive growers in the Australian industry.

Who is the report targeted at?

This report is targeted at the relatively new and actively growing group of olive oil producers in Australia. An understanding of the use of processing aids by oil producers will help them increase their profitability without affecting the quality of their product.

Where are the relevant industries located in Australia?

When we think about the new Australian olive industry, what comes to mind is a modern olive production model with the objectives of high yields and quality. These yields are in harmony with environmental conditions and have to be achieved with low production costs. It is estimated that 20 years ago, Australia had only 2000 hectares of traditional olive groves, which produced about 400 tonnes of oil. In 2018 Australia produced approximately 17 000 tonnes of oil. The majority of this new production came from the 30 000 hectares of modern olive groves that have been planted in the last 25 years.

Australian growers have made significant improvements in mechanical harvesting, achieving levels of efficiency and cost effectiveness without precedent in the world olive industry. Mechanical harvesting with trunk shakers has been considered the most reliable method for reducing labour costs during the past decades. A new generation of continuous harvesting machines has been adapted or developed for Australian conditions with great success and they are currently harvesting more than 75 per cent of Australian production.

Australia produces mostly extra virgin olive oil. The natural diversity of the Australian environment and the selection of the most productive world cultivars (which are harvested and processed under optimal conditions) are responsible for the wide range of high-quality olive oil products from the Australian olive industry. Almost 70 per cent of olive production comes from Victoria; South Australia, Western Australia and New South Wales are also significant contributors with approximately 10 per cent each; while Queensland and Tasmania are minor producers.
The following table shows the distribution of the planted area between groves of different scales.

Grove scale	Growers (Nº)	Hectares
Large (>100 ha)	35	14 000
Medium (10–100 ha)	200	7 000
Small (<10 ha)	1 000	9 000
TOTAL	**1 235**	**30 000**

Background

It has been found that talc powder, enzymes, calcium carbonate, salt and heat treatment induce changes in the rheological properties of olive paste that facilitate the liberation of the oil contained in the cell tissues thus increasing the efficiency of the oil extraction process.

In order to assess the industrial efficiency of the olive oil extraction process, a minimum benchmark of 85 per cent extraction efficiency has been generally accepted considering current Australian processing technology (Ravetti, 2008). It is estimated that the current industrial efficiency of the Australian olive oil industry ranges between 75 and 87 per cent. Each additional percentage point of improvement in this efficiency, by the proper use of these processing aids, would represent for the industry approximately $1 million worth of oil per year at current production levels and $2 million per year for expected future production levels by 2025.

Aims/objectives

This project expects to maximise the technological information available regarding the use of processing aids. It presents information on the appropriate use of available processing aids, both traditional and new. It also presents valuable information about processing management approaches, according to the rheological properties of olive pastes from the most important Australian olive varieties.

Methods used

The evaluation of the use of processing aids and techniques on the extractability of olive paste and the quality of the oil obtained was undertaken at both laboratory level and commercial scale in groves from central and northern Victoria.

Fruit from three different varieties (Manzanilla, Barnea and Arbequina) was crushed in an experimental olive oil mill (Abencor®). Each variety has a clearly different paste processing difficulty level and oil chemical profile and the evaluation was conducted following a proper statistical design.

The industrial processing practices and aids evaluated were:

- normal talcum powder (talc)
- microtalcum powder (microtalc)
- different enzymes
- common salt
- calcium carbonate
- warm water dipping.

Paste extractability was evaluated in each treatment. The chemical analyses were conducted according to the methodology proposed by the International Olive Council for official methods. These analyses included: free fatty acids, peroxide value, UV coefficients, bitterness, total polyphenols, polyphenol profile, colour, 1,2-diacylglycerides, pyropheophytins, shelf life and panel test. Additionally, conductivity and pH were measured in Barnea olive pomace (waste) with common salt (0.6 per cent) and calcium carbonate (0.6 per cent).

The core treatments were repeated at the large-scale processing- plant level using Barnea fruit to determine the reproducibility of the laboratory-level experimental results.

Results/key findings

All solid aids trialed provided higher extractability results than the control, and were particularly more effective with higher moisture fruit such as Manzanilla. While talc and microtalc did not have any significant impact on oil quality, calcium carbonate (at a rate of 2.0 per cent) led to some negative changes in the chemical and organoleptic composition of the oil. The use of common salt did not impact negatively on oil quality but led to a significant increase in olive pomace conductivity.

All enzymes showed better paste extractability with Arbequina and Barnea fruit, but provided poor results with Manzanilla fruit. It is likely that the high fruit-moisture levels of Manzanilla generated emulsions that limited the potential results of the enzymatic action. The addition of a solid aid prior to the addition of enzymes could help both in providing a structure to the paste of this variety at the malaxing step and in maximising the effect of the enzymes. The effectiveness of each particular enzyme seems to depend on the relative content of main-chain and side-chain pectins in the cell walls of the fruit. This relative content changes with ripening stage and also changes from year to year.

The warm water dipping technique showed slight extractability improvements only at 60°C. However, this water temperature also led to significant negative changes in the chemical and organoleptic characteristics of the oil.

Implications for relevant stakeholders

It is estimated that the current industrial efficiency of the Australian olive oil industry ranges between 75 and 87 per cent. Each additional percentage point of improvement in this efficiency by the proper use of the processing aids considered in this research work would represent for the industry approximately $1 million worth of oil per year at current production levels and $2 million per year for expected future production levels by 2025.

It has been reported that in large-scale operations in Australia, the use of processing aids can represent up to 30–40 per cent of the total direct oil processing costs. With both the subsidies scheme for olive growers and the olive industry in the European Community (Common Agricultural Policy, EC, 2003) and the current low oil prices, it becomes very important for our local industry to be able to be competitive in terms of production costs as well as to differentiate our product in terms of quality.

The use of some processing aids tested in this work would also allow Australian growers the possibility to start and finish the harvest earlier in order to both obtain better quality oils and minimise the negative impact of the olive tree annual bearing, all this without significantly compromising oil yields.

Recommendations

The use of processing aids in this project induced changes in the rheological properties of the olive paste from the three olive cultivars trialed. These changes facilitated the liberation of oil contained in the cell tissues, eventually increasing the efficiency of the oil extraction process.

Australian growers should consider the use of processing aids when dealing with olive varieties that show a high degree of processing difficulty. In order to determine the most appropriate processing tool in each case, it is necessary to assess the level and type of processing difficulty encountered.

It was found in this work that olive varieties with high fruit-moisture levels tend to produce oil/water emulsions during the crushing step of the oil extraction process. Solid aids such as talcum powder, microtalcum powder and calcium carbonate (in doses lower than 1.0 per cent) have been useful in breaking those emulsions and provide higher paste extractability results as a consequence; this occurs without impacting on oil quality.

These results are in line with scientific work carried by other researchers that demonstrated that talcum powder has a positive impact on the degradation of pectins and proteins of the fruit cell walls that allow for a better oil release (Sadkaoui et al, 2017).

A number of different enzymes were demonstrated to be very effective in changing the rheological properties of the olive paste, resulting in a significant impact on paste extractability. However, to improve their effectiveness on pastes coming from high-moisture fruit, enzymes require the prior addition of a solid aid. Due to their high biological specificity, enzymes used for olive oil processing do not alter the fatty acid composition of the oil and thus have no significant impact on oil quality.

It is important to point out that the oil obtained from all treatments was extra virgin according to International Olive Council quality standards. However, the use of calcium carbonate at a dose of 2.0 per cent worsened those chemical parameters in the oil that are related to its oxidative condition (peroxide value, K232, K270, total polyphenols, induction time). Additionally, calcium carbonate (2.0 per cent) also induced a change in the organoleptic character of the oil as well as a change in its colour.

The warm water dipping technique also impacted negatively on some oxidative parameters (induction time, total polyphenols, ortho-diphenols) and induced organoleptic and colour changes. The use of salt did not impact adversely on the quality of the oil, but it significantly increased the conductivity of the olive pomace; and since the olive waste is usually spread back in the grove, high conductivity values may represent an environmental issue and for this reason the use of salt as a processing tool will require further evaluation.

Finally, and based on the results of this work, when the characteristics of the olive fruit and/or paste require it, Australian growers can be safely advised to use talcum powder and microtalcum powder in combination with enzymes to improve the industrial efficiency of the olive oil extraction process without adversely impacting on oil quality.

Introduction

Processing aids have been used in the olive oil industry for more than 30 years in order to improve the extractability of oil from the olive paste. The introduction of processing aids was due to the difficulty of extracting oil from the paste of certain olive cultivars; a process that led to high oil losses in pomace (remnant solids after oil extraction). Amongst these aids, talcum powder, enzymes and warm water have been the most commonly used and studied in past years in Spain, Italy and other Mediterranean countries (Alba 1982; Hermoso et al. 1991; Ranalli et al. 2003; Sadkaoui, 2017). Furthermore, some new processing aids and techniques like common salt and hot water dipping have also been evaluated in recent works (Perez et al. 2003; Garcia et al. 2005; Cruz et al. 2007a, b). Oil extraction improvements ranging between 10–30 per cent have been reported by the individual and combined usage of these processing tools on olive pastes in those countries (Ranalli and DeMattia 1997; Millan Linares et al. 2006; Sanchez et al. 2007).

Recent research work has also shown the beneficial impact on oil quality by means of the use of some of the processing tools studied in this project (Ranalli et al. 2003; Garcia et al. 2005; Cruz et al. 2007a, b; Sanchez et al. 2007). Also, the appropriate use of talcum powder and enzymes has been reported to reduce the pollution potential of the processing waste water stream by up to 30 per cent (Ranalli et al. 2003).

In order to assess the industrial efficiency of the olive oil extraction process, a minimum benchmark of 85 per cent extraction efficiency has been generally accepted, considering the current processing technology used in the Australian industry (Ravetti 2008). It is estimated that the current industrial efficiency of the Australian olive oil industry ranges between 75 and 87 per cent. Each additional percentage point of improvement in this efficiency, by the proper use of these processing aids, would represent for the industry approximately $1 million worth of oil per year worth of oil at current production levels and $2 million per year for expected future production levels by 2025 (Ravetti 2008).

It has been reported that in large-scale operations in Australia, the use of processing aids can represent up to 30–40 per cent of the total direct oil processing costs of a processing plant. With both the new subsidies scheme for olive growers and the industry in the European Community (Common Agricultural Policy, EC, 2003) and the current low oil prices, it becomes very important for our local industry to be able to be competitive in terms of production costs as well as to differentiate our product in terms of quality.

Objectives

This work intends to generate information that leads to the accurate use of processing aids for improving olive oil processing efficiency and product quality. Determining the influence of traditional and new processing aids on industrial yields and oil quality of some of the most important Australian olive varieties is essential in supporting consistent production of high quality, healthy and safe olive oils that meet consumers' expectations.

By knowing the impact of processing aids management on both the industrial efficiency and oil quality when dealing with different olive varieties, Australian growers and processors will be better prepared to process their fruit in a more cost-effective manner while not compromising the oil quality and nutritional value of their product.

Methodology

Olive fruit for these trials was harvested from a commercial grove in Boort, Victoria (36.12 °S; 143.72 °E) during April 2009. Fruit from three different varieties (Manzanilla, Barnea and Arbequina) were processed at Modern Olives Laboratory Services, a state-of-the-art laboratory at Lara, Victoria.

The core treatments were repeated in 2010 on a large-scale processing-plant level at Boort Estate, Victoria, using Barnea fruit to determine the reproducibility of the experimental laboratory-scale results on a commercial scale.

Extraction process

In order to carry out each of the treatments, 54 kg of each variety were picked and divided into 18 groups of 3 kg each (three repetitions of 1 kg each). Each treatment consisted of three repetitions and the oil obtained from each of those repetitions was analysed in duplicate. The fruit was processed in an experimental olive oil mill (Abencor®) following the standard operational procedures stated in the system's instruction manual (see Photo 1). In 2010, the trials were conducted at the Boort Estate processing plant using two decanters, Amenduni 902, working in 2-phase system (see Photo 2).

In order to determine the fruit characteristics (Tables 1 and 2), a sample of fruit from each variety was taken and the following analyses were carried out: maturity index (method developed in 2004 by the CIFA Alameda del Obispo, Spain), fruit size (in grams), oil percentage in dry and fresh matter (determined by near infra-red (NIR)), and moisture content (determined by NIR).

Table 1 Fruit parameters in Arbequina, Barnea and Manzanilla for laboratory trials in 2009

	OFM (%)[1]	Moisture (%)	ODM (%)[2]	Maturity Index	Weight (gr)
Arbequina	18.8	56.0	42.8	2.2	0.9
Barnea	18.8	53.4	40.3	2.6	1.4
Manzanilla	12.8	62.2	34.0	1.2	3.2

[1]Oil on fresh matter
[2]Oil on dry matter

Table 2 Fruit parameters in Barnea for processing trials in 2010

	OFM (%)[1]	Moisture (%)	ODM (%)[2]	Maturity Index	Weight (gr)
Enzyme trials	17.7	53.6	38.2	2.1	2.9
Powder trials	17.9	56.5	41.0	2.4	3.6
Warm water trials	16.2	59.6	40.2	3.3	2.1

[1]Oil on fresh matter
[2]Oil on dry matter

Photo 1. The Abencor® system utilised in the laboratory trials in 2009

Photo 2. The processing plant and decanter used for trials in 2010

Processing aids and techniques

Talcum powder, salt and calcium carbonate

The fruit of the three varieties was treated with talcum powder (talc) at a rate of 2.0 per cent (20 kg of talc per tonne of olives crushed), microtalcum powder (microtalc) at a rate of 0.3 per cent, microtalc at a rate of 0.6 per cent, common salt (NaCl) at a rate of 2.0 per cent, and calcium carbonate at a rate of 2.0 per cent. The addition of these coadjuvants was made at the beginning of the malaxing step. The talc (Plustalc N275), microtalc (Plustalc N1250) and calcium carbonate (Omyacarb FG2 GL) were provided by Omya Australia. The common salt (Mermaid FG Premium) was provided by Cheetham Salt Ltd. The product specifications are presented in Tables 3, 4 and 5.

Table 3 Talc and microtalc powder specifications for trials in 2009 and 2010

	δ50% (µm)[1]	δ98% (µm)[2]	SSA (m^2/gr) BET[3]
Plustalc N275	8	38	3.6
Plustalc N1250	2	10	7.0

[1]Mean particle size
[2]Largest particle size
[3]Specific surface area

Table 4 Calcium carbonate specifications for trials in 2009 and 2010

	δ50% (µm)[1]	δ98% (µm)[2]	SG (gr/ml)[3]
Omyacarb FG 2	2.8	12	2.7

[1]Mean particle size
[2]Largest particle size
[3]Specific gravity

Table 5 Common salt specifications for trials in 2009 and 2010

	δ40% (mm)[1]	P (%)[2]	I (%)[3]
Mermaid FG	2.8	12	2.7

[1]Mean particle size
[2]Purity
[3]Insolubles

Enzymes

Four different enzyme preparations (Table 6) provided by Novozymes Australia Pty Ltd were used: Pectinex Ultra SP-L; NZ 33095; NZ33095/Celluclast 1.5 (50:50); and Viscozym L. The addition of these coadjuvants was made at the beginning of the malaxing step.

Warm dipping

Olives of the three different varieties were heated in warm water at three different temperatures: 30°C, 45°C and 60°C. The olives were immersed in a thermostatic water bath at the set temperatures for a period of 5 minutes prior to oil extraction.

Table 6 Enzyme preparations used for trials in 2009 and 2010 and their main composition

	Main chain activity[1]	Side chain activity[2]	Other
Pectinex Ultra SP-L	Low	High	Rhamno/hemicellulases
NZ 33095	High	Average	Rhamno/hemicellulases
NZ 33095/Celluclast 1.5	High	Average	Cellulases
Viscozym L	Average	High	Betaglucanases

[1]Enzymes working on main pectin chain or "smooth region": Polygalacturonase/Pectin methyl esterase/Pectin lyase activities
[2]Enzymes working on side pectin chain or "hairy region"

Determinations

Oil extractability: The calculation of oil extractability in the laboratory for each treatment was based on the following formula:

$$\frac{(A + B)/2}{Wp}$$

where:

A = oil yield (ml) obtained after 5 minutes of sedimentation in volumetric cylinder
B = oil yield (ml) obtained after 30 minutes of sedimentation in volumetric cylinder
Wp = weight (grams) of the paste treated and centrifuged in Abencor®

At the processing-plant level, pomace oil content was determined using NIR equipment.

In the case of the field trials carried out in 2010, oil extractability was calculated as follows:

$$\frac{Wo \times 100}{Wf \times OFM}$$

where:

Wo = weight of the oil obtained
Wf = weight of fruit
OFM = oil per cent on fresh matter basis

Basic quality parameters: Determination of free fatty acids (American Oil Chemists' Society (AOCS) method Ca 5a-40), peroxide value (AOCS Cd 8-53), UV coefficients K232 and K270 (AOCS Ch 5-91) were carried out. Results were expressed as percentage of oleic acid, meq O_2/kg oil, and extinction at 232 and 270 nm, respectively.

Induction time: Potential shelf life can be expressed as induction time. This parameter was measured with a 743 Rancimat (Metrohm & Co), using an oil sample of 2.5 g warmed at 130 ºC and exposed to a 20 l/h air flow. The results were expressed in hours.

Total polyphenols content: The phenol extract was isolated by SPE Diol column 6 ml/500 mg (Chromabond Macherey-Nagel GmbH & Co) using an elution solution of methanol:water. The Folin-Ciocalteu method was used to evaluate the concentration of total polyphenols in the samples at 725 nm. The results were expressed as mg/kg of caffeic acid.

Bitterness: The bitter compounds were isolated by SPE C18 column 6 ml/500 mg (Chromabond Macherey-Nagel GmbH & Co) using an elution solution of methanol:water. The obtained extract was

measured at 225 nm of absorbance against methanol:water as blank in a 1 cm quartz cuvette (Gutierrez et al. 1992). The results were expressed as extinction at 225 nm.

Organoleptic assessment: Sensory analysis of the samples was carried out by trained panel tasters according to the method described in International Olive Council (IOC/T.20/Nº15-Rev.10) (IOC 2018). The method involves, as a measurement instrument, a group of 8 to 12 persons suitably selected and trained to identify and evaluate the intensities of positive and negative sensory perceptions (Boskou 2006). Samples were randomly presented and tasters were requested to mark their perceptions on a profile sheet and to evaluate their intensity on an unstructured scale ranked from 0 to 10. The procedure was repeated three times in different order to minimise the error. The panel tasters are well trained to identify and quantify the typical organoleptic defects associated to olive oils. Data provided by tasters were statistically processed to verify the reliability of the test. The median values of the defect and attributes perceived were utilised and used to identify the oil category.

HPLC analysis of phenolic compounds: The phenol extract was isolated by SPE Diol using methanol as the elution reagent. The resulting solution was evaporated under vacuum and the residue dissolved in methanol:water (1:1). The clear solution was maintained at room temperature for 4 hours before being analysed by high-performance liquid chromatography (HPLC). Chromatograms were obtained at 280 nm.

Colour index: The method used was ABT modified for olive oil (UNE 55021), developed by Gutierrez Gonzalez-Quijano and Gutierrez Rosales (Fat and Oil Institute, CSIC, Seville, Spain).

Pyropheophytins (PPP): DGF method C-VI-15 (06) was used. The pigments (pheophytins, pyropheophytins, chlorophyll a and chlorophyll b) were separated using silica gel columns. The elution was analysed by HPLC using a RP C18 column and a UV-detector at 410nm. The concentration of pigments including pyropheophytins was calculated using peak areas. The oil samples from the treatments were analysed twice: three and nine months after completion of the oil extraction.

1,2-Diacylglicerides (DAGs): DGF method C-VI-16 (06) was used. Miniaturised silica gel column chromatography was used to separate the isomeric diacylglycerols from the more polar fraction of the other lipids. The ratios of 1,2 and 1,3-isomers were determined by gas chromatography after silylation of the sample. The oil samples from the treatments were analysed twice: three and nine months after completion of the oil extraction.

Additionally, conductivity and pH tests were carried out on pomace samples from Barnea treated with salt (0.6 per cent) and calcium carbonate (0.6 per cent).

Statistical analysis was conducted using the SAS version 8.02 (SAS Institute Inc., Cary, NC, USA).

Results

Data showing the results from all tests are presented in Tables 7 through 20 and these are found in Appendix 1.

Paste extractability

Talc and microtalc powder

Talc (2.0 per cent) and microtalc powder (0.6 per cent) significantly improved paste extractability in all three olive cultivars trialled at laboratory level (Table 7 and Figure 1). The highest improvements in paste extractability were achieved in cultivar Manzanilla, possibly due to the positive effect on the rheological properties of the paste by the use of powders in this high fruit-moisture variety. Results from processing-plant trials in 2010 with cultivar Barnea (Table 8) were consistent with results obtained at laboratory level. These results are also in agreement with other research work (Sanchez et al. 2007).

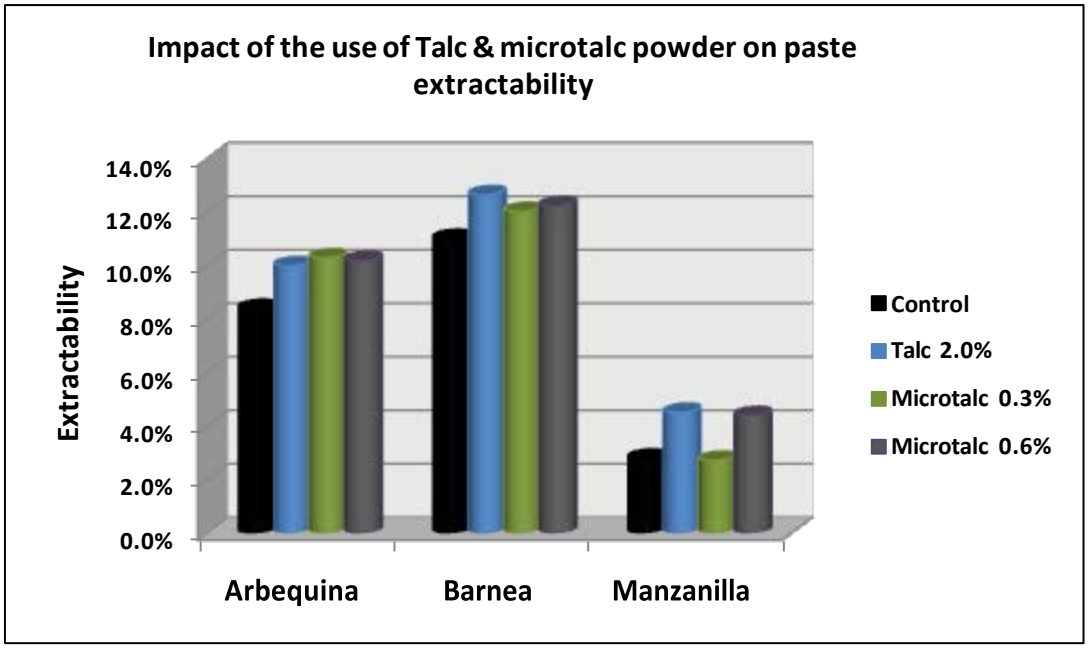

Figure 1. Impact of the use of talc and microtalc powder on paste extractability

Common carbonate and calcium salt

Calcium carbonate (2.0 per cent) provided consistently better paste-extractability results than the control in all three cultivars, though differences were statistically significant only in Arbequina and Manzanilla (Table 7 and Figure 2). The results obtained in cultivar Arbequina agree with other research work (Espinola et al. 2009). The highest improvements were obtained in Manzanilla, probably due to the same reasons stated above for talc powders. Common salt (2.0 per cent) showed better results than the control in Barnea and Arbequina and the differences were significant only in the last variety. The results obtained in cultivar Arbequina are also in agreement with other research work (Cruz et al. 2007b). Results from processing plant trials in 2010 with cultivar Barnea (Table 8) were consistent with those results obtained at laboratory level.

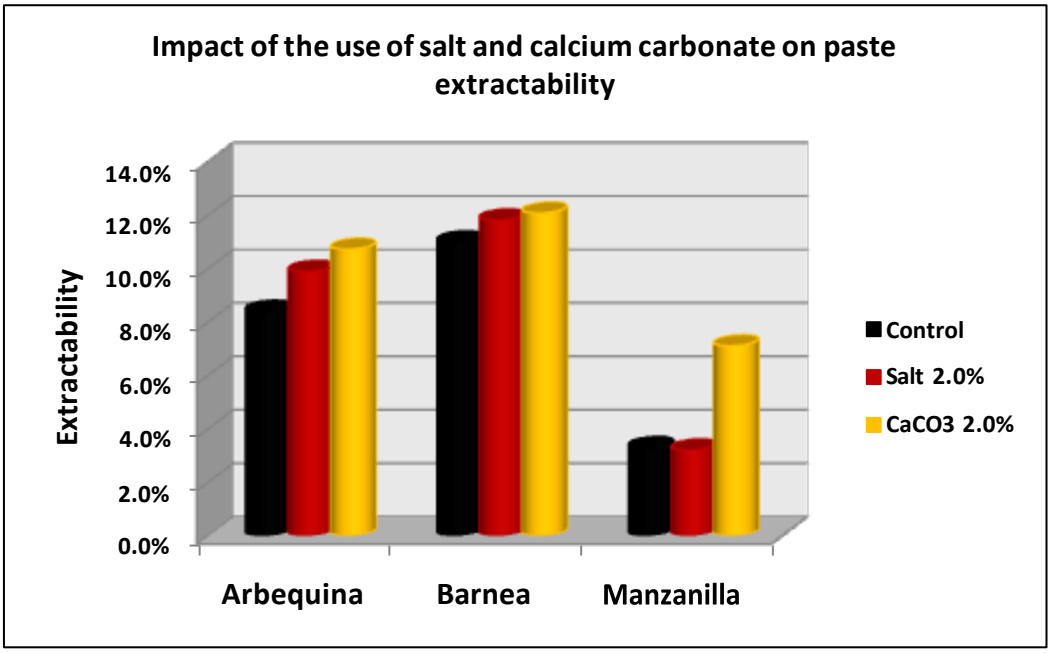

Figure 2. Impact of the use of salt and calcium carbonate on paste extractability

Enzymes

Laboratory trials in 2009 showed significant differences only in cultivar Arbequina (Table 7 and Figure 3), where the enzyme composition with the highest 'main chain' activity (NZ 33095, 0.3 per cent) had the highest paste extractability results and the enzyme with higher betaglucanase side-chain activity (Viscozym-L, 0.3 per cent) showed the lowest results but still significantly better than the control. It is noteworthy that in cultivar Manzanilla all four enzyme compositions provided lower paste-extractability results than the control treatment.

Results obtained at processing-plant level in 2010 with cultivar Barnea showed significant positive differences in paste extractability for all four enzyme preparations (Table 8), where Viscozym-L (high betaglucanase side-chain activity, 0.3 per cent) had the best results of all the enzymes. These positive extractability results are in agreement with other research work carried out on other olive varieties and using other pectinase enzyme products (Ranalli and DeMattia 1997; Ranalli et al. 2003).

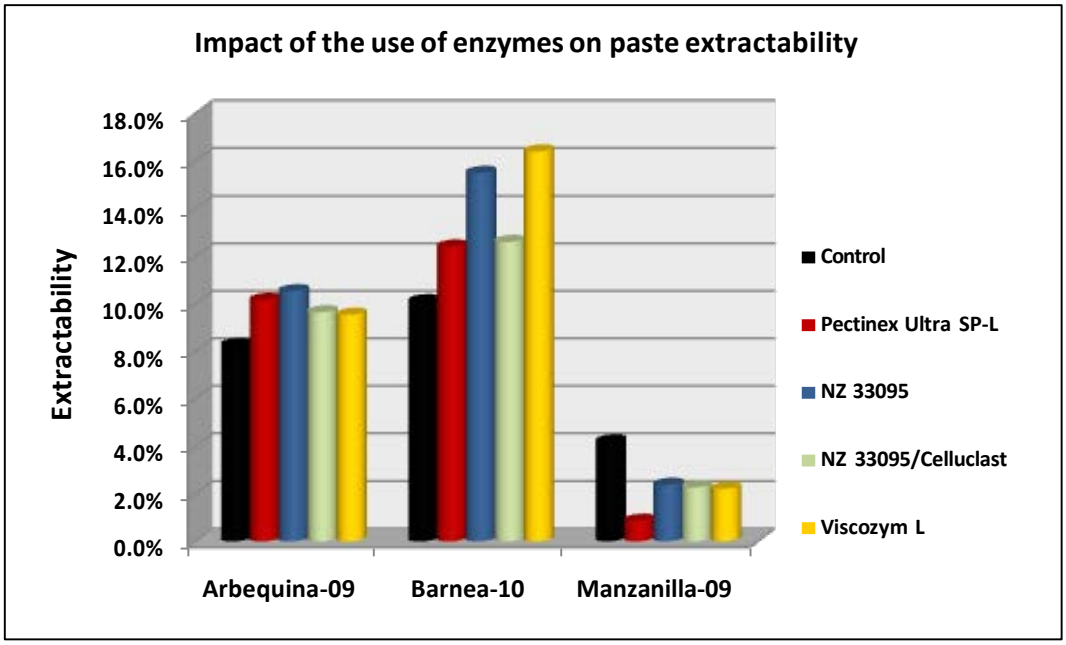

Figure 3. Impact of the use of enzymes on paste extractability

Warm water dipping

Laboratory trials in 2009 showed slight improvements in paste extractability only at 60°C for Barnea and Arbequina (Table 7 and Figure 4). The trials of Manzanilla fruit failed to improve the results obtained with the control, probably due to the increase in fruit moisture after the dipping of the olive fruit for 3 minutes in warm water. The trials in 2010 were carried out at laboratory level only using Barnea fruit (Table 8) and showed improvement in paste extractability at 45°C and 60°C with the difference being significant only in the last case.

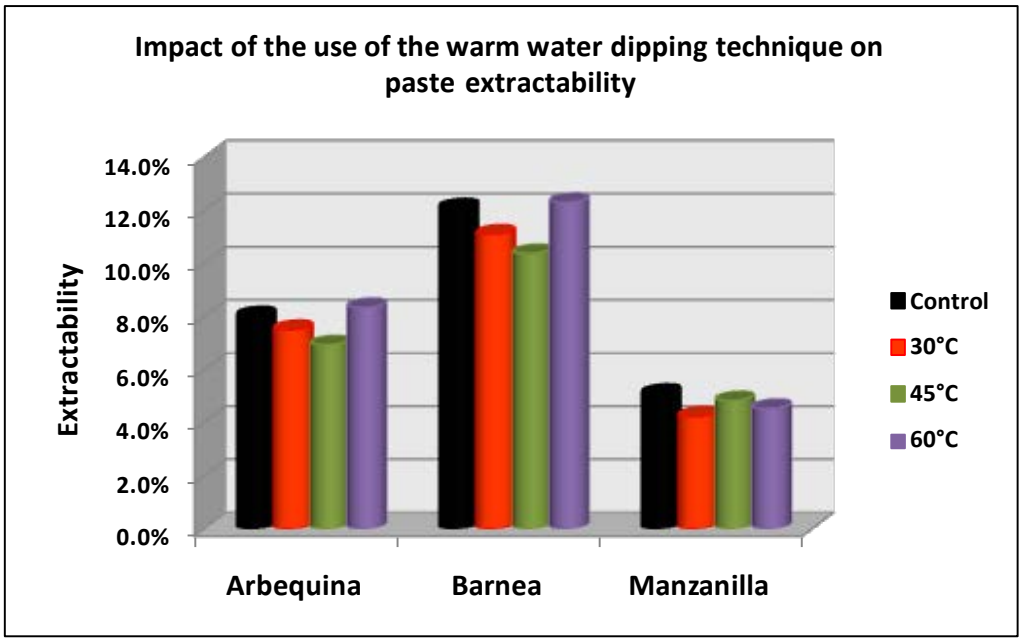

Figure 4. Impact of the use of warm water dipping on paste extractability

Oil quality

Talc, microtalc powder, salt and calcium carbonate

The oil quality produced from all solid aid treatments was extra virgin according to IOC standards. Talc (2.0 per cent) and microtalc powder (0.3 per cent and 0.6 per cent) showed significantly lower values of free fatty acids than the control (Table 9 and Figure 5). These results agree with other research work (Sanchez et al. 2007). The same aids showed lower induction time values than the control in all three olive cultivars trialled (Table 13). Common salt (2.0 per cent) showed lower peroxide value scores and higher values of total polyphenols (Table 14) than the control in cultivars Barnea and Manzanilla. Calcium carbonate (2.0 per cent) generated a positive reduction of the free fatty acids and an increase in 1,2-DAGs (Table 17), but it also showed a significant negative increase in peroxide value (Figure 6), K232, K270, and a decline in K225 (Table 15), total polyphenols and induction time. Additionally, there was an increase in the intensity of the green colour of the oil (Photo 3) and a change in its organoleptic character ('dry herbs' aroma and sweeter palate) by the use of calcium carbonate. The chemical and organoleptic differences obtained with the use of calcium carbonate in this research work disagree with other research work (Espinola et al. 2008). The chemical and organoleptic results obtained in the 2010 processing-plant trials with the use of calcium carbonate at a lower rate of 0.6 per cent dose did not show significant differences in any of the parameters measured (Table 20).

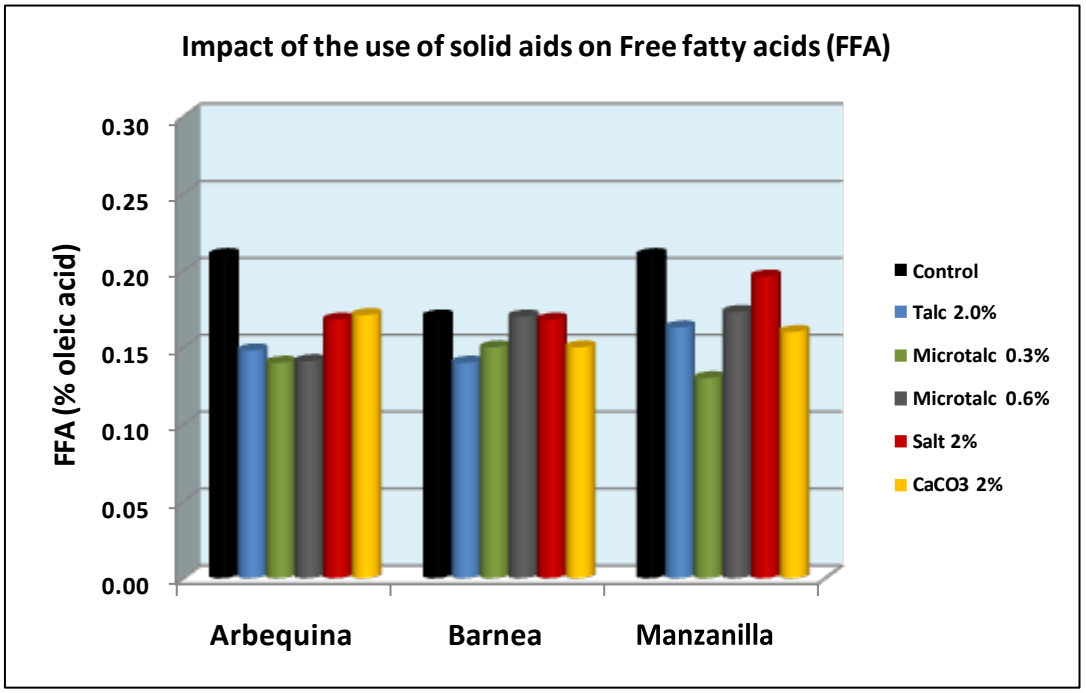

Figure 5. Impact of the use of solid aids on free fatty acids

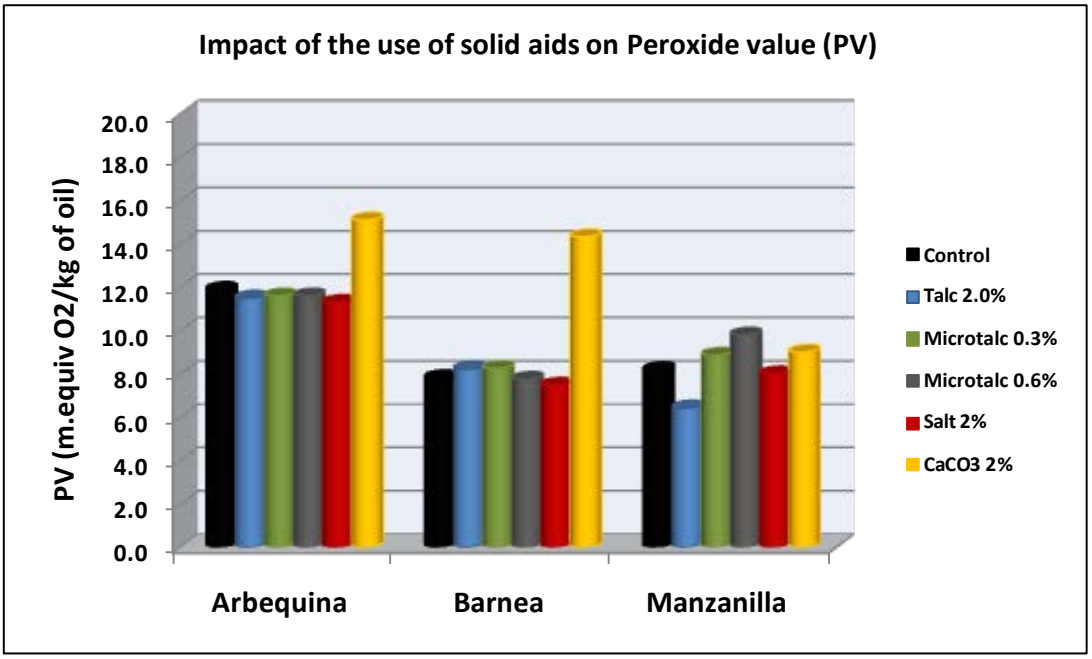

Figure 6. Impact of the use of solid aids on peroxide value

Enzymes

The oil quality produced from all enzyme treatments was extra virgin according to IOC standards. No significant differences or trends could be found by the addition of enzymes to the olive paste in the chemical parameters analysed. The enzyme NZ 33095 (high main-chain activity) showed consistently lower pyropheophytins values (Table 16 and Figure 7) and higher 1,2-diacylgliceride values (Figure 8) than the control. The total polyphenol values obtained at laboratory level in Barnea in 2009 and 2010 (Figure 9) showed no significant changes of this parameter when compared to the control.

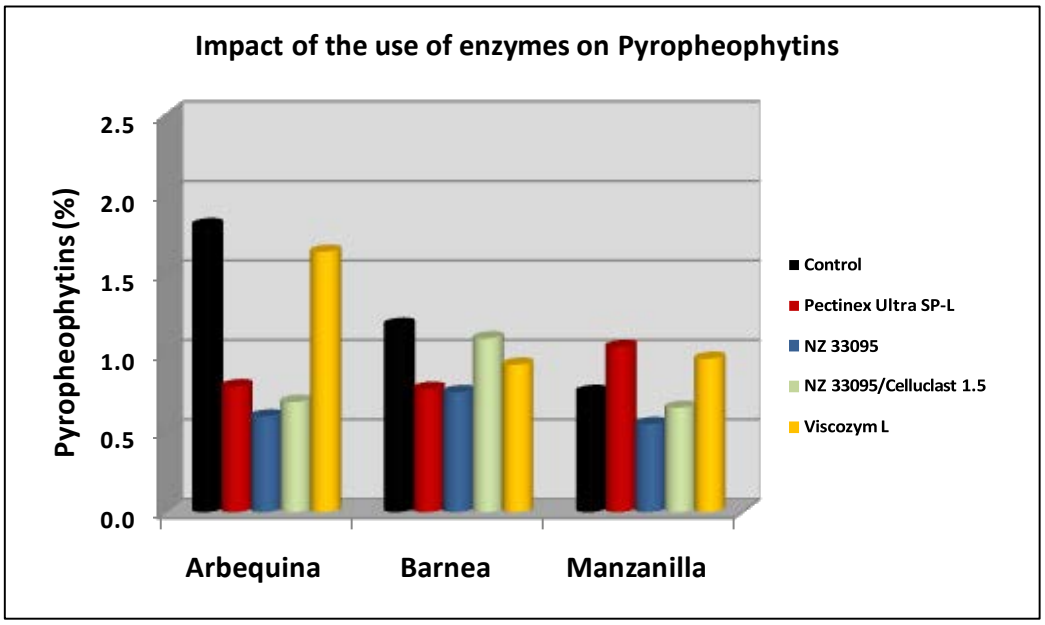

Figure 7. Impact of the use of enzymes on pyropheophytins

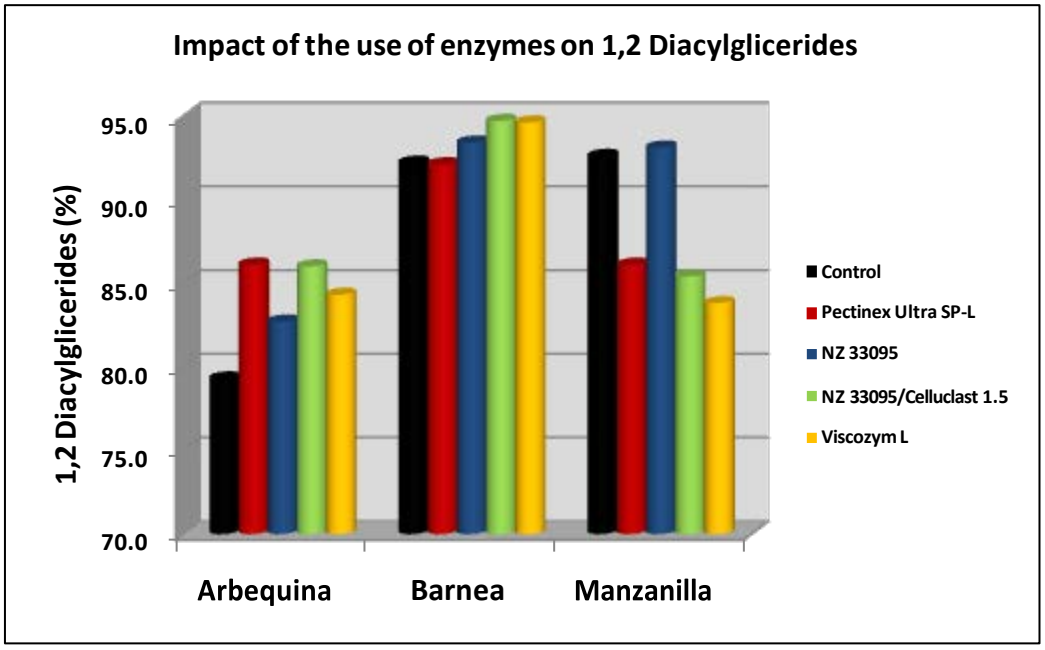

Figure 8. Impact of the use of enzymes on 1,2-diacylglicerides

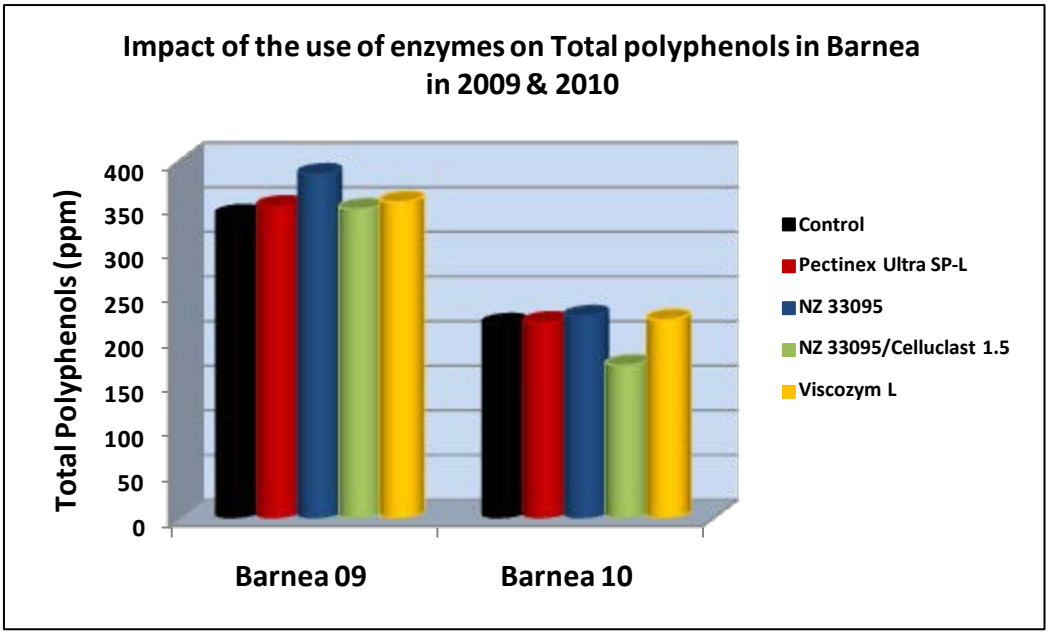

Figure 9. Impact of the use of enzymes on total polyphenols in Barnea

Warm water dipping

The increase in water temperature from 30°C to 60°C led to a decrease in free fatty acids and an increase in 1,2-DAGs. The same temperature increment generated a decrease in K225, total polyphenols (Table 14 and Figure 10) and induction time. The loss of polyphenols could be explained by the polar nature of these substances that makes them soluble in the warm water used for dipping. It could also be measured as an increment in the intensity of the green colour (Photo 4) and a change in the organoleptic character of the oil ('leafy' aroma and sweeter palate) at 60°C. Additionally, the concentration of ortho-diphenols and non-ortho-diphenols decreased with the increment of the water temperature (Table 18).

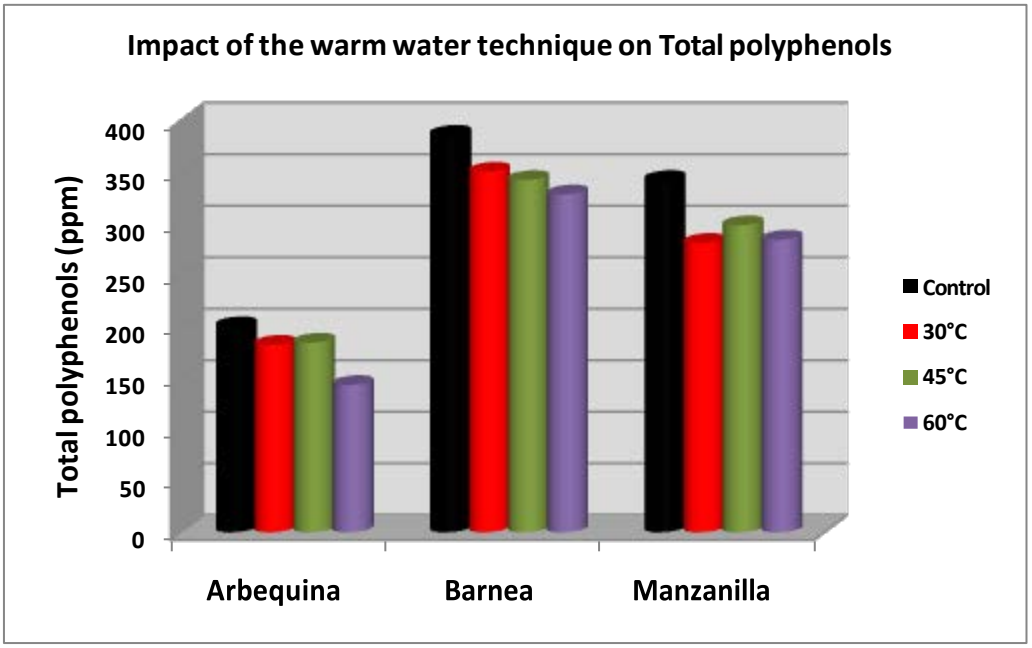

Figure 10. Impact of the warm water technique on total polyphenols

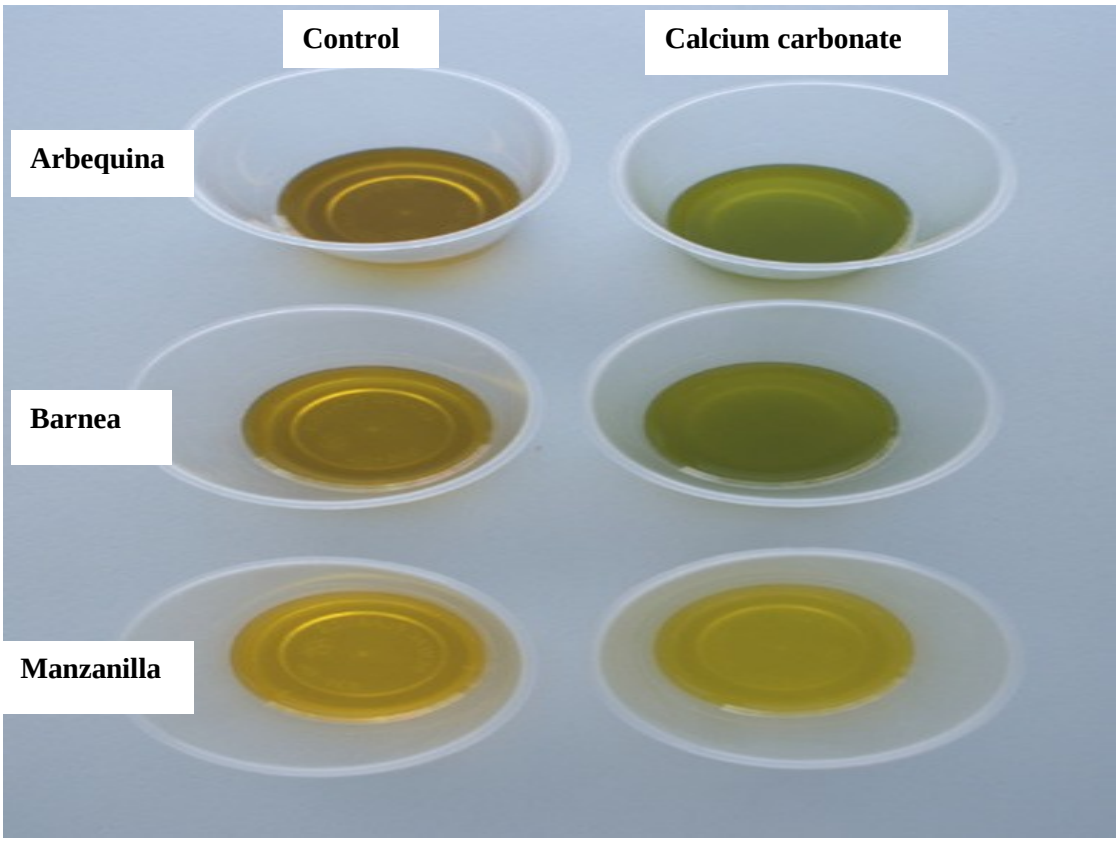

Photo 3. Oil colour in control treatment (without calcium carbonate) and treatment with calcium carbonate (2.0%) in varieties Arbequina, Barnea and Manzanilla

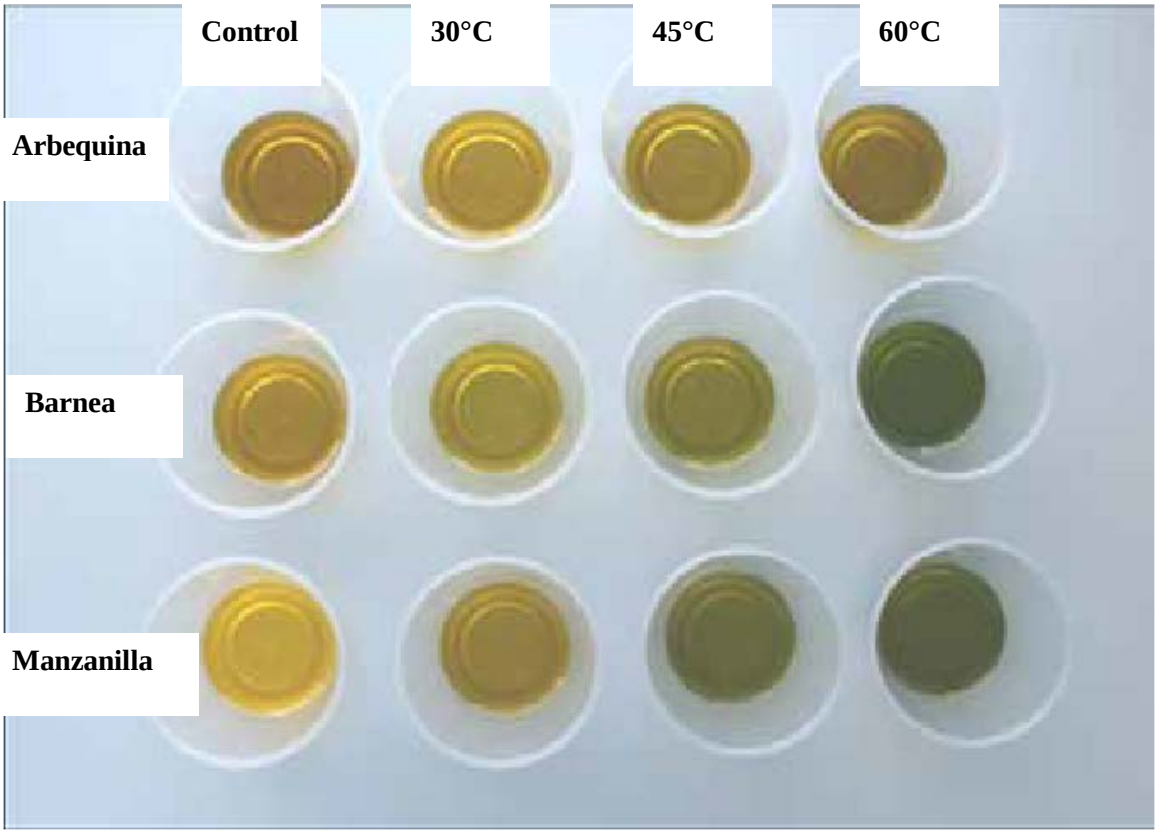

Photo 4. **Oil colour in control treatment (without water dipping) and treatments with water dipping at 30°C, 45°C and 60°C in varieties Arbequina, Barnea and Manzanilla**

Implications

The result of our research shows that the use of appropriate processing aids at the correct rates tends to improve oil extraction efficiency in a cost-effective way without adversely affecting the oil quality.

Given the fact that it is estimated that the current industrial efficiency of the Australian olive oil industry ranges between 75 and 87 per cent, each additional percentage point of improvement in this efficiency by the proper use of these processing aids would represent for the industry approximately $1 million worth of oil per year with the current production level and $2 million per year for expected future production levels by 2025.

The processing aids studied in this report are allowed for use in olive oil production under current Australian codes of practice (Australian Olive Association 2008). Consequently, the industry needs to be made aware of these outcomes. Australian growers and processors – characteristically focused on product quality – should consider the use of these processing tools for oil extraction improvement since they do not seem to impact negatively on oil quality.

From the quality perspective, it is important to note that the use of processing aids allow producers to reduce malaxation times and temperatures in order to obtain better quality oils, not significantly compromising oil yields (Tamborrino et al, 2017).

While the improvement in paste extractability translates into more oil obtained during the extraction process, it is important to highlight that, at the same time, a more exhausted olive waste is also a more environmentally friendly pomace if it is going to be composted or spread back directly onto groves.

Additionally, Australian growers that use wet olive pomace (from 2-phase systems) for composting purposes would benefit from the use of enzymes since other research works have reported a reduction in the pomace moisture when using this processing aid thus making this by-product more easily handled for composting (Sharma et al, 2007; Millán Linares et al, 2006).

Scientific works carried out by other researchers have proven that the use of some of these aids has a significant positive impact on the cleanliness of the oils obtained (Najafian et al, 2009; Sharma et al, 2007). These findings have important implications to small Australian growers that are not able to vertically centrifuge the oils produced since obtaining cleaner oils (less cloudy or turbid) makes them less exposed to sedimentation issues during storage.

Although not tested in this work, the use of enzymes has proven to help in reducing the energy consumption of malaxers, paste pump and decanter motors. This effect is due to the reduction in paste viscosity that is attributed to the degradation of pectins and the increase in fluidity generated by the action of enzymes. Australian growers should consider the use of this processing tool if industrially facing olive pastes of high viscosity (typically from low fruit maturity and/or low fruit moisture and/or low fruit oil content).

Recommendations

This study confirmed the beneficial impact of solid processing aids such as talc, microtalc, calcium carbonate and salt on processing efficiency when dealing with high-moisture fruit and potential emulsion problems. Olive varieties with high fruit-moisture levels tend to produce oil/water emulsions during the crushing step of the extraction process. Solid aids such as talc, microtalc and calcium carbonate (in doses lower than 1.0 per cent) have been useful in breaking those emulsions and provided higher paste-extractability results as a consequence, without impacting on the oil quality.

Apart from Manzanilla, other varieties that tend to show high fruit-moisture levels and that could benefit from the use of solid aids would be Picual, Hojiblanca, Leccino, Arbequina, and most table olive varieties that are processed for oil extraction.

Due to its high solubility in water and low solubility in oil, common salt induces changes in the density of the water phase of the fruit, stretching out the oil/water density differential. This seems to allow for better centrifugation performance and higher paste extractability results, as experienced in this research work.

However, while talc and microtalc didn't show any concerning issues, the use of calcium carbonate (in doses of 2.0 per cent) and common salt could lead to quality or environmental problems that may require further analysis.

Different enzymes were demonstrated to be very effective in changing the rheological properties of the olive paste, resulting in a significant positive impact on paste extractability. The enzyme treatment tends to be more effective with low-maturity fruit and when the pectin content in pulp cell walls is high.

In addition, enzymes may require the prior addition of a solid aid to potentiate their effectiveness when dealing with high-moisture fruit. Due to their high biological specificity, enzymes used for olive oil processing do not alter the fatty composition of the oil and have no negative impact on oil quality.

Warm water dipping prior to crushing seemed rather impractical, particularly for large operations. Furthermore, it only showed limited extraction efficiency improvements; this is possibly due to the increase of fruit moisture during the water dipping step. Additionally, this technique showed some impact on oil quality.

When fruit conditions are appropriate, the use of talc powder, microtalc powder and enzymes for olive oil extraction can be recommended as the results shown in this report demonstrate that these processing aids help increase oil paste extractability without impacting on oil quality and thus achieving a cost-effective result. Talc powder and enzymes can have a synergetic action provided that both aids are added at the start of the malaxing step of the extraction process and that the fruit condition requires both of them.

Due to its high lipophilic nature, talcum powder should be added to the freshly crushed paste at the beginning of the malaxation process. It is key to its performance that talc powder should be added slowly and continuously to the paste using proper dosing equipment. Similarly, enzymes should be added immediately after the crushing step in order to maximise contact time. It is recommended that enzymes are diluted in water (water/enzyme ratio = 5:1) and that they are added to the paste using pulsating pumps.

Based on these findings, Australian growers should be advised about the advantages and disadvantages of the use of processing aids as well as the processing aspects to evaluate before and during their use.

A strategic advantage of the use of processing aids for the Australian industry is the possibility they provide of starting the harvest earlier in order to obtain better quality oils without significantly compromising oil yields. Characteristically, oils from early harvest tend to have a longer shelf life, which is also an aspect of the quality of the oil that both the Australian Standard and the *OliveCare*®

program have emphasized on over recent years.

Agrifutures Australia (previously RIRDC) and Australian Olive Association (AOA) should disseminate the details of this study to the industry with some urgency. The AOA has access to a large portion of the industry through its members and the well-utilised AOA web page and this data can quickly be made available to those who may be willing to improve their processing efficiencies reducing oil losses without impacting on quality.

Appendix 1

Table 7 **Paste extractability results (values in %) in Arbequina, Barnea and Manzanilla fruit with the use of different processing aids and techniques using Abencor® in 2009[1]**

	Arbequina	Barnea	Manzanilla
Control	8.4% b	11.0% b	2.8% b
Talc powder (2.0%)	9.9% a	12.6% a	4.5% a
Microtalc powder (0.3%)	10.2% a	12.0% ab	2.7% b
Microtalc powder (0.6%)	10.2% a	12.2% a	4.3% a
F[2]	35.85	7.659	35.14
Significance	< 0.0001	0.0097	< 0.0001
Control	8.4% c	11.0% a	3.3% b
Common salt (2.0%)	9.8% b	11.8% a	3.2% b
Calcium carbonate (2.0%)	10.7% a	12.1% a	7.1% a
F[2]	26.62	5.112	244.5
Significance	0.001	0.051	< 0.0001
Control	8.2% d	10.1%[3]	4.2% a
Pectinex Ultra SP-L (0.3%)	10.2% b	12.4%[3]	0.9% c
NZ 33095 (0.3%)	10.5% a	15.5%[3]	2.4% b
NZ 33095/Celluclast 1.5 (0.3%)	9.6% c	12.6%[3]	2.3% b
Viscozym L (0.3%)	9.5% c	16.4%[3]	2.2% b
F[2]	26.57		53.5
Significance	< 0.0001		< 0.0001
Control	8.0% a	12.1% a	5.1% a
30°C	7.5% a	11.1% b	4.2% d
45°C	6.9% a	10.4% b	4.8% b
60°C	8.3% a	12.3% a	4.5% c
F[2]	2.573	13.3	7.397
Significance	0.13	0.0018	0.011

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test $\alpha = 0.05$)

[2] F tests the effect of the processing aid or technique

[3] Results obtained at processing plant level

Table 8 Paste extractability results (values in %) in Barnea fruit with the use of different processing aids and techniques at processing plant level in 2010 (5000 kg/h decanter)[1]

	Barnea
Control	11.7%
Talc powder (0.6%)	13.9%
Microtalc powder (0.6%)	14.4%
Control	11.7%
Common salt (0.6%)	13.3%
Calcium carbonate (0.6%)	13.1%
Control	10.1%
Pectinex Ultra SP-L (0.3%)	12.4%
NZ 33095 (0.3%)	15.5%
NZ 33095/Celluclast 1.5 (0.3%)	12.6%
Viscozym L (0.3%)	16.4%
Control	6.4% b
30°C	6.4% b
45°C	7.5% b
60°C	9.3% a

[1]Results obtained at laboratory level in 2010 using Abencor®

Means followed by the same roman letter do not present significant differences (Duncan's multiple range test α = 0.05)

Table 9 Free fatty acids (values as % oleic acid) in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques[1]

	Arbequina	Barnea	Manzanilla
Control	0.21 b	0.17 c	0.21 b
Talc powder (2.0%)	0.15 a	0.14 a	0.16 a
Microtalc powder (0.3%)	0.14 a	0.15 b	0.13 a
Microtalc powder (0.6%)	0.14 a	0.17 c	0.17 ab
F[2]	3.384	3.8	0.5606
Significance	0.038	0.026	0.64
Control	0.21 b	0.19 c	0.16 a
Common salt (2.0%)	0.17 a	0.17 b	0.20 b
Calcium carbonate (2.0%)	0.17 a	0.15 a	0.16 a
F[2]	1.338	12.39	1.65
Significance	0.29	0.0007	0.21
Control	0.21 c	0.18 b	0.18 a
Pectinex Ultra SP-L (0.3%)	0.15 ab	0.16 a	0.16 a
NZ 33095 (0.3%)	0.17 b	0.16 a	0.21 b
NZ 33095/Celluclast 1.5 (0.3%)	0.14 a	0.16 a	0.37 d
Viscozym L (0.3%)	0.20 c	0.16 a	0.27 c
F[2]	2.635	0.2584	22.83
Significance	0.058	0.9	<0.0001
Control	0.27 c	0.17 c	0.19 a
30°C	0.18 a	0.14 a	0.19 a
45°C	0.22 b	0.15 b	0.16 a
60°C	0.21 b	0.17 c	0.16 a
F[2]	6.533	3.8	3.72
Significance	0.0029	0.026	0.017

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test α = 0.05)

[2] F tests the effect of the processing aid or technique

Table 10 Peroxide value (meq O2/kg) in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques[1]

	Arbequina	Barnea	Manzanilla
Control	11.9 a	7.8 a	8.2 bc
Talc powder (2.0%)	11.5 a	8.2 a	6.4 ab
Microtalc powder (0.3%)	11.6 a	8.3 a	8.9 c
Microtalc powder (0.6%)	11.6 a	7.8 a	9.8 c
F[2]	0.2316	1.309	9.455
Significance	0.87	0.3	<0.0001
Control	11.9 a	7.8 a	8.2 a
Common salt (2.0%)	11.3 a	7.5 a	8.0 a
Calcium carbonate (2.0%)	15.1 b	14.3 b	9.0 a
F[2]	34.92	604.7	0.9686
Significance	<0.0001	<0.0001	0.39
Control	11.9 bc	9.1 a	5.8 a
Pectinex Ultra SP-L (0.3%)	13.8 cd	8.7 a	5.2 a
NZ 33095 (0.3%)	14.7 d	9.0 a	6.4 a
NZ 33095/Celluclast 1.5 (0.3%)	11.3 b	9.6 a	6.7 a
Viscozym L (0.3%)	8.8 a	9.9 a	7.2 a
F[2]	24.36	0.3881	1.265
Significance	<0.0001	0.82	0.3
Control	9.6 a	10.5 b	6.1 a
30°C	8.6 a	8.2 a	7.3 ab
45°C	10.3 ab	8.0 a	8.6 b
60°C	11.6 b	7.9 a	7.5 ab
F[2]	7.395	12.19	4.837
Significance	0.0016	<0.0001	0.0049

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test $\alpha = 0.05$)

[2] F tests the effect of the processing aid or technique

Table 11 K232 values in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques[1]

	Arbequina	Barnea	Manzanilla
Control	1.609 c	1.367 a	1.474 a
Talc powder (2.0%)	1.540 a	1.421 b	1.462 a
Microtalc powder (0.3%)	1.581 b	1.481 c	1.507 b
Microtalc powder (0.6%)	1.580 b	1.435 b	1.460 a
F[2]	3.991	13.24	1.64
Significance	0.022	<0.0001	0.2
Control	1.609 a	1.367 a	1.463 a
Common salt (2.0%)	1.592 a	1.612 b	1.541 b
Calcium carbonate (2.0%)	2.148 b	2.113 c	1.586 c
F[2]	95.96	70.44	13.24
Significance	<0.0001	<0.0001	<0.0001
Control	1.609 a	1.479 a	1.406 bc
Pectinex Ultra SP-L (0.3%)	1.762 c	1.574 ab	1.398 b
NZ 33095 (0.3%)	1.936 e	1.597 b	1.446 c
NZ 33095/Celluclast 1.5 (0.3%)	1.822 d	1.652 b	1.348 a
Viscozym L (0.3%)	1.681 b	1.617 b	1.367 ab
F[2]	15.87	0.2764	3.41
Significance	<0.0001	0.89	0.017
Control	1.504 a	1.589 c	1.421 a
30°C	1.519 a	1.593 c	1.466 b
45°C	1.666 c	1.543 b	1.444 ab
60°C	1.624 b	1.468 a	1.432 a
F[2]	6.488	15.32	1.815
Significance	0.003	<0.0001	0.16

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range testα = 0.05)

[2] F tests the effect of the processing aid or technique

Table 12 K270 values in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques[1]

	Arbequina	Barnea	Manzanilla
Control	0.152 b	0.135 b	0.129 bc
Talc powder (2.0%)	0.168 c	0.126 a	0.124 a
Microtalc powder (0.3%)	0.150 b	0.126 a	0.131 c
Microtalc powder (0.6%)	0.131 a	0.129 a	0.126 ab
F[2]	11.18	1.196	0.5029
Significance	0.0002	0.34	0.68
Control	0.152 c	0.135 a	0.135 a
Common salt (2.0%)	0.144 b	0.149 b	0.132 a
Calcium carbonate (2.0%)	0.137 a	0.175 c	0.156 b
F[2]	3.886	8.647	15.39
Significance	0.044	0.0032	<0.0001
Control	0.152 d	0.140 a	0.267 b
Pectinex Ultra SP-L (0.3%)	0.132 b	0.153 b	0.112 a
NZ 33095 (0.3%)	0.126 a	0.142 a	0.123 a
NZ 33095/Celluclast 1.5 (0.3%)	0.138 c	0.142 a	0.123 a
Viscozym L (0.3%)	0.162 e	0.143 a	0.116 a
F[2]	24.96	0.5461	0.6335
Significance	<0.0001	0.7	0.64
Control	0.152 c	0.144 c	0.265 b
30°C	0.127 a	0.131 b	0.131 a
45°C	0.135 b	0.129 b	0.122 a
60°C	0.132 b	0.117 a	0.121 a
F[2]	13.34	6.223	0.3038
Significance	<0.0001	0.0037	0.82

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test $\alpha = 0.05$)

[2] F tests the effect of the processing aid or technique

Table 13 Induction time (values in hours at 130 °C in Rancimat®) in Arbequina, Barnea and Manzanilla oils with the use of processing aids and techniques[1]

	Arbequina	Barnea	Manzanilla
Control	6.2 a	7.9 a	11.3 a
Talc powder (2.0%)	5.0 b	7.8 ab	10.7 a
Microtalc powder (0.3%)	4.7 b	7.1 bc	9.7 a
Microtalc powder (0.6%)	5.1 b	6.6 c	10.3 a
F[2]	3.53	8.466	0.7345
Significance	0.068	0.0073	0.55
Control	6.2 a	7.9 a	13.0 a
Common salt (2.0%)	6.3 a	7.5 a	11.0 a
Calcium carbonate (2.0%)	3.0 b	4.7 b	11.5 a
F[2]	21.62	43.99	0.433
Significance	0.0018	0.0003	0.66
Control	6.2 a	7.9 a	11.8 a
Pectinex Ultra SP-L (0.3%)	4.3 b	7.3 a	8.8 a
NZ 33095 (0.3%)	4.4 b	7.9 a	9.6 a
NZ 33095/Celluclast 1.5 (0.3%)	5.2 ab	7.4 a	10.4 a
Viscozym L (0.3%)	6.0 a	7.6 a	10.0 a
F[2]	7.831	0.4211	1.821
Significance	0.004	0.79	0.17
Control	6.0 a	7.9 a	10.4 ab
30°C	5.3 a	6.6 a	10.7 a
45°C	5.7 a	7.1 a	9.3 bc
60°C	5.4 a	7.1 a	8.5 c
F[2]	1.291	2.424	12.91
Significance	0.34	0.14	<0.0001

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test $\alpha = 0.05$)

[2] F tests the effect of the processing aid or technique

Table 14 Total polyphenols (values in ppm) in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques[1]

	Arbequina	Barnea	Manzanilla
Control	240 a	292 ab	302 a
Talc powder (2.0%)	166 b	307 a	323 a
Microtalc powder (0.3%)	146 c	298 ab	280 a
Microtalc powder (0.6%)	126 d	270 b	319 a
F[2]	9.77	3.518	1.703
Significance	0.0004	0.034	0.18
Control	240 a	292 b	336 a
Common salt (2.0%)	228 a	332 a	348 a
Calcium carbonate (2.0%)	125 b	196 c	308 a
F[2]	25.12	51.06	3.061
Significance	<0.0001	<0.0001	0.06
Control	240 a	339 a	318 a
Pectinex Ultra SP-L (0.3%)	133 c	349 a	213 c
NZ 33095 (0.3%)	146 bc	385 a	290 b
NZ 33095/Celluclast 1.5 (0.3%)	182 b	346 a	228 bc
Viscozym L (0.3%)	233 a	354 a	224 bc
F[2]	19.5	3.195	6.963
Significance	<0.0001	0.018	0.0002
Control	200 a	386 a	342 a
30°C	182 a	350 a	281 a
45°C	184 a	342 a	298 a
60°C	143 b	328 a	284 a
F[2]	8.612	2.963	0.1581
Significance	0.0007	0.057	0.92

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test $\alpha = 0.05$)

[2] F tests the effect of the processing aid or technique

Table 15 K225 values in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques [1]

	Arbequina	Barnea	Manzanilla
Control	0.20 b	0.21 c	0.23 b
Talc powder (2.0%)	0.15 ab	0.23 d	0.18 a
Microtalc powder (0.3%)	0.14 a	0.18 b	0.20 a
Microtalc powder (0.6%)	0.16 ab	0.17 a	0.20 a
F [2]	10.68	21.46	0.4655
Significance	0.0002	<0.0001	0.71
Control	0.20 b	0.21 c	0.21 b
Common salt (2.0%)	0.20 b	0.19 b	0.17 a
Calcium carbonate (2.0%)	0.11 a	0.15 a	0.18 a
F [2]	28.51	10.98	1.726
Significance	<0.0001	0.0012	0.19
Control	0.20 d	0.25 a	0.16 c
Pectinex Ultra SP-L (0.3%)	0.11 a	0.25 a	0.14 ab
NZ 33095 (0.3%)	0.11 a	0.28 b	0.15 bc
NZ 33095/Celluclast 1.5 (0.3%)	0.13 b	0.25 a	0.13 a
Viscozym L (0.3%)	0.18 c	0.27 ab	0.13 a
F [2]	14.69	4.315	2.267
Significance	<0.0001	0.0034	0.078
Control	0.15 b	0.29 c	0.15 b
30°C	0.12 a	0.26 b	0.17 c
45°C	0.15 b	0.27 b	0.13 a
60°C	0.12 a	0.23 a	0.16 bc
F [2]	5.884	6.165	3.236
Significance	0.0048	0.0038	0.03

[1] Means followed by the same roman letter do not present significant differences (Duncan's multiple range test $\alpha = 0.05$)

[2] F tests the effect of the processing aid or technique

Table 16 Pyropheophytins values (%) in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques

	Arbequina	Barnea	Manzanilla
Control	1.8	1.5	0.8
Talc powder (2.0%)	1.2	0.9	1.2
Microtalc powder (0.3%)			
Microtalc powder (0.6%)	1.1	1.0	1.1
F²			
Significance			
Control	1.8	1.5	0.9
Common salt (2.0%)	1.3	1.0	0.9
Calcium carbonate (2.0%)	0.6	0.5	1.0
F²			
Significance			
Control	1.8	1.2	0.8
Pectinex Ultra SP-L (0.3%)	0.8	0.8	1.0
NZ 33095 (0.3%)	0.6	0.8	0.6
NZ 33095/Celluclast 1.5 (0.3%)	0.7	1.1	0.7
Viscozym L (0.3%)	1.6	0.9	1.0
F²			
Significance			
Control	1.7	0.9	0.8
30°C	1.2	1.0	0.9
45°C	1.2	1.2	0.8
60°C	1.0	0.9	0.8
F²			
Significance			

Table 17 **1,2-Diacylglicerides values (%) in Arbequina, Barnea and Manzanilla oils with the use of different processing aids and techniques**

	Arbequina	Barnea	Manzanilla
Control	79.3	90.4	91.5
Talc powder (2.0%)	88.1	94.9	87.7
Microtalc powder (0.3%)			
Microtalc powder (0.6%)	86.3	90.1	94.1
F²			
Significance			
Control	79.3	90.4	92.5
Common salt (2.0%)	83.6	93.4	90.0
Calcium carbonate (2.0%)	85.8	93.1	95.3
F²			
Significance			
Control	79.3	92.2	92.6
Pectinex Ultra SP-L (0.3%)	86.1	92.1	86.1
NZ 33095 (0.3%)	82.7	93.4	93.1
NZ 33095/Celluclast 1.5 (0.3%)	86.0	94.7	85.4
Viscozym L (0.3%)	84.3	94.6	83.8
F²			
Significance			
Control	83.1	94.1	93.3
30°C	84.4	94.9	87.0
45°C	81.4	95.1	94.3
60°C	87.7	94.2	94.7
F²			
Significance			

Table 18 **Orto-diphenols & non-orto-diphenols content (values in ppm) in Arbequina, Manzanilla and Barnea oils using the warm water dipping technique**

	Arbequina		Barnea		Manzanilla	
	O-diph	Non-o	O-diph	Non-o	O-diph	Non-o
Control	56.1	69.9	216.8	143.5	101.4	64.7
30°C	124.8	128.7	37.5	259.3	88.6	77.0
45°C	43.5	54.7	163.4	129.0	92.7	58.8
60°C	41.9	25.8	148.3	104.4	68.3	71.3

Table 19 Conductivity μS) and pH in pomace from Barnea with the use of salt and calcium carbonate

	pH	Conductivity (μS)
Control	5.1	17750
Salt (0.6%)	5.0	46040
Calcium carbonate (0.6%)	5.5	23140

Table 20 Chemical parameters and organoleptic evaluation in Barnea oil with the use of calcium carbonate (0.6%) in field trials in 2010

	Control	Calcium carbonate (06%)
FFA (%)	0.18	0.20
PV (meqO2/kg)	6.0	6.4
K232	1.451	1.546
K270	0.100	0.135
ΔK	-0.002	0.001
K225	0.16	0.17
Total polyphenols (ppm)	217.0	153.0
Induction time (hours)	28.0	22.0
1,2 Diacylglycerides (%)	95.7	95.6
Organoleptic change	No	No

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This report analyses the impact of the use of traditional and new processing aids on olive oil extraction and oil quality.

The information generated by this project aims to provide new tools for improving olive oil processing that can increase both the extraction efficiency and profitability for olive producers in the Australian industry.

The report is targeted at the relatively new and actively growing group of olive oil processors in Australia. An understanding of the use of processing aids by oil producers will help them increase their profitability without affecting the quality of their product.

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