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Cultivation of Olives in Australia

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1. Introduction

Australia, by European standards, is a very young country with the first European settlers arriving as recently as 1788. Olives were not native to Australia but it took only a short time before the species was introduced. The first introduction of an olive tree to Australia was in 1800 (Spennemann, 2000), 12 years after the country was settled. Other importations have been recorded into New South Wales (NSW) including a tree planted by John Macarthur, one of Australia's pioneers and a man considered to be the father of the Australian sheep wool industry. A remaining olive tree still stands at Elizabeth Farm where he lived.

Despite the early start in the new settlement in NSW, little development occurred in that state over subsequent years. As the colony moved to other areas in Australia, olive production was spurred on by European immigrants particularly in the states of South Australia and Victoria. The NSW Department of Agriculture was formed in 1890 with an agenda to introduce new and useful species and study orchard farming and animal husbandry. The Department established experimental farms at sites throughout NSW including Wollongbar and Hawkesbury which became sites for evaluating olive production. In 1891 several Department of Agriculture research stations established schools and experimental farms including one at Wagga Wagga in Southern NSW, which included olive growing.

One of the most significant early developments for the olive industry was through the efforts of Sir Samuel Davenport (1818 – 1906), one of the early settlers of Australia, who became a landowner and parliamentarian in South Australia. His father was an agent of the "South Australia Company" in England and purchased land in South Australia. Samuel and his wife Margaret went to Australia in 1843 and ventured into mixed farming, almonds and vines. He tried sheep-farming and in 1860 he bought land near Port Augusta, SA, and turned to ranching horses and cattle. Davenport strongly promoted agriculture in South Australia and between 1864 and 1872 he published a number of papers, some concerning the cultivation of olives and manufacture of olive oil (en.wikipedia.org). In 1891 Davenport provided the NSW Department of Agriculture and other parts of the colony with olive cuttings from four cultivars, Verdale, Pigale, Blanquette and Bouquettier, from the south of France which were trialled for fruit production at the experimental farms.

In 1894, the farm at Wagga Wagga established orchards for evaluation of various fruits including plums, pears, persimmons and others. It was decided to establish a complete collection of olive cultivars within that orchard (Wagga Wagga Advertiser, 14 June 1894

from Spennemann 2000). Spennemann reports (2000) that by 1895, 8 acres of olives had been sown in Wagga Wagga "which now had the finest collection of cultivars in Australia" including many from California. By the turn of the century approximately 60 cultivars were present in the Wagga Wagga collection.

In future years significant studies were carried out on oil production and fruit pickling based on cultivars including *cvv*: Amelau, Blanquette, Bouquettier, Boutillan, Corregiola, Cucco, Dr Fiaschi, Gros Redondou, Macrocarpa, Nevadillo Blanco, Pigalle and Pleureur. Small scale commercial production and sales occurred after 1900 with the sale of olive oil and the distribution of olive cuttings for orchard development.

New cultivars continued to be introduced and the grove at Wagga Wagga expanded over subsequent years with several lines brought from Spain in 1932. Despite the excellent collection which had been established at Wagga Wagga, in 1959 it was decided to remove many of the trees due to low demand for the product. Although one of each of the cultivars was to be retained, subsequent loses through trees dying or being removed resulted in confusion about tree identification.

Fig. 1. One of over 100 trees and 60 cultivars planted at the Wagga Experimental Farm in 1891.

There was resurgence in interest in olive production in 1995 with the formation of the Australian Olive Association. At that time, Charles Sturt University, which had taken over ownership of the olive collection, made an attempt to resurrect the grove. The trees were severely pruned back from the massive size to which they had grown. A project funded by Rural Industries and Research Organisation (RIRDC) (Mailer & May, 2002) analysed DNA from leaves of the individual trees using RAPD analysis to attempt to identify the collection. This study was successful in naming many of the trees but for others there were no matches and identification was not possible. Some of the trees by this time had been named by areas in which the cuttings had been taken, such as Pera Bore or Hawkesbury Agricultural College, although logically, they were of European origin. At the same time, research on yield, oil content and oil quality was being carried out.

Based on this research, together with data from the original maps and planting diagrams, the Wagga Wagga orchard became the source of cuttings for some of Australia's leading

nurseries. Many trees were propagated and sold to new growers. Despite the best attempts to ensure correct identification, many of these new trees were misidentified and created problems for new orchardists in future years.

Amelon	Dr Fiiaschi	Pecholine
Arecrizza	Frantojo	Pecholine de St Chamis
Atro Violacca	Gros Redoneaux	Pendulina
Attica	Hardy's Mammoth	Pera Bore
Attro Rubens	Hawkesbury Agric. College	Pigalle
Barouni	Large Fruited	Polymorpha
Belle d'Espagne	Lucca	Praecox
Big Spanish	Manzanillo No.14	Regalaise de Languedoc
Blanquette	Manzanillo No.2.	Regalis
Borregiola	Marcocarpa	Rubra
Bouchine	Nevadillo Blanco	Saloma
Bouquettier	O de Gras	Sevillano
Boutillon	Oblitza	Tarascoa
Columella	Oblonga	Verdale
Corregiolla	Oje Blanco Doncel	
Cucco	Olive de Gras	

Table 1. Olive Cultivars included in the historic Wagga Wagga Olive Grove. NB. *Names and spelling of cultivars are from the Spennemann report (1997). Some names are descriptive (e.g. large fruited) or the source of cuttings (e.g. Pera Bore).*

Despite an early start, for over 100 years olive production showed only minor indications of becoming a substantial crop in Australia. Olive oil production remained only a boutique industry with the bulk of olive products being imported, almost entirely from Spain, Italy and Greece. There were several feasibility studies carried out which indicated a potential for an olive industry. These included a report published by Farnell Hobman (1995), a Senior Research Officer with the South Australian Department of Primary Industries, on the economic feasibility of olive growing. This reported stimulated further interest.

Olives today are planted throughout Australia, from the most southern point of Western Australia to the northern tropical areas of Queensland (Fig. 2.). The trees have been found to be capable of surviving in a wide range of environments from hot tropical regions to the cold areas of Tasmania. Over many years, birds have spread seeds across the land around many of these established orchards and numerous feral trees now grow throughout olive production areas, reinforcing the suitability of the Australian environment to grow olive trees. Studies to select for new cultivars from these wild trees (Sedgley, 2000) failed to establish any outstanding new cultivars. These wild trees are now considered a pest to native flora and in some States have been declared noxious weeds.

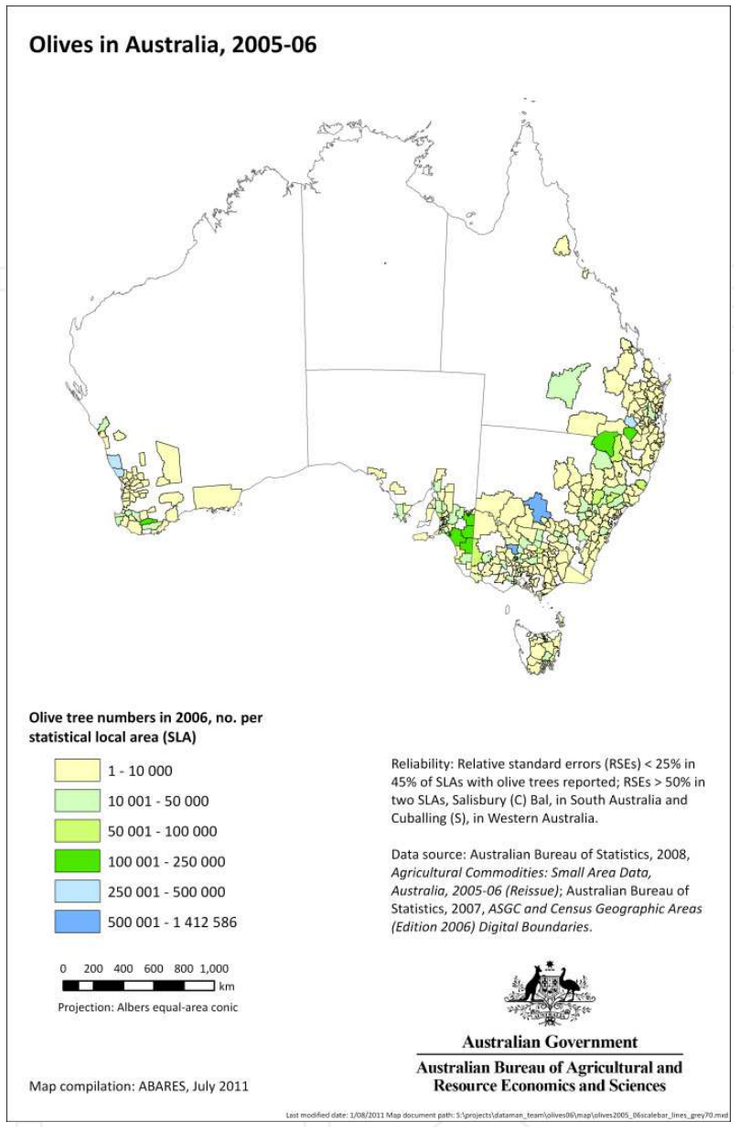

Fig. 2. Olive growing regions and intensity in Australia.

Today, the Australian olive industry is a modern production system for excellent quality oil. High yields have been achieved with low production costs. It is estimated that in the late 1990s, Australia had only 2,000 hectares of traditional olive groves, producing about 400 tonnes of oil. By 2008, Australia produced approximately 12,000 tonnes of oil. By 2013 it is expected that this production will have doubled. Most of this new oil production comes from 30,000 hectares of modern olive groves planted since 2000. There have been significant improvements in mechanical harvesting to achieve high levels of efficiency and economy which is comparable with any in the world. In traditional olive growing regions mechanical harvesting using trunk shakers was once considered as the best and most reliable method for reducing labour costs over the past decade. Today, continuous straddle harvesting machines are used which have been adapted or developed for Australian conditions with great success. These are currently used for more than 75% of Australian production.

Australia produces mostly extra virgin olive oil. The natural diversity of the Australian environment along with the selection of the most productive cultivars, harvested and processed under optimal conditions, is responsible for the exciting range of high quality olive oil products from Australia.

2. Formal development of an Australian Olive Association

The first national symposium on olive growing was held at the Roseworthy Campus of the Adelaide University in 1994, with strong interest spurred on by the economic feasibility report by Farnell Hobman (1995). The symposium was attended by over 100 participants. A decision was made to form an "olive industry group". Over the next two years this olive group drafted a constitution which was to become the Australian Olive Association (AOA).

The AOA committee had identified several issues which were critical to the development of a new industry (Rowe and Parsons 2005). These included:

The lack of any Australian or State quality standard for olives
A lack of knowledge about cultivars suited to the large range of environments
Strong optimism about growing olives in Australia
A network needed to be established for the free transfer of information.

The constitution was adopted by the committee in Mildura in May, 1995. Of the 100 participants at that meeting, 65 became members of the new AOA. The committee adopted a number of objectives:

a. To promote interest in olive growing and processing
b. To foster cooperation between regional groups
c. To facilitate research
d. Encourage education and information
e. Develop and distribute superior genetic olive material
f. Market research and promotion
g. Quality assurance

Following the formation of the AOA, several State industry organisations were then formed. The first publication of the AOA magazine, the Olive Press, was printed in 1995. By the end of 1995 regional grower groups had been established in Queensland (Qld), New South Wales (NSW), South Australia (SA) and Tasmania (Tas).

The International Olive Oil Council (IOC) provided assistance to the developing industry in Australia. The IOC funded olive experts to attend workshops held in Wagga Wagga NSW and Roseworthy, SA and provided information to further encourage the industry in Australia. This included the development of Australia's first organoleptic panel, in South Australia in 1997. The AOA and State Departments also held industry and grower workshops throughout the country on oil quality and production.

The AOA developed a five year strategic plan for the industry in 1997. This plan described the AOA as an "umbrella organisation" with a national industry structure (Rowe & Parsons 2005) overseeing State grower groups. In 1999 the Association was well established with the creation of 27 Regional Olive Associations and 1000 members.

The AOA made a commitment to establish an Australian standard. Existing international standards were based on oil produced under limited environmental variation, particularly in Mediterranean climates, and failed to recognise the natural variation in Australian olive oil. The AOA, together with the Australian Government and international organisations has been able to illustrate the high quality of Australian oil and the limitations of existing standards. The Australian standards were approved by Standards Australia in June 2011.

Today the Australian Olive Association Limited is recognised as the Peak Industry Body in Australia for olive growers. In its own words "*The Australian Olive Association (AOA) is the national body representing the Australian olive industry. Formed in 1995 as a result of a burgeoning industry that recognised the need for collective action in developing and supporting the industry, it now represents over 800 people nationwide. Members are involved in all aspects of the Australian olive industry, from grower (small and large), processors to end-user and associated business partners and service industries*" (http://www.australianolives.com.au).

The Australian Olive Association exists to:

- set and maintain quality standards for Australian-produced olive products
- provide quality research & development to create and maintain a sustainable integrated olive industry
- implement an ongoing consumer awareness programme to promote the benefits, and create a preference for Australian olive products
- provide a focal organisation which facilitates progressive direction for stakeholders in the olive industry.

The AOA holds an annual conference (Expo) within Australia to address the latest technology and research. The National Extra Virgin Olive Oil and the Australian Table Olive Competitions are held concurrently with the Expo to highlight the quality of Australian olive products.

3. The code of practice

One of the major outcomes of the AOA has been a Code of Practice. This was developed to ensure to consumers that signatories to this Code have undergone rigorous procedures to certify that the contents of a bottle of olive oil being sold is indeed Australian extra virgin olive oil. Signatories to the Code of Practice are listed on the Australian Extra Virgin website. To conform to the code of practice, producers must apply for registration and have their oil tested to ensure it meets specific criteria.

Australian extra virgin olive oil must have the following characteristics:

- be produced only from olives grown in Australia
- have a free fatty acid content of not more than 0.8 grams per 100 grams (as oleic acid)
- have a peroxide value of less than 20 (mEq peroxide oxygen per kg of oil)
- not exceed the following extinction coefficients for ultra-violet absorbency tests:
  - An absorbance value at 270nm of no greater than 0.22
  - An absorbance value at 232nm of no greater than 2.5
  - A ΔK value of no greater than 0.01

- have been assessed organoleptically by a person or persons accredited by the Australian Olive Association Ltd or in accordance with processes determined by the Australian Olive Association Ltd as having positive attributes such as fruitiness and not having any defects including fusty, muddy, musty, rancid or winey characteristics.

The chemical analyses for these purposes shall be undertaken by a person or organisation accredited by the Australian Olive Association. A sample from each batch identified on labels needs to meet the above tests before the claim that the oil is Australian extra virgin olive oil can legitimately be made. Inclusion of a 'best before' date on a label shall not be more than the equivalent of 30 days for every hour of the oil in Rancimat® at 110°C. Where the oil is a blend and the constituent oils have been tested separately the 'best before' date shall be that for the lowest scoring constituent.

In 2010 there were 230 Australian producers signed up to the Code of Practice including grocery retailers who use the Code as an internal standard for extra virgin olive oils (http://www.australianolives.com.au/).

4. Interaction with the International Olive Council

The Australian olive industry has learnt and benefited from input from the IOC and continues to work with their members. Both chemists and producers utilise the IOC website and advice from the IOC technical experts. Australia has two chemical laboratories and sensory laboratory which continue to participate in the IOC proficiency program. The laboratories utilise IOC methods of analysis and generally follow the limits of IOC standards.

The IOC initially provided funding for representatives to attend IOC meetings and during the 1990s the Australian Government Analytical Laboratories (AGAL), Sydney, gained IOC accreditation. Unfortunately, this provided no support for the industry due to a lack of contact between the two organisations.

In 1996 the NSW Government laboratory at Wagga Wagga pursued accreditation for the laboratory and in 2005, with funds from Horticulture Australia Limited, the organoleptic laboratory was also accredited (Mailer, 2005a). In 2007 the Modern Olives laboratory in Victoria also gained IOC accreditation. The sensory panels and chemical laboratories provide the industry with a resource to monitor quality and to meet the stringent requirements of the IOC and international standards.

During the period through 1995 - 2000, the IOC helped raise awareness of the health benefits of olive oil. Partly, as a result of the Olive Council's interaction, olive oil imports increased in Australia from 7 million litres in 1978 to 15 million litres in 1992 and to 30 million litres by 2000. The IOC continues to play a role in the Australian industry. Accredited Australian chemists are invited to attend chemists meetings in Madrid and the laboratories are invited to participate in proficiency programs and ring tests in the development of new methods.

5. Codex alimentarius

During the early years of the olive industry, although Australian growers were producing high quality olive oil, it was recognised that there were minor differences in the chemical profile of oil from olives grown across the range of Australian environment. These oils had a

spectrum of flavours and qualities not apparent in olives grown in the limited environmental fluctuations of the Mediterranean climate. The first workshops in Wagga Wagga in 1996, identified linolenic acid levels from 0.6 – 1.8% whereas the IOC standard for olive oil was <1.0%. Many studies have shown that fatty acid profiles are strongly influenced by environment, particularly the temperature during fruit development. Although insignificant in value, and no problem in terms of nutritional quality, this factor needed to be considered within international standards.

Further studies at WWAI in subsequent years showed other chemical parameters to sometimes vary from the existing and restrictive limits of the IOC standards (Mailer, 2007). Some cultivars being grown in Australia, particularly *cv* Barnea, from Israel, contained up to 5% campesterol whereas the limit imposed by IOC was <4.0%. These limits, developed as a means to detect adulteration, have no bearing on the nutritional value in olive oil. These components became a limitation for exporters of Australian olive oil but it became apparent that not only did Australian oils fail to meet these standards but many countries from the Southern Hemisphere (Argentina, Australia, Chile and New Zealand) also failed.

Through Food Standards Australia and New Zealand (FSANZ) Australia has attempted to have these limitations in the standards amended so that the standards represent olive oil grown throughout the world. Over several years Australia has sent representatives to Codex meetings to discuss these issues. IOC have responded vigorously, defending the standards on the basis that changes will encourage fraud, despite the fact that genuine oils, such as those growing in countries in the Southern Hemisphere, fail these limits. Due to the lack of agreement Codex have failed to come to a conclusion and particularly, an accepted level for linolenic acid in virgin olive oil has not been agreed upon.

6. An Australian standard

The lack of an Australian standard left Australia exposed to a lack of control of imported product as well as limitations for the domestic industry. Until recently no testing was done within Australia on imported olive oil. Several recent studies of imported olive oil products taken from supermarket shelves has illustrated that a significant proportion of it does not meet the international trade standards of IOC and Codex Alimentarius. Similar recent studies have shown that many imported oils into the USA do not meet European and international standards (Frankel et al 2011).

Surveys of Australian olive cultivars have been used to determine compliance with international standards (Mailer et al, 2002). Reports show the effects of olive cultivars, the influence of harvest timing and the changes to quality as a result of site and seasonal growing conditions.

From the first inception of the Australian Olive Association, it has been recognised that Australia must have its own standards for olive oil. The standards are required to set guidelines for Australian producers to ensure the oil was authentic and of acceptable quality. It was also critical to allow authorities to determine if the imported and local product meets the quality levels demanded by the industry and the consumers. The

standard was created with consultation within the industry including producers, marketing and exporters. It needed to address issues of authenticity, to detect any efforts to blend or mislabel the product. It needed also to be able to detect oil which had been heated and/or refined or if the oil had exceeded its potential use by date.

The standard was established with the support of Australian Standards organisation (www.standards.org.au). A wide spectrum of representatives from the industry contributed. A final draft was made available to the public for comment in early 2011. The draft drew both praise and criticism from all aspects of the industry both domestically and internationally. Ultimately it had strong support and was accepted with the final standard approved in July 2011 for release during 2011.

The new standard is similar in many ways to that of the IOC. The standard allows for a higher level of linolenic acid and campesterol, reflecting the actual properties of the Australian product. It has also included some new tests developed by the German DGF which allow traders to identify fresh oil from old oils or oil which has undergone heating, such as in refining. The standard is available from Standards Australia.

7. Consumption and production

7.1 Development of a boutique industry

In the early years of Australian settlement, there was not a strong demand for olive oil. Olives were grown for personal use or for a small boutique industry. The major edible oils used continue to be refined sunflower, cottonseed and canola oil. It was not until the late 20th Century that the olive industry began to grow. Australia had an increasingly cosmopolitan population including a large portion of Greek and Italian migrant workers who increased the demand for olive oil production. Despite this, the industry continued for many years as a boutique industry with small farms of only a few trees in which people produced their own oil or sold small quantities to others. Olive oil was imported from Spain, Greece and Italy for many years and by the 1990s the value of the imported olive oil products was in excess of $100 million dollars per annum.

7.2 Australian consumption

Outside the Mediterranean region, Australia is currently the largest consumer of olive oil per capita, consuming about 32,000 tonnes of olive oil in 2008. The demand for olive oil continues to grow, creating a good opportunity for the domestic market. The increased demand is highlighted by the increase in total imports of olive products in the last five years (Table 2).

7.3 Australian production

Australia currently has about 10 million olive trees spread across approximately 30,000 ha. Although the initial plantings of olives in Australia included a large number of cultivars, today about 90 percent of Australian olive oil is produced from 10 major cultivars including Arbequina, Barnea, Coratina, Corregiola, Frantoio, Koroneiki, Leccino, Manzanillo, Pendolino and Picual. These cultivars have been found to be agronomically suitable while at

the same time producing a good range of oil types. Barnea, a cultivar from Israel, is a recent addition to the other predominantly European cultivars but is today the most prolific.

Commercial production increased rapidly from the mid 1990s onwards, designed using state of the art equipment and methodologies. From an almost non-existent crop prior to 1990, olive oil production in Australia reached 12,000 tonnes in 2008. Due to the modern technologies used, that production is almost 100% extra virgin olive oil with no facilities or requirements for solvent extraction and only limited refining capacity for the oil. Only rarely do harvest conditions produce poor quality fruit which requires refining. These refined oils would generally be marketed as alternative products. Hence, Australian olive oils in supermarkets are all extra virgin olive oil. Additionally, around 10 per cent of Australian groves have organic certification, representing an increase of 60 per cent since 2006 (Australian Olive Association).

Most of Australia's olives are grown in the east, south and west of the country. Although South Australia was originally the largest producer, with 39% of total production in 2003, Victoria has become the leader with 48% of the production in 2009. New South Wales, Queensland, Western Australia and South Australia share the other half of production. The main harvest time is May to July although Queensland tends to harvest first due to climate, although harvest time vary across the states.

Australia's share of the world's extra virgin olive oil production has grown from only 0.31 percent in 2006, to 3 per cent of the world market with a 2008 harvest of 12,000 tonnes. By 2014, production is expected to reach 25,000 tonnes.

	Production		EVOO		Table Olives	
Year	Table Olives	Olive Oil	Imports (tonnes)	Exports (tonnes)	Imports (tonnes)	Exports (tonnes)
2001		500	27,680	385	11,545	74
2002		750	28,987	300	12,618	199
2003		1,500	28,447	278	14,483	138
2004	2,000	2,500	32,657	501	13,711	265
2005	2,700	5,000	29,062	1,652	15,143	215
2006	3,200	8,650	34,511	2,988	15,608	230
2007	2,500	9,250	43,404	2,502	16,364	207
2008	2,200	12,000	23,952	4,169	17,542	239
2009	3,000	15,000	31,169	6,960	16,210	366

Table 2. Extra virgin olive oil and table olive production, imports and exports (www.australianoliveoil.com)

The majority of olives grown are for oil production. Much of the production is from a few large producers although there are a large number of small producers spread throughout the growing regions of Australia. Despite the rapid increase in production, Australians are continuing to increase their consumption of olive oil and imports have been maintained at around 20-30,000 tonnes per annum. It would seem however, that there is some import

replacement with imports of 43,000 tonnes in 2007 being reduced to around 31,000 tonnes in 2009.

Fig. 3. a. Harvesting at night at Boundary Bend and b. aerial photograph of olive harvesting at Boundary Bend (photo courtesy of Boundary Bend)

7.4 Australian imports / exports of extra virgin olive oil

Australia imports in excess of 31,000 tonnes of olive oil per annum. Despite that, an increasing percentage of olive oil is being exported. In 2004, 501 tonnes, or 20 per cent of Australian production was exported while in 2009, 6,959 tonnes, or around 46 per cent, was destined for the export market, an average annual increase of 85 per cent. The value of exports in 2009 was $37.8m (Source ABS).

The top five countries buying Australian extra virgin olive oil have been the United States, England, China, Singapore and Japan. The Australian customers are changing over time, with the United States and Italy now being major destinations of Australian olive oils. Exports to China are also increasing albeit from a very low base.

The export figures from Table 2 indicate that there is a demand and an opportunity for Australian olive producers to continue to sell olive oil overseas. Despite that, a significant level of import replacement is a long term goal for the Australian olive industry and is on track to being achieved. The amount of Australian produced olive oil that is consumed domestically is now one quarter of the sum total of olive oil that is imported. The increased

percentage of Australian olive oil that is being consumed domestically has occurred in the context of fairly static import volumes over the last 5 years. Further increases in market share for Australian extra virgin olive oil in the domestic market will require further investment in consumer education.

7.5 Table olives

Data about table olive production in Australia is less well known than for olive oil. Although olives for oil production have been increasing rapidly, table olives have not had such success with production figures increasing from 2000 tonnes in 2004 to only 3000 tonnes in 2009 (Table 2). Although there are many boutique operations, a few operations have the capacity to process hundreds of tonnes of olives. Table olives are appearing more on domestic and export markets but large-scale production is still limited by the costs of harvesting. Despite the limited increase in production of table olives, the demand for them continues to increase. Imports of table olives have increased from 12,000 tonnes in 2001 to 16,000 tonnes in 2009 (Table 2.). Exports of Australian table olives have remained steady over the past few years, with around $800,000 worth of table olives having been exported in 2007.

By far the greater amount of research on olives has been directed toward the production of high quality olive oil. However, in addition to this research on oil and applications in Australia, some work has also been carried out on table olives (Kailis & Harris, 2004). The Australian table olive industry and trade currently has no nationally accepted guidelines for ensuring the quality and safety of processed table olives and the Kailis report was prepared for olive growers and processors from both national and international viewpoints.

		Percentage of production for Australian States					
Year	**Olive Oil (tonnes)**	**NSW**	**Qld**	**SA**	**Vic**	**Tas**	**WA**
2001	500	-	-	-	-	-	-
2002	750	-	-	-	-	-	-
2003	1,500	11	12	39	28	1	9
2004	2,500	12	8	16	47	1	16
2005	5,000	12.1	5	16.2	40.1	0.4	26.2
2006	8,650	8.3	4	18.2	53.9	0.2	15.4
2007	9,250	8	4.1	14.6	49.2	0.2	23.9
2008	12,000	7.7	4.1	19.5	53	0.2	15.5
2009	15,000	9.0	4.3	14.5	48.0	0.2	24

Table 3. Percentage of olive oil produced per State.

8. Quality

Australian olive oil quality is generally of high quality using modern technology for growing, harvesting, processing and packaging. The majority of the crop is mechanically harvested and transported to processing facilities within a few hours. Everything from the

machines used to harvest the fruit through to the temperature controlled stainless steel storage vessels are built on new technology. Oil extractors are generally centrifugal machines which are kept hygienically clean and housed in temperature controlled facilities.

The oil produced is almost entirely extra virgin olive oil and is ensured through the Australian Olive Association's "Code of Practice". The code requires olive growers to have their oil tested to ensure EVOO quality at the time of bottling. It also requires that the oil remains within specifications throughout the oils "best before" date to provide the consumer with confidence that the product meets the label qualifications. Only fruit that may have been damaged through frost, insect or disease generally fails EVOO quality. In these cases the oil is refined and redirected toward alternative uses.

Australia maintains two IOC accredited laboratories and sensory panels which advise the industry on oil quality. There is a continuous educational program through workshops and conferences to inform producers and consumers to help them understand defects and attributes in olive oil. The AOA presents several industry awards to olive oil producers at the annual AOA Expo. In addition, many regional growers groups have their own olive competitions judged by trained sensory personnel. All of the olive competitions demand that the oil passes basic chemical requirements.

8.1 Fatty acids

For commercial samples, the majority of oil analysis is carried out by the two Australian IOC accredited laboratories. This allows the laboratories to keep accurate records of the quality of oil being produced in Australia from year to year.

Free fatty acid value (FFA) of olive oil is a general indicator of how sound the olive fruit was at harvest and how carefully it was processed into oil. Table 4 shows a typical range for free fatty acids (FFA) and peroxide value (PV). The range shows that the majority of oils are well within acceptable limits with the median value of 0.18 FFA and 8 mEq oxygen/kg. Occasionally, due to fruit damage or climatic factors, oils may be outside of acceptable standards. However, less than 3.3% of FFA samples and 2.2% of PV samples failed to meet the IOC limits in 2006.

2006	Free Fatty Acid	Peroxide Value
Minimum	0.05	0
Maximum	3.48	48
Average	0.26	9
Median	0.18	8
No of samples	585	501

Table 4. Typical range of free fatty acids and peroxide value in Australian olive oil based on commercial samples in 2006.

The quality of Australian extra virgin olive oil has improved over the last decade. A summary of the FFA's of olive oils submitted to the Australian National EVOO Competition since 1997 (Table 5) shows how oil quality has improved. Between 1997 and 2002, only 34%

of the oils were less than 0.19% free fatty acids. In the following six years, from 2003 to 2009, 62% were less than 0.19% FFA.

1997-2002		2003-2009	
<0.19	34%	<0.19	62%
0.20-0.29	33%	0.20-0.29	26%
0.30-0.39	14%	0.30-0.3	8%
>0.40	19%	>0.40	4%

Table 5. Average free fatty acid levels of Australian olive over two periods (AOA)

The variable Australian climate and differences in temperature during fruit development has a strong influence on fatty acid profiles (FAP) as shown for oil analyses carried out in 2006 (Table 6). The profile of the fatty acids covers the full IOC range for acceptable limits but exceeds that range in several instances. Although the range is not indicative of nutritive value, the issues of compliance to international standards are significant.

Sample	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0
IOC limits	7.5- 20.0	0.3-3.5	≤ 0.3	≤ 0.3	0.5 - 5.0	55.0 - 83.0	3.5 - 21.0	≤ 1.0	≤ 0.6	≤ 0.4	≤ 0.2
Average	12.3	0.9	0.1	0.1	2.1	74.1	8.9	0.7	0.3	0.3	0.1
Min	7.4	0.4	0.0	0.0	1.1	55.7	2.7	0.4	0.2	0.1	0.0
Max	18.3	1.9	0.4	0.6	4.0	84.9	23.4	1.5	0.5	0.5	0.2

Table 6. Average, minimum and maximum limits for FAP of Australian olive oil in 2006 (n=468).

The range of fatty acids is further demonstrated with the analysis of samples from New Zealand, a cooler climate to that of the Australian olive producing areas. The FAP of 56 randomly selected samples in 2006 (Table 7) show that the oleic acid level often (23%) exceeds the IOC values which suggest these oils are nutritionally superior to those with high levels of saturated fat. However, these oils would officially fail the IOC standard. Many samples are lower (17%) than the IOC standard for palmitic (saturated) acid.

Fatty Acids	**C16:0**	**C16:1**	**C17:0**	**C17:1**	**C18:0**	**C18:1**	**C18:2**	**C18:3**	**C20:0**	**C20:1**	**C22:0**
Max	12.4	0.9	0.06	0.11	2.59	**85.5**	7.6	0.9	0.4	0.4	0.2
Min	**6.4**	0.3	0.03	0.06	1.12	78.2	3.0	0.5	0.2	0.2	0.1

Table 7. Fatty acid profile of 56 randomly selected New Zealand oils from 2006.

8.2 Phytosterols

There is also a significant range in the phytosterol content and profile in Australian olive oil (Table 8). In particular, the level of campesterol often exceeds 4.0%, generally due to the production level of *cv* Barnea which is higher in campesterol than other cultivars. Due to the

suitability of this cultivar to the Australian climate and its high production rate, this cultivar will continue to be a significant portion of the Australian crop. As for other parameters, these components may exceed the international limits.

Sterols (%)	Cholesterol	Brassicasterol	24-Methylene-cholesterol	Campesterol	Campestanol	Stigmasterol	D-7- Avenasterol	D-7- Stigmastenol	D-7-Campesterol
Average	0.08	0.00	0.09	3.61	0.16	0.63	0.50	0.19	0.13
Min.	0.03	0.00	0.02	2.27	0.10	0.34	0.22	0.00	0.00
Max.	0.16	0.02	0.48	4.89	0.25	1.41	1.00	0.52	0.59
Median	0.07	0.00	0.07	3.49	0.15	0.56	0.47	0.19	0.06
	β-Sitosterol	**D-5- Avenasterol**	**D-5,23-Stigmastadienol**	**Clerosterol**	**Sitostanol**	**D-5,24-Stigmastadienol**	**Apparent β sitosterol**	**Diols**	**Total Sterols (mg/kg)**
Average	85.08	7.34	0.01	0.58	0.93	0.68	94.62	1.11	1537.8
Min.	79.45	5.21	0.00	0.20	0.28	0.21	93.83	0.64	1131.7
Max.	88.24	13.66	0.13	0.93	2.51	1.27	96.38	3.09	2153.8
Median	85.75	6.81	0.00	0.60	0.48	0.58	94.56	1.06	1520.9

Table 8. Phytosterols profile in Australian olive oil showing the range and the average and median values for each component.

9. Research

9.1 Funding

A new agricultural industry requires significant research and development support to optimise the industry. Such was the case with the awakening of the olive industry in Australia. It created a need for Australian research scientists to develop an understanding of the agronomy and the chemistry of the crop, essential for producing the highest yield with the best quality. The research effort has been supported strongly by the Australian Olive Association and financial support from some of the larger producers. Much of the financial support has come from the Federal Governments "Rural Industries Research and

Development Council" (www.rirdc.gov.au) which has consistently supported projects the olive industry considered to be of significant value.

Although most Australian agricultural industries pay a levy to the Federal Government to support research, olives have always been considered a new crop and have been exempt from a levy. However, in 2011, through support from the Australian Olive Association, the industry has agreed to contribute to a crop levy. This guarantees ongoing funding for the research and development of this industry in the future.

9.2 Cultivar selection

Determining which cultivars to grow was an early requirement for growers. At the early stages of development one of Australia's best resources was the historic olive orchard at Wagga Wagga. This orchard, with over 50 cultivars and trees which, in some cases, were over 100 years old, provided an ideal resource for study. Such was one of the first research projects funded by RIRDC (Ayton et al., 2001) in which oil content, oil quality and initial attempts to identify cultivars by DNA were carried out. The range of trees, some of which were grafting experiments and others with varying levels of irrigation, appeared to be an ideal study. Although the trees were producing reasonable crops due to poor maintenance for such a long period, and the variable conditions under which each of the trees were grown, the use of the data was limited.

There remained considerable confusion about cultivars being grown in Australia and if they were true to type. After many years, maps of the grove had been altered and many trees removed. Using RAPD DNA methods to discriminate between the cultivars (Mailer & May, 2002), dendrograms were constructed showing the relationship of the cultivars to each other. Although some trees were identified, it was not possible to obtain reference standards for many of the cultivars and they remained unknown. Errors in this labelling on the map became evident as shown by the dendrogram of trees labelled as *cv* Manzanillo in Fig 4. The comparison of trees, reportedly to be the same cultivar, was clearly different, based on DNA patterns and seed morphology.

There was little data on the performance of any olive variety for optimal yields and quality under Australian conditions and the industry has relied on information from the Northern hemisphere, particularly from Mediterranean sources. Performance characteristics of cultivars are the basis on which a selection is made for a particular use or physical situation. The National Olive Variety Assessment (NOVA) project was established to help resolve the confusion in olive variety identity and to evaluate the performance, in different climatic regions of Australia, of the majority of known commercial olive varieties. (Sweeney, 2005). The establishment of a national varietal grove at Roseworthy provided an opportunity for growers to evaluate different cultivars, grown at that site.

At the same time studies were being undertaken on wild olive trees which had become established in the Adelaide Hills to attempt to identify feral olives which may be better adapted to the Australian conditions (Sedgley, 2000). Despite these investigations, the Australian industry has been established on common European cultivars and some more recently introduced including *cv* Barnea from Israel.

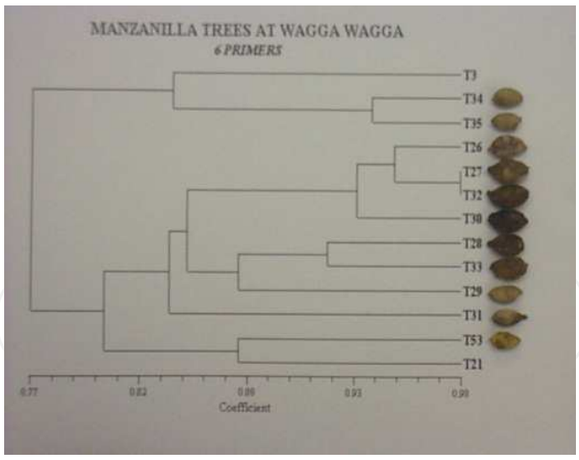

Fig. 4. Dendrogram created with 10 RAPD primers illustrating differences in seed morphology of 11 trees identified by the historic map as *cv* Manzanillo (Mailer unpublished).

9.3 Environment

Perhaps the main issue for Australian oils was the very variable environmental conditions under which the crop was being grown. Oil quantity and quality rely heavily on crop management, moisture availability, harvest timing, processing methodology and storage. As a result of these differences Australian oils showed a wide range in the fatty acid profiles (Mailer, 2005b). The diversity in other quality characteristics and sensory analysis were also significant.

In the initial stages of the development of this industry, there was little understanding of the intricacies of these crop management practices and the resultant crop yield, chemical quality and sensory attributes such as taste, colour and odour. For these reasons, several studies have been undertaken to look at the relationship between oil quality and harvest timing, irrigation treatments, yield and sensory characteristics (Mailer 2007).

As a result of the low rainfall and unpredictable nature of the Australian environment, almost all Australian olive groves are irrigated. Irrigation provides more predictable yields and harvest timing unlike dryland groves. Due to the importance of irrigation, research has focussed on water requirements, particularly in the stages from planting to commercial harvesting (De Barro, 2005). This research has been aimed at increasing the understanding of olive water use and requirements in the period from planting to early fruit bearing. As most Australian olive groves are irrigated several studies have focussed on variation in maturity, yield, oil quality and sensory attributes under variable moisture availability (Ayton et al., 2007) and with different harvest times.

Environmental effects on oil production have created unexpected issues for Australian producers. The variation in quality and sensory has created a new spectrum of oils with unique qualities and sometimes more variable attributes than has been produced in Mediterranean climates. This sometimes results in the oil being outside the limited range of existing international standards (Mailer, 2007).

9.4 Harvesting and processing

Along with the determination of the best cultivars, the methods of harvesting and processing have been evaluated. Many types of harvesters and extractors, generally from European manufacturers, were being used throughout the industry. Hand harvesting and many types of vibrating rakes, tree shakers and accessories were unsuitable for large scale production. Larger producers investigated straddle harvesters (Fig. 3) which underwent several modifications to make them suitable. These are used widely today.

Processing also went through stages. Some producers tried mechanical mat presses or stone mills (Mailer & Ayton, 2004) in the early stages but these were never used for large scale production The majority of processors have installed modern two or three phase centrifugal extraction mills.

Fig. 5. One of the early harvesting methods adopted in an Australian olive grove.

9.5 Quality analysis

As the industry developed, a need for quality evaluation increased. Using the resources of the International Olive Oil Council, Australian laboratories were able to set up methods to determine oil quality. Many of the existing methods were time consuming, reasonably difficult to carry out and expensive. This prompted the investigation of more rapid methods such as the near infra red spectrometry (Mailer, 2004), a rapid screening analytical tool whilst more intensive, wet chemistry methods were maintained as checks where necessary.

Minor compounds in olive oil were recognised as the basis of the sensory attributes, nutritional value and stability, or antioxidant capacity, of the oil. Additionally, minor compounds are used to ensure authenticity in Australian research, particularly the sterol profile. As Australian oil has a wide spectrum for each of the sterol components, which may lie outside the limits of the IOC standards, this has been an important focus for Australian scientists (Guillaume et al., 2010). Environmental effects and irrigation on polyphenols both showed a significant effect (Mailer et al 2007). The influence of frost on these compounds and the resulting changes in sensory and chemical characteristics has also been investigated (Guillaume et al., 2009). Frost is one of the most important weather related hazards for the Australian olive industry and has caused significant economic losses during the past decade. Its impact on oil quality has been significant in 2006 with more than 20 per cent of Australian

oil of that year being affected to some degree. Early frosts will normally affect the fruit leading to significant changes in the chemical and organoleptic characteristics of the oils.

9.6 Shelf life

Although oil may be acceptable when it is processed, maintaining the quality after processing became a major consideration. Two studies carried out in 2008 by the Australian Olive Association on supermarket oils (AOA Report – unpublished) included 22 oils initially and later, a further 33 oils of random brands. The reports revealed that many oils would not pass IOC tests most likely because of poor storage or old age, although some oils were clearly adulterated. The AOA and RIRDC have funded long term storage studies under extremes of temperature, light and oxygen exposure to determine potential shelf life and develop an understanding of methods used to advise marketing on potential shelf life.

Shelf life depends heavily on the type of material the oil is stored in. Although most experts would recommend the use of glass or stainless steel, often oil is stored temporarily in plastic bottles or collapsible bags. Studies on the effects of the different types of containers used for transport and sometimes for long term storage have been published (Mailer & Graham, 2009). The study reinforces that the best storage conditions for olive oil is in opaque, impervious and inert containers, stored at cool temperatures. Metallised flexible bags used for short term transport may provide reasonable protection. Storage in clear plastic, particularly in the light and at elevated temperatures, is unacceptable and results in loss of extra-virgin olive oil quality within a short period. Re-use of these containers is highly undesirable and would cause more rapid degradation.

9.7 Pest and disease

Australia has been free of many cosmopolitan olive pests due to its isolation but the rapid expansion of the olive industry in all mainland states has led to increased problems with pests and diseases. The control of these problems became a focus for all growers. A report on sustainable Pest & Disease Management in Australia Olive Production (Spooner-Hart, 2005) describes sustainable management, monitoring pest and beneficial species in groves and identified a number of previously unreported pests and diseases. Further publications have included a field guide to olive pests, diseases and disorders in Australia (Spooner-Hart et al., 2007) designed as a quick reference to take into the grove and use to identify pests and diseases and the damage they cause.

9.8 Waste management

Dealing with by-products of olive oil processing is another important issue in modern agriculture. A study on recycling of solid waste from the olive oil extraction process (Tan & Markham, 2008) and a subsequent report outlines methods for developing an environmentally sustainable system to manage solid waste from the 2- and 3-phase olive oil mill extraction processes. The expanding Australian olive industry over recent years, with significant increase in fruit production, has resulted in vast quantities of solid and liquid wastes generated to the detriment of the environment. The industry is been faced with the

challenge to manage these wastes in order to achieve sustainable production under a clean environment. The research work provided the industry with a tool to recycle processed oil mill waste to improve the health of the crop and the status of the soil.

9.9 Reviews

The revival and development of the olive industry stimulated wide areas of research over a relatively short period. The quest for information has been intense. This has led to the publication of several reviews being carried out, particularly regarding the potential for olive production in Australia. These include studies by McEvoy et al. (1999) in which the market for the development of an olive industry in Australia was examined based on analysis of: trends in international production and trade; consumer segments and product characteristics; whether Australia could compete with imported olive products.

Another review contains detailed steps required to establish an olive grove in Australia and is a comprehensive survey of the Australian Industry (Meyers Strategy Group, 2010). It was developed as a method of establishing how Australia could compete in a rapidly growing olive industry worldwide.

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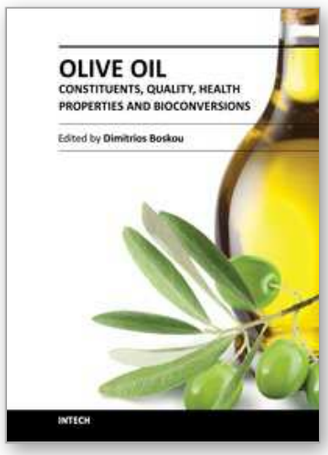

Olive Oil - Constituents, Quality, Health Properties and Bioconversions

Edited by Dr. Dimitrios Boskou

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The health-promoting effects attributed to olive oil, and the development of the olive oil industry have intensified the quest for new information, stimulating wide areas of research. This book is a source of recently accumulated information. It covers a broad range of topics from chemistry, technology, and quality assessment, to bioavailability and function of important molecules, recovery of bioactive compounds, preparation of olive oil-based functional products, and identification of novel pharmacological targets for the prevention and treatment of certain diseases.

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