particularly the case when the oil has been produced without prior dehulling of the sunflower seed, as this raises the wax content of the oil significantly.

Degumming of crude palm oil, which has a relatively low phospholipid content, is an essential process stage before the physical refining of the oil. It normally comprises a 'dry' pre-treatment with phosphoric acid and bleaching earth, followed by filtration. This removes not only the phospholipids present but also traces of pro-oxidant metals, such as iron and copper.

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FEATURE

Avocado oil: a new edible oil from Australasia

Laurence Eyres, Nimma Sherpa and Glenn Hendriks

Oil from the flesh of the avocado pear has been an item of commerce for many years and it has been produced on a large scale in several countries, notably Mexico, South Africa and Israel. However, this oil has been extracted initially from poor quality and waste avocados using solvents, then refined, bleached and deodorized. It has been used mainly as a first-class cosmetic raw material and it has not been viewed as edible oil. A new industry has begun in New Zealand whereby oil is produced from good quality avocados and is of such quality that it is termed extra-virgin and is ideal as top quality culinary oil.

Introduction

The avocado pear (*Persea americana*) originated in Mexico and was prized by the Aztecs as a health-enhancing fruit, both for its nutritious qualities and as an excellent emollient for the skin. For many years it has been processed for oil in Mexico and other countries as a method of utilizing the waste fruit.

Although there are no readily-available published data for production and international trade of avocado oil, the production volume in the USA is said by industry sources to be around 1000 tonnes. The main outlet for this trade is into the cosmetics industry where the oil is highly valued for its beneficial effects on skin. The relative production of avocados by country shows that Mexico is the largest producer (34%), followed by the USA (8%), Israel (4%) and South Africa (2%) with the total production being an estimated 250 000 tonnes.

Avocado fruit production has increased significantly in New Zealand (**Figure 1**) and projected avocado production figures suggest that there will be a large surplus of second-grade (that is, non-export quality) avocados in the near future. Recent agricultural data indicate a growth in exports of 20–25% a year and an almost doubling of the land under cultivation for this crop. This will present a problem for avocado growers that will increase with their production volumes. The small population of New Zealand (3.8 million) can consume only a limited amount of avocados, even with marketing campaigns encouraging the increase in avocado consumption. This over-supply is likely to result in a drop in avocado prices, making them less economical for growers.

An alternative to wasting these second-grade fruit is to turn them into useful by-products. Avocados have a relatively high oil content, which is comparable to the oil content of olives. This oil can be extracted as a way of utilizing surplus fruit as well as producing a value-added product. The oil is of good quality because the processed fruit is still intrinsically sound and is only termed second-grade because of its appearance.

Avocado oil is not recognized as significant on the world market because the raw material cost is relatively high and production is small in scale. For this reason, producing a 'cold-pressed' extra-virgin avocado oil (analogous to extra-virgin olive oil) would be more likely to recover the value of the fruit. Such a process has been commercialized in New Zealand using modern Alfa Laval centrifugal extraction equipment. The company concerned is Olivado New Zealand Ltd, a medium-sized private company located in Northland, and planning currently to expand into Australia. Currently, there are two processing plants in New Zealand and both can produce olive oil as well as avocado oil.

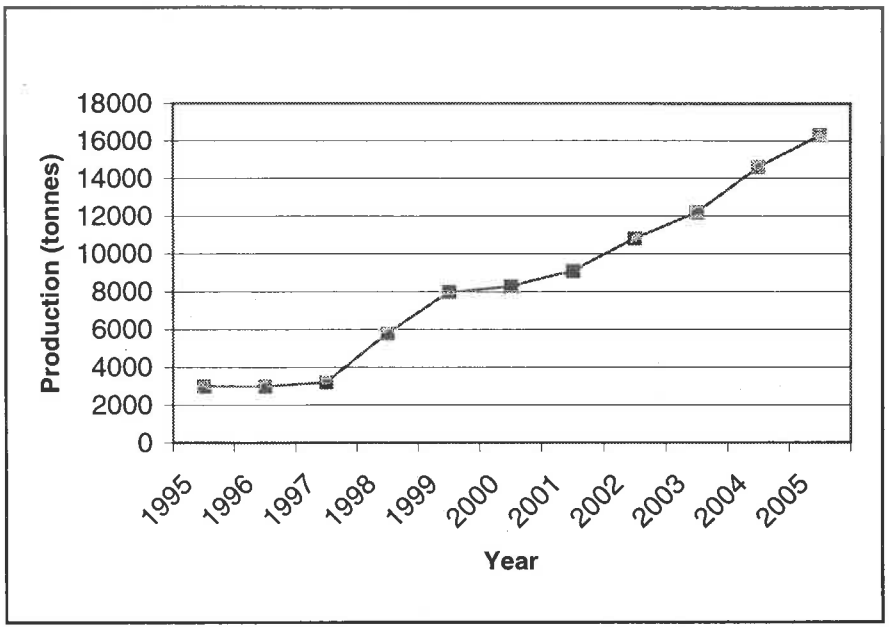

Figure 1. Projected trend for avocado production in New Zealand (1).

Raw material

In the major traditional producing countries, avocado oil has been available only as solvent-extracted, refined, bleached and deodorized oil. This is because the crude oil has been extracted from fruit of very poor quality and the oil component had already undergone significant degradation. This processed oil was available mainly to the cosmetics industry for use in skin treatments.

In contrast, extra-virgin avocado oil undergoes only minimal cold-press extraction (see below) and the fruit that are processed must be of good quality. In New Zealand, this means that there is a consistent outlet available for fruit that are of high quality, but which fail to make export grade for aesthetic reasons. Previously these had been sold locally but their value has become low due to the oversupply. (Minimal cold-press extraction means that only warm water is used as an additive to the avocado pulp; after centrifugation no other unit operations such as earth bleaching or steam stripping are employed; and no chemicals are used in the production process.)

Fruit of the 'Hass' variety has been found to be the most compatible with cold-press oil extraction procedures. It has a high content of flesh **(Figure 2)** that contains high levels of oil. Depending on the location of the orchard, oil content in the flesh of this fruit can range from 16–17% in September to 25–30% in April (1). Not only is there more oil in fruit from late season, but also the oil is easier to extract from the fat-containing 'idioblast' cells.

Extraction

Modern equipment for 'cold-pressing' does not involve pressing oil from the fruit. Instead, the fruit flesh is macerated by a high-speed grinder and the resulting pulp is mixed in malaxers (horizontal stainless steel tanks equipped with slow scraping stirrers). After this process, the oil, water and solids are separated by a three-phase decanter and then polished using multi-cone centrifuges. This is

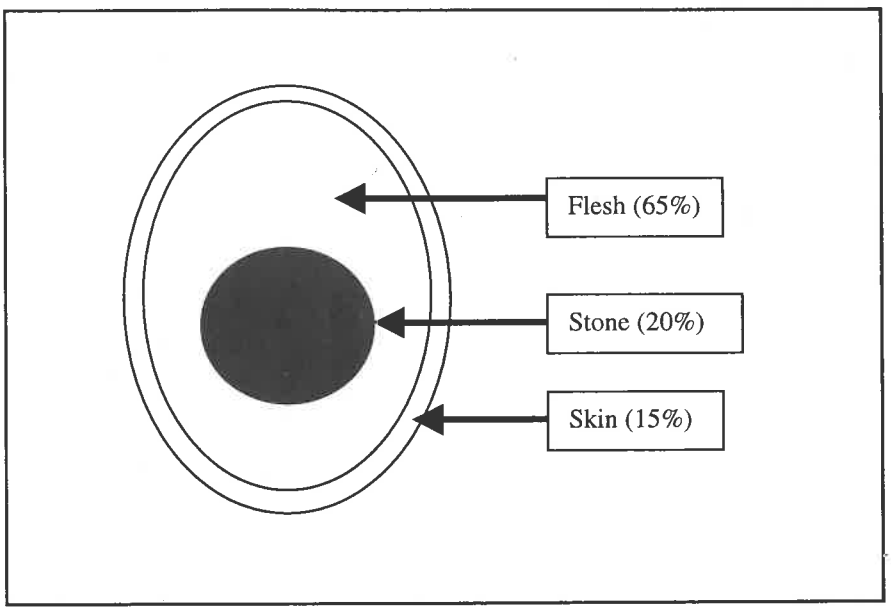

Figure 2. Typical proportions (wet weight) of skin, flesh and stone for a New Zealand avocado of the 'Hass' variety.

Table 1. Typical analyses of extra-virgin avocado and olive oils produced in New Zealand.

Analytical result	Avocado	Olive
Colour (chlorophyll) (ppm)	40–60	4–6
FFA (as oleic; %)	0.08–0.17	0.15–0.25
PV (fresh, mEq/kg fat)	0.1–0.2	1.0–2.0
Specific gravity (25°C)	0.915–0.916	0.914–.918
Iodine value (from GC)	82–84	75–82
β–Sitosterol (%)	0.45–1.0	0.1–0.2
Total vitamin E (mg/kg)	130–200	100–150
α–Tocopherol (mg/kg)	130	100
β/γ–Tocopherol	15	10
δ–Tocopherol	5	10

why the extra-virgin oil reflects the quality parameters of the incoming fruit and why the utmost care is taken with post-harvest handling.

These tasks are performed in New Zealand by modern Alfa Laval olive oil processing units that have been modified to suit the parameters of the avocado fruit. Seminal work in this area was performed by Werman and Neeman (2), who studied the effects of centrifugation rate, pH, salt and mixing temperature on the centrifugal extraction efficiency of avocado oil. These workers also characterized in detail the compositional analyses of Israeli avocado oil. The analyses do not appear to differ significantly from results obtained for the New Zealand oil.

Extraction rates obviously vary during the season because of the change in absolute oil content and typically vary from 10–18% of the whole fruit. Disposal of the remaining portion is as vegetable water and two solid phases — the husks (seed and stones expelled from the de-stoner) and pomace-exhausted fruit flesh expelled from the three-phase decanter.

Table 2. Typical analysis of refined, bleached and deodorized avocado oil.

Colour (5¼ inch cell)	10Y, 1R
Free fatty acids (oleic; %)	0.1
Peroxide value (mEq/kg)	0.1
Flavour	Bland

Economics

The purchase price of the fruit at the factory door is the main determinant of the manufacturing cost and resultant selling price of avocado oil. The skin and seed are discarded so the ultimate yield of oil can range from 10–18% of the original weight of the fruit. Currently, the oil retails at approximately US$5 per bottle (250 ml) on the New Zealand market and at a comparable price in Australia. Extra-virgin olive oil sells for anywhere in the range US$2–10 for the same volume, depending on whether it is the cheaper, imported, oil or that produced in New Zealand. The NZ oil has only a 2% market share of the total bottled vegetable oil market. Bulk avocado oil sales are at $10 per litre and are increasing as overseas users become aware of the reliable supply in New Zealand.

After only one season, the avocado growers have already seen the positive effects of extracting oil as an alternative to supplying the domestic market with low-grade fruit. The 2000–01 season saw approximately 1200 tonnes of fruit processed, yielding around 160 tonnes of oil. It is estimated that turning the low-grade avocados into oil has benefitted the industry by approximately US$500 000

Oil quality

The minimal processing used to extract oil from avocado (see above) means that many natural constituents of the fruit are retained. These can have both positive and negative effects on the stability of the oil.

Recent research performed on avocado oil at Massey University (Auckland, New Zealand) showed that, unlike virgin olive oil, the free fatty acid values were consistently very low (**Table 1**). This indicates that there is little lipase activity and suggests that oxidative deterioration is the main route of quality loss in this oil. The analyses of avocado oil are shown in Table 1 and compared with recent work carried out on New Zealand olive oil by Reed and colleagues (3).

The oil is composed primarily of triacylglycerols with minor amounts of free fatty acids and up to 1.5% unsaponifiable matter. It is similar to olive oil in many respects but has a higher β-sitosterol content and lower levels of squalene and polyphenols.

High levels of chlorophyll in avocado oil (40–60 ppm) can adversely affect the oxidative stability of the oil when stored under light (4). They cause rapid formation of oxidation products through the photosensitized singlet oxygen pathway. However, the emerald green colour of the oil (originating from high chlorophyll levels) has been identified by consumers as desirable. A novel approach to increasing the oxidative stability of this unique oil is currently being studied. It will include minimizing oxygen and light exposure during handling of the

oil (including shelf storage in dark glass bottles).

There is a growing trend worldwide toward organic production of fruits and vegetables and a significant proportion of the avocado crop meets this specification. The samples of oil in Table 1 were screened for pesticide and elemental copper analysis and the results were favourable; pesticides could not be detected and copper was less than 0.1 ppm in both cases.

Further processing of extra-virgin oil

Refined, bleached and deodorized (RBD) avocado oil has been produced recently in New Zealand from cold-pressed oil that does not meet extra-virgin quality standards. This process removes high levels of peroxides and free fatty acids from the oil. Alkali is used to remove free fatty acids (refining), bleaching earth to remove colour-producing substances (bleaching), and finally steam distillation (deodorizing) to strip objectionable flavours and odours. This RBD process removes almost all chlorophyll and other components of avocado oil that give extra-virgin oil its unique properties.

The resulting oil is pale yellow (instead of green) and has little remaining avocado odour or taste. This oil will be destined for cooking (since it still contains a desirable fatty acid profile) and cosmetic use. The target quality for the bland oil is pale-colour, low acidity and high stability. Typical results for the processed oil are seen in **Table 2**. Like olive oil, avocado oil is rich in monounsaturated fatty acids (**Table 3**). This makes it an excellent component of the Mediterranean-style diet claimed to be good for health. A comparison of the composition of triacylglycerols in the avocado oil and olive oil is shown in **Table 4**.

Table 3. Fatty acid composition of cold-pressed avocado oil and olive oil produced in New Zealand (% of total; the oleic value for avocado includes 5% 18:1 isomer).

Fatty acid		Avocado	Olive
Palmitic	16:0	12.5–14.0	8.6–12.9
Palmitoleic	16:1	4.0–5.0	0.3–0.7
Stearic	18:0	0.2–0.4	2.1–2.8
Oleic	18:1	70–74	77.0–82.6
Linoleic	18:2	9.0–10.0	4.6–7.5
α-Linolenic	18:3	0.3–0.6	0.5–0.7
Arachidic	20:0	0.1	0.0–0.6
Gadoleic	20:1	0.1	0.0–1.4

Table 4. Comparison of the triacylglycerol (TAG) compositions of New Zealand avocado and olive oils determined by HPLC (area %).

Peak ECN	TAG	Avocado	Olive
44	OLL + P'OL	1.5	4.2
46	OOP' + OOL + POL	21	19.3
48	OOO + POO	50	71.0
48	OPP	26	–
50	SOO	1.0	5.2

ECN = total number of carbon atoms in the fatty acids in the TAG molecule minus 2*n*, where *n* is the total number of double bonds.
L = linoleic; O = oleic; P = palmitic; P' = palmitoleic; S = stearic.

We intend to carry our further work on the fractions obtained by winterizing avocado oil.

Applications

The extra-virgin avocado oil has a mild flavour and the main current application in New Zealand is as an excellent salad and cooking oil and an alternative to extra-virgin olive oil which some consumers find too strong in flavour. Its low levels of free fatty acids and phosphatides give it a high smoke point (250°C) and the oil is proving popular in the shallow pan-frying of fish, poultry and venison. It makes an attractive green dressing when mixed with lemon juice, herbs and white wine vinegar. As a simple drizzle on potatoes and vegetables, it makes a suitable replacement for the common saturated animal fats — a change currently seen as desirable for Australasian consumers by nutrition professionals in both Australia and New Zealand.

Like the extra-virgin oil, refined avocado oil also has a high smoke point. This, and its high stability, make it suitable for general-purpose uses in frying and baking, similar to pure olive oil. It is particularly appropriate for barbecues because most common vegetable oils such as soybean and rapeseed tend to oxidize and polymerize on the hot surfaces and open flames used in much of the southern hemisphere's cuisine.

Full benefit will be taken of the beneficial effect that avocado oil has on the skin — the RBD oil makes an ideal component in hand creams and sunscreens. There have been many reports from other countries of workers who developed excellent skin texture through handling avocado

oil. The deodorized oil would make an ideal replacement for those companies who need a substitute for peanut oil after the publicity relating to possible peanut allergies in children using creams containing the traditional oil (see *Lipid Technology Newsletter*, June 2001, pp.55–56).

There seem to be particular beneficial properties in some of the unsaponifiable components, which have been linked to inhibition of lysyl oxidase. This enzyme initiates cross-linking in collagen by oxidative deamination of the amino groups of lysine and hydroxylysine residues in the protein. This inhibition of enzyme activity may open up new areas for application of the oil in the treatment of wounds and burns (5).

Potential health benefits

Avocado oil is an ideal candidate for the 'Mediterranean diet' because it is predominantly monounsaturated and is low in saturates. An added benefit is that it contains significant amounts (0.5–1.0%) of β-sitosterol. This is claimed to lower blood cholesterol levels and its consumption in the diet is being encouraged worldwide.

A further potential benefit for males over 50 years of age is that β-sitosterol is claimed to alleviate the symptoms of benign prostatic hypertrophy (BPH) (6). Extract of saw palmetto already finds acceptance around the world for treatment of this disorder and the active ingredient in the extract is β-sitosterol, present at a concentration of 0.2%. The effective daily dosage is 60–100 mg a day when administered as a drug. This is equivalent to taking 10–15 g a day of avocado oil — an intake totally in keeping with a healthy lifestyle.

Research into the mechanism of BPH alleviation still continues but there have been sufficient clinical trials to confirm the effect. The suggested mode of action involves inhibition of the 5-α-reductase enzyme involved in steroid metabolism. This enzyme reduces testosterone in the prostate to dihydrotestosterone (DHT). The reaction produces a hormone imbalance, which causes a progressive thickening of the epithelial and fibromuscular structures within the prostate gland. The resultant hyperplasia causes obstruction, resulting in abnormal urinary functions. In the ageing process, levels of testosterone fall whereas DHT remains high. Reports claim that β- sitosterol reduces the uptake of both testosterone and DHT and also inhibits the conversion reaction. Daguet recently reviewed the exciting potential for phytosterols in *Lipid Technology* (7).

An interesting observation has been made by some consumers about the satiety effects of avocado oil. They report that taking about 10 ml as a smoothie (thick milk-shake based on banana, yoghurt, milk, fruit, vitamins etc) in the morning alleviated the desire for mid-morning snacks. This is an interesting area for future research because the more technically-sophisticated and expensive ingredients such as Olibra (8) have been slow to gain acceptance.

Future research

The recent introduction of extra-virgin avocado oil into the New Zealand market has generated much interest in this area of research. At Massey University we are currently studying the following areas.

- Oxidative stability of the extra-virgin oil and kinetics of photo-oxidation.
- Effects of fruit quality on oil quality and yield.
- Extraction process optimization using natural enzymes.
- Full compositional analysis and seasonal variability.

Topics for future research may involve other components of the avocado, such as avocatins in the fruit skin — reported to have antiviral and insecticidal properties (9) — and the unsaponifiable components in the fruit seed, as well as further characterization of the non-lipid components of the extra-virgin oil.

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