INTERNATIONAL TRENDS IN FRESH AVOCADO AND AVOCADO OIL PRODUCTION AND SEASONAL VARIATION OF FATTY ACIDS IN NEW ZEALAND-GROWN *cv.* HASS

A thesis presented in partial fulfilment of the requirements for the degree of Master in Applied Science in Agribusiness at Massey University
New Zealand

L. Cecilia Requejo-Tapia

1999

Supervisors:

Prof. W.C. Bailey, Chair of Agribusiness, Massey University
Prof. E. Hewett, Horticultural Science, Massey University

Table of Contents

List of Tables

List of Figures

Table of Contents

ACKNOWLEDGEMENTS

- To The Lord, my God who has accompanied me all the way and has given me physical and spiritual strength to achieve my goals.

- I would like also to express my gratitude to the people who have been of great help through these two years at Massey University:

- Bill Bailey and Errol Hewett: Thank you for being my great supervisors and for encouraging me every moment during the writing up of this thesis.

- Allan Woolf and Anne White from HortResearch, for the enormous opportunity to work with you and undertake the experimental part of this research. It was a great experience that allowed me to grow as a professional.

- The New Zealand Avocado Industry Council (NZAIC) and its representatives, who funded part of this research and help me with the information needed.

- Ministry of Foreign Affairs and Trade: Thank you for providing me with the NZODA scholarship to undertake my studies at Massey University.

- Margaret Smillie and Charles Chua from the International Student Office: Thank you for your support and understanding and for those many things you have sorted out for me.

- To all my friends in New Zealand who supported me in one way or another to achieve my aim: a Masters degree.

- Kevin Harris from the Multimedia Lab: Thank you for your care, encouragement, sense of humour and all your great help!

- Ms. Consuelo Berrocal in Lima, for encouraging me to take this way, that positively changed my life.

- Last but not least to my all my family especially: Papa Marco (Abuelita Susana), Mama Lourdes, Susan, Sheilah, Marquito and my grandparents Papa Elias and Mama Marujita. Thank you for having me in your prays, and for giving me unmeasurable support while I was here far from you.

Cecilia
3:05 am.
Palmerston North, 1999

ABSTRACT

Intensive cultivation of avocados for commercial purposes began in California and Florida and later in Israel, South Africa and Chile. Although a range of avocado cultivars are grown, Hass is the world's most widely-grown and exported cultivar. Avocado fruit has shown good commercial perspectives and planted areas show a tendency to increase. World production of avocado has grown on average 4.3% (over 760,000 MT) between 1988 and 1998. The main producers of avocado are Mexico (34%), USA (8%), Dominican Republic (7%), Indonesia (6%) Brazil (4%) and Israel (4%), Chile (2.4%), Spain (3%) and South Africa (2%) which during 1997 contributed together to 70% of the world production.

Avocado world trade has increased greatly from 57,576 tonnes in 1980 to 238,306 tonnes in 1997. In 1997, the main players in the export market were Israel, Mexico, South Africa, USA and Chile. The main importers of this fruit were in Europe: Belgium, France, The Netherlands, Sweden, Switzerland, the United Kingdom, Germany, Spain, and in America: the USA and Canada and in Asia: Japan has emerged as a strong market since 1995. Average prices paid per metric ton have decreased over the years as higher volumes of fruit are traded and new exporters enter into the business. Avocado producer countries will face major challenges because of increasing production and low prices over the short and medium term. With the exception of Mexico, Israel and the U.S. the rest of the studied country producers are fairly new in the industry, thus, they possess great potential for growing.

In New Zealand avocados are mainly cultivated in the North Island specifically in the Bay of Plenty and Northland areas. The New Zealand avocado Industry is based on the Hass cultivar. Avocado trees in New Zealand continue to be widely planted and with the entrance of new growers, in the future, the orchard area will continue to increase. The avocado industry in New Zealand is export driven. New Zealand's main export markets are Australia and recently the United States. Actual Australian market dominance by New Zealand would be reduced in the following 5 years due to a constant increase in Australian domestic avocado production. Since 1996, the U.S. has become an important market of destination for New Zealand avocados. Traditional supplier of the U.S. market has been Chile and it represents New Zealand's main competitor

In avocado export leader countries usually the local market is supplied with fruit that does not meet export (usually strict) quality requirements. Great increases in production and export volumes are expected, therefore, it is forecast that large volumes of low price rated avocados would exist and would force the industry to look for alternative uses for avocados. Those avocados rejected during classification for export markets mainly due to defects in cosmetic appearance might be used for avocado oil extraction. The oil industry generally considered a by- product of the fresh fruit industry. For the multiplicity of applications and high prices that it achieves, avocado oil represents an interesting industry that should be further research.

Lipids are an important part of the composition of avocado fruit for a range of reasons. They contribute significantly to the taste of the fruit, an are used indirectly as a means of defining maturity since they correlate highly with dry matter. Although there has been some work carried out in New Zealand examining lipid changes and maturity, there has been no examination of the fatty acid makeup of the lipids, how they vary between regions, and what the lipid content is later in a commercial season. Such information is important from a fruit quality, health and marketing points of view.

On seven occasions between September 1998 and April 1999, fruit from two orchards located in Te Puke and the Far North were harvested and analised for dry matter, lipid content and fatty acid composition. Dry matter assessments were carried out using the commercial method and, the lipid fraction was extracted using a modification of the Bligh and Dyer technique. Later, the fatty acid analysis of the lipids was carried out by gas chromatography.

Average dry matter increased over the period of study (September to April). Dry matter for Te Puke fruit increased from 24.6% to 36.4%, while dry matter from the Far North fruit increased from 24.1% to 32.3% over the same period of time. Total lipid content increased from 17.2% to 31.3% in Te Puke and from 16.4% to 26.7% in the Far North from September to April. The results imply that fruit from Te Puke could be preferred from the point of view of oil extraction because higher yields can be obtained than from fruit from the Far North.

It was found a high and positive relationship existent between total lipids and dry matter content in avocados. During the study period, fruit from Te Puke showed consistently higher lipid content (and dry matter content) than fruit from the Far North. At both sites, the beneficial monounsaturated oleic acid was the major fatty acid synthesised, however, fruit from Te Puke showed higher levels of oleic acid than fruit from the Far North. From the nutrition point of view the ratio of monounsaturated (oleic and palmitoleic acid) to saturated fatty acids (palmitic acid) and the ratio of polyunsaturated (linoleic and linolenic acid) to saturated fatty acids found for the Far North and Te Puke regions compare favourably with those of the recommended olive oil.

Due to similarities in lipid composition between olive oil and avocado oil, it can be implied that the high concentration of monounsaturated fatty acids in avocado will be beneficial to lower blood lipids as olive oil does. The food industry makes use of avocado oil to prepare concentrated foods, while the cosmetics industry prepares lotions and soaps for hair and skin treatments. Lastly, prestigious laboratories are also analysing the property of the flesh and oil for medical purposes.

The information compiled here confirms that avocado oil compares to olive oil and can be regarded as a high- value product from the nutritional and the commercial point of view.

On current production trends in New Zealand, the likelihood of an oil-extraction plant is not remote. An oil industry in New Zealand would benefit the growers because it will absorb the surplus of avocados in the local market that otherwise would compete with their first grade fruit.

Justification

New Zealand avocado production has increased from just under 1000 tones in 1987 to 3250 tones in 1997. Approximately 16 % of the 1,221 ha is planted with trees less than five years of age which leaves considerable potential for further increases in production.

Avocados are getting an important place in the world fruit trade. However as the fruit is becoming as a typical commodity it could experience surpluses which would be reflected in lower prices affecting the economy of country producers. One way of maintaining a differentiated place in the world market is by means of effective produce marketing. Efficient and effective marketing strategy is only possible by increasing the knowledge of the features of the product to be sold

As in the avocado leader producer countries marketing plannification is supported by intensive research. The success of traditional avocado producers and exporters such as California is regarded to the acquisition of continuous knowledge of their fruit that allows confident in the planning of marketing activities.

In general New Zealand agricultural produce enjoys a unique image in the international market. This is also true for avocados. Over 50% of New Zealand avocados produced are destined to export markets which makes the actual avocado export industry worth around $ 20 million.

The relative success of the New Zealand Avocado export industry is based on the quality of the produce it trades. Nevertheless there is a little research about New Zealand- grown avocados and its main feature which is its oil content. Better knowledge in the variations in oil level and composition in the fruit is necessary for the determination of a maturity index for avocados in New Zealand that could give support to locally and internationally marketing efforts, with highest confidence.

Hypotheses

1. There is considerable increase in world demand for fresh avocado fruit therefore New Zealand avocado industry needs further understanding of its fruit and its main components such as oil and its variation in content and composition during the commercial season.

2. The volume of undergrade fruit in New Zealand is increasing due to large increases in production and exports volumes. In the future, these fruit could represent the raw material for oil extraction and other processed products.

Objectives

1. To undertake a preliminary analysis of the avocado world market to analyse the potential and actual situation of New Zealand avocado industry.

2. To develop a rapid extraction technique for the quantitative analysis of oil from avocado fruit.

3. To obtain further knowledge of New Zealand avocado fruit with reference to the oil component by determining the influence of harvest time and growing region on dry matter, total oil concentration and oil composition.

4. To undertake a preliminary analysis of the potential of using New Zealand avocado fruit that does not meet export quality standards for oil extraction.

Chapter 1 The Avocado

1 Botanical Description of the Avocado

1.1 The Avocado Tree

Avocado (*Persea americana Mill.*) is a relative of the laurel, cinnamon, bay and sassafras. The avocado probably originated in southern Mexico and was domesticated several thousand years ago in Central America. It was cultivated from the Rio Grande to central Peru before the arrival of Europeans (Smith et al., 1992)

The avocado is an evergreen tree that flowers in spring from the tips of the previous summer growth (Whiley et al., 1987). It grows fast and can reach 80 feet in height, although it is usually less, and it generally branches to form a broad tree. Grafted plants normally produce fruit within one to two years compared to 8 - 20 years for seedlings. Leaves of West Indian cultivars are scentless, Guatemalan types are occasionally anise-scented and have medicinal use. While Mexican types have a pronounced anise scent when crushed. The leaves are high in oils and slow to compost and may collect in mounds beneath trees (CRFG, 1998)

An avocado tree produces over a million flowers in excess, however only a small number of them become fruit. Avocado flowers appear in terminal panicles of 200 - 300 small yellow-green blooms. Each panicle will produce only one to three fruits. The flowers are perfect, but are either receptive to pollen in the morning and shed pollen the following afternoon (type A), or are receptive to pollen in the afternoon, and shed pollen the following morning (type B). Production is best with cross-pollination between types A and B. Avocado trees require bees or other large flying insects for pollination and usually need to be fertilised by a neighbouring tree (Bergh, 1975 cited by Wolstenholme, 1988). The tree is predisposed towards vegetative growth rather than fruit production. The

reasons for this are firstly the high turnover of leaves and secondly the evolution of the avocado in the rain forest under competitive light conditions (Whiley et al., 1987).
When compared to orchards of apples or citrus, avocado yields are low. This is partly due to the high-energy cost associated with the production of a rich oil-storing fruit with a relatively large seed (Whiley et al., 1987).

1.2 The Avocado Fruit

The avocado fruit is botanically described as a berry with a thick, fleshy mesocarp surrounding a single large seed. Fruits are globose, have a yellow-green to maroon or purple skin, which can be smooth or warty, and range in weight from 50 gr. to 1 kg (Schaffer and Andersen, 1994). The avocado fruit consists of an exocarp or rind, a fleshy mesocarp, a thin fleshy endocarp (collectively the flesh or pulp) and the seed. The edible flesh or mesocarp contributes to 50 to 80% of total fruit while the large seed of the avocado comprises 10 to 25% of the total fruit weight (Lewis, 1978). The seed consists of two fleshy cotyledons covered by two thin seed coats adhering to each other. The cotyledons consist of parenchyma tissue with scattered oil drops and contain starch as the main storage material (Biale and Young, 1969).
Avocados are divided into three horticultural races or species according to the areas of origin and distinctive features: Guatemalan (*Persea nubigena* var. *guatamalensis* L. Wms.), Mexican (*P. americana* var. *drymifolia* Blake), West Indian (*P. americana* Mill. var. *americana*). Hybrid forms exist between all three types (CRFG, 1998).

The Mexican race originated from the highlands in Mexico. Mexican avocados can be grown at elevations up to 3,000 meters and are characterised by small black or green thin-skinned fruit. Mexican avocados mature relatively quickly within six to eight months and are the richest of all avocados with as much as 30% lipid content. Fruit from the Guatemalan race also originated from the highlands in Central America but at lower elevations than the Mexican race. Guatemalan avocados have thick woody skins and are

generally the latest maturing of the three races (Schroeder, 1952; Schaffer and Andersen, 1994), taking a year or longer before they are ready for harvest. Guatemalan avocados are generally small (the size of a tennis ball) and typically have a lipid content around 8 to 15 percent (Smith et al., 1992). The West Indian race occurs in lowland forests of Central America and northwestern parts of South America. The West Indian avocados are large have a leathery skin, mature in 6 to 9 months, weight up to 1.5 kilograms and have the lowest lipid content (only 3 to 10 percent) of all avocados (Smith et al., 1992).
West Indian avocados are the most cold sensitive and well adapted to high temperatures. Due to their origin in the cool highlands, fruit of the Mexican race are the most cold tolerant and because of this, they do not show normal development in high temperatures either. On the other hand avocados of the Guatemalan race fall in between the other two showing more sensitivity to high temperatures (Whitmore, 1986 cited by Bower and Cutting, 1988). The main characteristics for the three races are shown in Table 1.1.

Most avocado trees grown in commercial plantations are a mix of Guatemala and Mexican ancestors or have Guatemala and West Indian parents. Avocado cultivars found in the market are the result of selection among the three avocado races with advantages for commercialization and cross-breeding work done basically in California, US (CAC, 1998). For instance, Pollok, Peterson, and Waldin cultivars have their origins in the West Indian avocado race, McArthur, Orotava, Nabal, Anaheim, Hass, Booth 7 and Booth 8 belong to the Guatemalan race and Puebla, Mayapan, Zutano, Topa-Topa, Bacon and Criollo originally belong to the Mexican race. Fuerte, Ettinger, Rincon, Robusto and Lula are among the Mexican-Guatemalan hybrids whereas Gema and Choquette, are among the West Indian- Guatemalan hybrids. Systematic studies have classified more than 500 avocado cultivars (Smith et al., 1992). However only a few of them possess good characteristics for commercialisation.

Table 1. 1. Comparison of the Three Main Avocado Races.

Trait	Mexican	Guatemalan	West Indian
TREE			
Climatic adaptation	Semitropical	Subtropical	Tropical
Cold tolerance	Most	Intermediate	Least
Salt tolerance	Least	Intermediate	Most
Hairiness	Most	Less	Less
Leaf anisette	Present	Absent	Absent
Leaf colour	Medium	Often redder	Paler
FRUIT			
Months to mature	6	12 or more	5
Size	small	variable	variable
Pedicel (stem)	slender	thick	nail-head
Skin thickness	very thin	thick	medium
Skin surface	waxy bloom	rough	shiny
Seed size	large	small	variable
Oil content	highest	high	low
Pulp flavour	spicy	often nutty	mild

After Bergh & Ellstrand, 1989.

1.2.1 Fuerte and Hass cultivars

Fuerte, (Spanish for strong), is one of the single most successful commercial avocado cultivars. It originated by a chance crossing between Guatemalan and Mexican avocado trees. Fuerte was selected as an early- maturing cold-tolerance chance seedling in Mexico in 1911 (Bergh, 1975 cited by Wolstenholme, 1988). Fuerte arrived in California from

Atlixco-Mexico in 1911 where the cultivar was improved by breeding and expanded to the world. Fuerte avocados dominated the world market for many years. For instance, in the late

mid 1970's, Fuerte accounted for about half of California productive avocado orchards but by 1987, the once dominant cultivar accounted for less than a quarter of the state's avocado crop (Shepherd, 1988). It is thought that this cultivar lost flavour due to low and erratic yield during 1950s and 1960s (Wolstenholme, 1988). In addition this cultivar is very susceptible to fruit diseases and physiological disorders. Nevertheless Fuerte is important in some warmer areas such as South Africa and Israel.

When Hass was developed it quickly displaced Fuerte avocado because of its excellent growing characteristics, quality and good postharvest handling features (CAC, 1998).

Hass was named after Rudolph Hass in California in 1935 (Smith et al., 1992). This cultivar also arose by accident. Hass has its origins in the Guatemalan race but also contains Mexican genes. Hass has replaced Fuerte as the leading cultivar in California. Its popularity was attributed to its characteristics of high yields (on average fifty percent more than Fuerte) consistent bearing, unlike Fuerte which tends to fruit erratically (Bergh, 1985). In addition, Hass fruit has longer shelf life and durability during transport than Fuerte. Moreover Hass is dark at maturity (when stored at 20 °C), a fact that eases it marketability. Thus, Hass popularity spread over the world and currently constitutes the leading cultivar in Mexico, Israel, New Zealand, and is second to Fuerte in Chile.

Although this cultivar has some excellent attributes such as good eating quality, relatively high yields under favourable conditions and fairly reliable postharvest attributes, the cultivar presents also a number of problems. Some of these problems include small fruit size (especially as the tree ages); intolerance to extreme climatic conditions; alternate bearing; and sensitivity to certain insect pests (greenhouse thrips, persea mite and avocado thrips) (CAC, 1998).

Due to its popularity and extensive planted in New Zealand this report will concentrate discussing features of the Hass cultivar.

1.2.2 Chemical Composition of the Avocado Fruit

Wardlaw (1937) reported that the avocado fruit has a "calorific value" three times that of banana and 50% time that of beef-steak, with abundant amounts of vitamin A, B and E and a mineral matter higher than other fruit. Avocado is an unusual fruit because its characteristic composition drastically varies with race, cultivar, time in the season and climatic growing conditions. The differences in chemical composition of some cultivars grown in various regions in California and Florida are shown in Table 1.2.

Table 1. 2. Composition of the Several Cultivars of Avocado Fruit

Cultivar And Location	Fruit weight (g)	%Fruit Weight					
		Edible Portion	Moisture	Protein	Fat	Carbohyd	Ash
Fuerte Altadena CA.	256	71.3	65.7	1.51	26.6	4.62	1.6
Fuerte Yorba Linda . CA.	566	73.5	68.3	1.36	24.2	4.82	1.27
Hass California	200	75.0	68.4	1.80	20.0	7.80	1.20
Dickenson California	254	70.0	72.0	1.56	20.4	4.69	1.35
Lula Florida	496	63.3	73.9	1.21	13.6	1.78	0.92
Trapp Florida	422	72.2	83.5	0.90	6.3	1.56	0.64
Taylor Florida	298	64.8	76.9	1.40	13.0	1.52	0.87

Jaffe and Gross, 1923; Hall et al., 1955 and Wolfe et al., 1934 In Biale & Young, 1969.

Sugar content (total carbohydrates) in avocados is very variable. For instance, concentration of sugar decreases rapidly during storage and ripening. Thus, sugar content may vary depending on growth conditions, the exact picking time and the length of storage before the analysis is carried out (Biale and Young, 1969). While most fruit contain less than 1% protein, protein concentrations are high in avocados and also vary among cultivars. Florida cultivars for example have a slightly lower protein content than California cultivars.

As can be seen, aside from moisture, lipids are one of the major components in avocados and perhaps the most interesting attribute of this fruit (Table 1.2). The concentrations of these components, especially lipids are variable depending on the cultivar, location and maturity (time in the season) (Davenport and Ellis, 1959).

1.3 Lipid Content of Avocado Fruit

Among all fruits, only the olive (*Olea europea*) and the oil palm fruit (*Eleaeis guineensis*) can rival avocado in oil content (Lewis, 1978). There is great variability in the lipid concentration in the avocado. For instance, West Indian cultivars are lowest with 4-7%; Guatemalan fruit vary from 10 to 13% while the Mexican race yields between 10 and 15% in Mexico and 15 to 25 % in California (Biale and Young, 1969).

In general, lipids in plants have two basic functions; either structural or as a storage mechanism. The structural lipids are present in membranes where they exist forming the lipid bilayer as phospholipids and glycolipids. Lipids constitute an important part of the cell membrane because they are actively involved in membrane exchange processes (Stumpf and Conn, 1987). Thus, structural lipids are present in tissues in relatively small amounts and are therefore consumed as part of the fruit. Many of the components of the structural lipids in foods will be incorporated into the structural lipids in the body of the consumer (Enser, 1995).
The storage lipids are the triacylglycerols present in the avocado mesocarp fat cells or idioblasts (Schroeder, 1953; Platt-Aloia et al., 1983), with around 85 percent of the lipids in avocados present in this form (Platt-Aloia and Thomson, 1981). Triglycerides are normally regarded as storage material to provide carbon and energy to other organs such as germinating seeds.

Kikuta and Erickson (1968) reported that lipid content tended to increase during storage however, recent research have showed that the lipids are synthesised only during growth and maturation of fruit on the tree (Platt-Aloia and Thomson, 1981; Luza et al., 1990) and that the reported increase was due to fruit undergoing dehydration during postharvest handling and storage. Moreover, high activity rates of fat synthesising enzymes have been reported during development. For instance, Simoni et al. (1967) isolated and purified two fat synthesising enzymes from Fuerte and Hass avocado mesocarp. The biosynthesis of triglycerides in avocado fruit was elucidated by Barron and Stumpf in 1962. The biosynthetic pathway appears to be essentially the same as in animal tissue. In addition, among the many enzymes reported to be present in the fruit no evidence of a fat degrading system has been found in avocado (Appleman, 1969). The biochemistry of lipids is very complex and will not be discussed in this research.

Avocado lipids also contain a non- saponifiable fraction, which comprises some flavour compounds such as esters, terpenes, sterols and nutritionally important vitamins (A, C, E). The seed contains 55% of unsaponifiable material (Werman and Neeman, 1987).

A complete analysis of the types of lipids in the mesocarp part of mature Fuerte cv. was made by Kikuta and Erickson (1968) using silicic acid chromatography (Table 1.3). They found that as much as 86% of the lipid fraction existed as triglycerides while the free fatty acid fraction was very low (0.10%). In the mesocarp, diglycerides were approximately 1.3% and monoglycerides and phospolipids 0.78 and 0.39% respectively.

The lipid content depended on the cultivar and was one of the distinguishing features of the avocado. Kaiser et al. (1992) pointed out that among other functions in the fruit, lipids impart a unique and desirable taste to the fruit.

Table 1. 3. Percentages of the various classes of lipids in mesocarp of mature Fuerte avocados.

Class	% Fresh weight
Free fatty acids	0.10
Triglycerides	19.96
Diglycerides	1.29
Monoglycerides	0.78
Phospholipids	0.39
Others*	0.28
Total	22.80

*Other substances extracted in chloroform: methanol (2:1).

After Kikuta and Erickson, 1968.

1.3.1 Localisation of Lipids in Avocado Fruit

Avocado lipids accumulate in a specialised type of cell in the mesocarp called an idioblast (Schroeder, 1953). The avocado mesocarp is composed of uniform isodiametric parenchyma cells permeated by vascular strands and also scattered idioblasts (Platt-Aloia and Thompson, 1981). Although there are small droplets of oil in the parenchyma cells, Schroeder (1985, 1987) showed that the highest concentration of lipids is inside the idioblasts. In addition, it was shown that there is a higher concentration of idioblasts at the pedicel end of the fruit and this decreases towards the seed.

Idioblasts are distinguished by their large size and complex cell walls. In mature fruit these cells are about 60 µm in diameter (Kaiser and Wolstenholme, 1992; Werman and Neeman, 1987). Dolendo et al. (1966) reported that the fat cells are bound together by pectin substances of the middle lamella and that although the total lipid content of the fruit is high at the moment of harvest, it is most difficult to extract due to the high amounts of protopectin (the binding or cementing substances in middle lamella of the lipid cells which also contribute to the observed changes in fruit texture. Thus, during softening a decrease in degree of esterification of pectin in avocado fruit loosens the cells from each other and at that stage cells may be more easily ruptured, resulting in release of the lipids.

In contrast, Ross et al. (1993) studying the presence of oleosin proteins in avocado and olive seeds, found that unlike olives, the avocado seed is not a major site of storage lipid accumulation, containing only about 1% on a fresh weight basis (Biale and Young 1969).

The lipid content and composition of avocados is affected by many factors such as fruit race, fruit position on the tree (Hatton et al., 1957) site within the fruit (Schroeder, 1987), maturity (Davenport and Ellis, 1959; Mazliak, 1965a; Kikuta and Erickson, 1968; Vakis et al., 1985; Eaks, 1990; Inoue and Tateishi, 1995), cultural practices (irrigation) (Lahav and Kalmar, 1977; Kruger and Claassens, 1996a), environmental conditions (rainfall, temperature) (Kaiser and Wolstenholme, 1994; Kruger and Claassens, 1996b; Mc Onie and Wolstenholme, 1982) and post harvest handling (atmosphere storage composition) (Mazliak, 1965b). Some of these factors will be reviewed later.

1.3.2 Fatty Acid Composition of Lipids in Avocado Fruit

Triglycerides contain a wide variety of fatty acids although in avocado fruit only five or six are usually present in significant amounts. These include the saturated fatty acids such as palmitic acid (16:0), stearic acid (18:0), the monounsaturated fatty acids palmitoleic acid (16:1), oleic acid (18:1), and polyunsaturated fatty acids linoleic acid (18:2) and linolenic acid (18:3). During the last part of fruit development the predominant fatty acid is oleic representing up to 60 per cent of the lipid fraction (Mazliak, 1965a; Kikuta and Erickson, 1968; Luza et al., 1990). In general, the combination of fatty acids in the triglyceride fraction determines the physical and nutritional characteristics of the lipid. To date the qualitative changes in fatty acids have not been studied in New Zealand fruit since most maturity studies have concentrated on total lipid content.

1.3.2.1 Saturated and Unsaturated Fatty Acids

Lipids are chemical compounds containing one or more fatty acids. Fatty acids are organic acids and as such composed mostly of carbon and hydrogen atoms. The short chain organic acids, with less than ten carbon atoms are all water-soluble. The long chain fatty acids however are much less soluble in water due to the size of the hydrocarbon chain. The fatty acids found in the avocado are long chain, with 16 carbon atoms or more (Kikuta and Erickson, 1968).

There are three main types of fatty acids: saturated, monounsaturated and polyunsaturated fatty acids. A saturated fatty acid has the maximum possible number of hydrogen atoms attached to every carbon atom. It is therefore said to be "saturated" with hydrogen atoms. Some fatty acids are missing one pair of hydrogen atoms in the middle of the molecule. This gap is called an "unsaturation" and the fatty acid is said to be "monounsaturated" because it has one gap. Fatty acids that are missing more than one pair of hydrogen atoms are called "polyunsaturated" (Mayfield, 1994). Unlike saturated and monounsaturated fatty acids, polyunsaturated are very unstable and could easily oxidise if exposed to oxygen and light. Phospholipids and glycolipids usually present in membrane structures are often highly unsaturated with linoleic (18:2) and linolenic (18:3) fatty acids. Such lipids are stable to oxidation *in situ*, in the tissues, for reasons that are not clearly understood (Hudson, 1975 cited by Lewis et al., 1987). In addition, Luza et al. (1990) mentioned that preservation of fatty acid composition during after storage might be due to the presence of tocopherols or Vitamin E in avocados. Tocopherols are natural antioxidants that contribute to lipid stability, as it will be discussed later.

The usual shorthand nomenclature for fatty acids shows two numbers, the first signifying the length of the chain and position of the unsaturation, and the second the number of double bonds; for example: '18:2' denotes a fatty acid of 18 carbon chain length and 2 double bonds. When dealing with plants, it denotes linoleic acid (Octadec-9, 12-dienoic acid). Similarly, a saturated fatty acid , such as palmitic acid will be denoted as "16:0".

Generally saturated (S) fatty acids are found in foods of animal origin while monounsaturated (M) and polyunsaturated (P) fatty acids are found mostly in foods of plant origin.

1.3.2.2 Lipids and Health

Cholesterol is a soft, waxy substance found among the large family of chemical compounds called lipids. All the cholesterol the body needs is made by the liver (about 1,000 mg/day) (AHA, 1998). It is used to build cell membranes, brain and nerve tissues. Cholesterol also helps the body to produce steroid hormones needed for body regulation, including processing food, and bile acids indispensable for digestion. People do not need to consume dietary cholesterol because the body can make enough for its needs (Mayfield, 1994). However the average American man consumes about 360 mg of cholesterol a day; the average woman, between 220 and 260 mg/day (AHA, 1998). Cholesterol is measured in miligrams per deciliter (mg/dl) (a deciliter is a tenth of a liter). Doctors recommend that total blood cholesterol should be kept below 200 mg/dl. Studies in the United States and other countries have consistently shown that total cholesterol levels above 200 to 220 mg/dl are linked with an increased risk of coronary heart disease (Mayfield, 1994).

The consumption of fats from animals contain cholesterol, a high proportion of saturated fatty acids and a low proportion of unsaturated fatty acids (Enser, 1995). The avocado fruit contain no cholesterol itself (Kaiser et al., 1992)

Cholesterol is transported in the bloodstream in large molecules called lipoproteins. A lipoprotein is a chemical compound made of fat and protein. There are two main kinds of lipoproteins; Low-Density Lipoprotein (LDL), that have more fat than protein and High-Density Lipoprotein (HDL), that have more protein than fat (Mayfield, 1994). Low-density lipoprotein is the major cholesterol carrier in the blood. When a person has too much LDL-cholesterol circulating in the blood, it can slowly build up within the walls of the arteries that feed the heart and the brain. Together with other substances it can form “plaque”, a thick, hard deposit that can clog those arteries. This condition is know as "atherosclerosis" and can cause coronary heart diseases (CHD) and strokes. On the contrary, high density lipoproteins (HDL) which transport one-third to one-fourth of blood cholesterol are thought to carry excess cholesterol away from the arteries and back to the liver (AHA, 1998).

Fat is a major component of the human diet contributing up to 40% of the calories in the diet of the developed countries (Enser, 1995). For many years the nutritional benefits of such a high consumption has been questioned, particularly the consumption of a high proportion of saturated (S) fatty acids (cholesterol-promoting fatty acids) and lower proportions of unsaturated (U) fatty acids, specially monounsaturated (M) fatty acids (cholesterol-reducing fatty acids) (WHO, 1982; COMA, 1984). The fatty acids types are very important with regard to health. Saturated fatty acids are responsible for actively increasing the LDL levels and thus cholesterol (Human, 1987; Bergh, 1991). Diets high in polyunsaturated fatty acids (PUFA), commonly found in oil from vegetable seeds have long been known to reduce LDL, cholesterol in blood, however, they could also depress HDL after certain limits, which are protective against coronary heart diseases. On the other hand, the monounsaturated fatty acids (MUFA) such as oleic acid, were shown to lower levels of LDL in the blood system and protect the HDL (Grundy, 1986; 1988).

Dr, Grundy (1986) examined the effects of monounsaturated further. He fed patients three liquid diets that varied in fat content. For four weeks his patients drank a liquid that looked and taste like a vanilla milkshake high in saturated fat. For another four weeks the patients drank a similar shake but this time low in fat and high in carbohydrates. During another four weeks they drank a third shake, high in monounsaturated fat. Results showed that the patients' blood cholesterol level peaked on the saturated-fat diet which was not a surprise. It is well known that certain types of saturated fat (mostly found in rich dairy products) raise blood cholesterol substantially. In contrast, the low- fat, high carbohydrate diet significantly lowered total cholesterol. This was again not a surprise because cutting fat (especially saturated fat) and replace it with carbohydrates (fruit, vegetable and grains) has been the traditional prescription for lowering blood cholesterol. It was also found that this low-fat, high carbohydrate diet lowered both major types of cholesterol: LDL, the so-called "bad" cholesterol and the HDL, the "good" cholesterol that helps clear the arteries. Finally, the monunsaturated-fat diet, also lowered total cholesterol but even more than the low fat diet. The surprising results were that the monounsaturated selectively lowered the LDL cholesterol leaving the HDL intact. Since Dr. Grundy (1986) conducted his study other authors have suggested that it is unnecessary to restrict total fat and that monounsaturated fatty acids can be use instead of complex carbohydrates or polyunsaturates as a substitute for saturated fatty acids (Grundy, 1988, James et al., 1989). These recommendations have been based on studies showing that when olive oil is added to a diet in individuals, blood cholesterol concentrations decreased and there was a preservation of HDL concentrations (Colguhoun et al., 1992)

In Mediterranean communities, despite a moderate to high intake of fat, blood cholesterol concentrations are low as is the incidence of Coronary heart diseases. In Greece for instance, 40% of energy comes from fat, however the saturated fatty acid intake is low (<10% of energy) and the diet is high in olive oil, in which the major fat is the monounsaturated oleic acid (Keys, 1970 cited by Colguhoun et al., 1992).

Different dietary approaches have been recommended to lower blood cholesterol concentrations. In general these recommendations have involved a reduction of total fat and a moderate increase in polyunsaturates and fibre in the diet. Thus, the commonly recommended dietary ratio of polyunsaturated to saturated fatty acids (P: S ratio) may be inappropriate as a measure of whether a diet promotes or not coronary heart diseases (Kinsella et al., 1990; Enser, 1995). Therefore the P:S ratio is being replaced by a monounsaturated to saturated fatty acids (M:S) dietary ratio. Monounsaturated fatty acids as part of a diet, have not been intensively studied as polyunsaturated fatty acids, in fact oleic acid is the only monounsaturated fatty acid that has been studied so far (Ulbritch and SouthGate, 1991).

Avocado fruit is a food source high in monounsaturated fatty acids. During the last part of development contain on average 55 to 78 % oleic acid and low levels of polyunsaturated fatty acids (0.1-17%) depending on cultivar, growing region and time in the season (Kikuta and Erickson, 1968; Slater et al., 1975; Luza et al., 1990; Eaks, 1990; Kaiser and Wolstenholme, 1994; Inoue and Tateishi, 1995). This compares favourably to olive oil which contains 56- 83 % oleic acid and from 1 to 23.6 % polyunsaturated fatty acids (depending on the growing region) (IOOC, 1984 summarised from a table by Kiritsakis, 1990). The nutritional properties of olive oil, as a cholesterol-reducing food, are well known, and are shown by the low indexes of coronary diseases in Mediterranean countries, where consumption of this product is high (Andrikopolous, 1989). In fact, among people who live around the Mediterranean, heart disease is uncommon (Grundy, 1988). The high concentration of monounsaturated fatty acids in avocado suggests that a diet rich in avocado will have beneficial effects on blood lipids.

Avocado oil has been found to be one of the most nutritionally valuable oils. Moreover, avocado oil has being ranked fifth in the list of most desirable oils known as an anticholesterol agent (Pearce, 1959).

There is little information available on the fatty acid composition of New Zealand avocados. This requires further studies because it has been shown that the lipid composition varies among regions.

1.3.3 Lipid and Moisture Content

It is well known that as avocado fruit mature on the tree, the lipid content gradually increases while moisture content decreases (Appleman 1969; Kikuta and Erickson, 1968; Pearson, 1975; Lawes, 1980; Hopkirk, 1989). This was observed by scanning electron microscope (Kaiser et al., 1992). During fruit development lipids began to accumulate in the vacuoles displacing water, filling the cell up with lipid-vacuoles. Interestingly, Kikuta and Erickson (1968) found that the fruit ceased growth before maximum accumulation of lipids and decrease in water content occurred.

Based on the strong relationship between lipid and water content during maturation, Hughes (1971, cited by Lewis 1978) suggested that lipid and water content sum to a constant value (≅ 91) for Fuerte avocados. This sum for Hass avocados, was reported to average a constant value of 89.5 (Slater et al., 1975). Other constant values found for Hass are 87.8 (Swarts, 1976 cited by Kruger et al., 1995); 86.5 (Kruger et al., 1995); 88 (Hopkirk, 1989) and 91 (Pearson, 1975).

This relationship also suggests that the non-oil dry matter content remains constant at all times during maturation. Hopkirk (1989) found that for fruit from the Bay of Plenty the non-lipid dry matter value was 10.5%.
Thus, the percentage lipid in fruit can be easily calculated by subtracting the percentage of water from the constant value. However, Lee (1981) indicated that the constant value may not be the same for all cultivars and may vary slightly among locations. In addition, Stahl (1933) considered water content could be altered following rainfall. Nevertheless, it was found recently that water content of the fruit does not increase after heavy rains or frequent irrigation programs (Kruger and Claassens, 1996a).

Thus, since percent water content was highly correlated with total lipids, a minimum maturity standard based on dry matter gained acceptability in the industry due its convenience and fast determination in comparison with lipid content determination. Nevertheless, for a particular growing region it is suggested to use a higher percent dry matter value than the absolute value found in the maturity test as the maturity standard, in order to reduce the influence of climatic factors such as rainfall (Van den Dool and Wolstenholme, 1983).

Thus there is a standard dry matter for harvesting different cultivars depending on environmental conditions. For instance, in New South Wales, Australia, Hass avocados are harvested at a minimum maturity of 21% dry weight while 26.1% is the minimum dry matter content for harvesting avocados in Chile (Undurraga et al., 1987). In California the actual (1998/99) minimum dry matter values that the fruit must reach before they can be commercially harvested and sold to the public (CAC, 1998) vary according to cultivar (Table 1.4).

As maturity index is specific for a cultivar and for a growing region, cultivars grown in Florida would have different minimum maturity standard values. In fact, producer countries and sellers of fresh avocados have developed a marketing strategy based on knowledge of their fruit and specifically on the knowledge of the lipid levels and dry weight changes during development and maturation.

The California avocado industry designed a maturity index based on dry weight and fruit size. By measuring growth rate of avocados at intervals during the season they could design a model for the development of the fruit and could predict at what date the fruit will reach maturity and assign a picking date. Of course these predictions could be influenced by several factors, such as heavy rainfall, in which case the fruit would be tested for a minimum maturity standard.

Table 1. 4 Minimum Maturity Standards for Some California Cultivars (season 1998/99)

Cultivar	% Dry Matter
Bacon	17.7
Fuerte	19.0
Gwen	24.2
Hass	20.8
Jim	19.3
Pinkerton	21.6
Reed	18.7
Rincon	20.4
Zutano	18.7
Susan	18.4

California Avocado Commission (CAC), 1998

This system based on size maturity date releases and dry matter values would allow avocados to move in a uniform manner and aid the distribution and marketing plans (CAC, 1998).

In New Zealand the harvest maturity standard is also based on moisture content (or the equivalent dry matter content) of the fruit. There is no legal standard but it is recommended the fruit reach a minimum of 26% dry matter before being harvested. However, in years characterised by long dry summers the fruit may reach this percentage earlier in the season than usual (August), due to water stress, but be too immature to harvest. This is why a maturity index should be based on more than one parameter to avoid possible distortion by external factors.

The determination of a maturity index is important because it gives confidence to the industry, protects the consumer and allows the planning of marketing activities such as arrival dates of fruit in the market, and permits the efficient use of labour resources through better programming of orchard activities (Hodgkin, 1928 cited by Lewis, 1978).

1.3.4 Factors Influencing Lipid Content and Composition in Avocado Fruit

1.3.4.1 Race and Cultivar

As indicated previously the percentage of lipids in avocados varies depending on the cultivar. Moreover, lipid content varies continuously during development and maturation of the fruit. These facts make difficult to talk about average or typical values for a specific cultivar (Lewis, 1978). It was found that the lipid content in avocados varies from region to region and from fruit to fruit inside the same race. For instance, at maturity lipid content of West Indian cultivars is about 10% of California cultivars (10 to 30%) (Schaffer and Andersen, 1994).

In general, at maturity fruit of Mexican and Guatemalan races have higher lipid content in their mesocarp (10-30%) than fruit from the West Indian race (3-10%). West Indian races show rapid development and lower lipid content. Biale and Young (1969) suggested that the rapid development might not give fruit time to synthesise higher lipid levels. Hass cultivar is a product of crossbreeding and as such its lipid levels are also influenced by its origins (Guatemalan) (Smith et al., 1992). Thus, mature Hass fruit have been reported to contain on average 20% on a whole fruit, fresh weight basis (Biale and Young, 1969), although it can sometimes exceed 40% (Davenport and Ellis, 1959).

Even though there is limited published information on avocado lipid composition it is known that it varies with cultivar. Luza et al. (1990) reported differences in fatty acid concentration at harvest time between the Mexican cultivars Ampolleta Grande and Negra La Cruz and the hybrid Fuerte. Differences in the main fatty acid, oleic acid, were apparent among the three cultivars where Fuerte showed 69.5% oleic acid while Ampolleta Grande and Negra La Cruz showed 61.4 and 73.3% respectively. Moreover, Negra La Cruz had the lowest concentration of the polyunsaturated fatty acid linolenic acid (0.99 %) while Fuerte had the highest concentration (2.3%). Luza et al. (1990) concluded that since fatty acid concentrations were different and almost specific for each cultivar, it should be possible to characterise avocado cultivars through both morphological and lipid analysis. Previously, it was found that Lula, Bacon, Fuerte and Zutano cultivars were distinct in their fatty acid composition during development and that a cultivar fatty acid profile could be used as a chemical index of fruit development and cultivar identification (Ratovohery et al., 1988).

1.3.4.2 Within Fruit Variation

Schroeder (1985) found for Hass that a gradient in lipid content existed between tissue near the stem insertion (31.6 %) and the seed (16.8%) as well as variability in lipid concentration in the mid-pericarp area surrounding the fruit. They found a low lipid concentration beneath the skin, a higher concentration of lipids in the middle fleshy portion of the fruit and a comparatively low accumulation of lipids along any of these sections.

Apparently, the differences in lipid content within the fruit are reflected in the fatty acid composition as well. Mazliak (1965a, cited by Biale and Young, 1969) reported differences in the fatty acid composition of lipids in different parts of mature Fuerte fruit, (Table 1.5).

Table 1. 5. Fatty Acid Composition of Lipids of Mature Fuerte Avocado Fruit (% of total fatty acids)

Fraction	**C 14:0**	**C16:0**	**C16:1**	**C18:0**	**C 18:1**	**C 18:2**	**C 18:3**	**C 20:0**
Exocarp	T	12-22	2.5-5.5	T	59-70	12-15	1.2-2.3	T-0.3
Mesocarp	T	13-17	3.0-5.1	T	67-72	10-12	T-1.5	T
Endocarp	T	13-20	5.0-7.3	T	62-70	10-12	T-1.2	T
Seed	0.8	22	3.2	0.6	25	42	5.1	T

T = trace; Mazliak, 1965a.

Excluding the seed, Mazliak (1965a) found avocados to be rich in oleic (18:1), palmitic (16:0), linoleic (18:2) and palmitoleic (16:1) acids. Usually stearic acid (18:0) is only found in trace amounts in Fuerte avocado. Inoue and Tateishi (1995) found five major fatty acids in different concentrations in the mesocarp of mature Fuerte at harvest; oleic acid (50%), palmitic (22%), linoleic (11%), palmitoleic (10%) and linolenic (0.3%). These differences in results for the same cultivar (Fuerte) may be due to different maturity stage of the fruit at the moment of analysis.

1.3.4.3 Fruit Size

A positive correlation between lipid content and fruit size was found for Fuerte (Lavah and Kalmar, 1977). Conversely, Hatton et al. (1957) found a low correlation between fruit weight and percentage of lipids for Lula. Similarly, Hopkirk (1989) reported that fruit size does not appear to be related to lipid content. In other words, large fruit were not necessarily more mature.

1.3.4.4 Fruit Position on Tree

Results from a four-season trial in New Zealand showed that fruit from northern or western sides of the tree had a higher lipid content than fruit from the east or south (Hopkirk 1989). Hatton et al. (1957) reported that mature fruit (Lula cv.) harvested from the top half of the tree would contain higher lipid content than fruit picked from the bottom half. In addition, they also found that there was little difference in percentage of lipid in fruit selected from different compass directions on the tree.

1.3.4.5 Time in the Season

It is well known that lipid content increases during development of avocado fruit. For example in California fruit lipid content generally starts to increase slowly at the beginning of the season then more rapidly from late November to March where it finally seems to level-off (Davenport and Ellis, 1959; Kikuta and Erickson, 1968; Appleman, 1969; Eaks, 1990).

Such is the importance of the lipid content and its variability during the season, that in some countries it is the percentage of lipids that indicates the beginning of the picking season and the industry marketing activities.

Thus, lipid content has been traditionally considered an indicator of the stage of maturity. Moreover, the maturity of harvested perishable commodities has an important role on their postharvest life and quality because it affects the way they are handled, transported and marketed (Reid, 1992).

Interestingly, in California Eaks (1990) found that lipids on a fresh mass basis increased during development of Hass and began to decrease after a peak of 15% through May (about October in Southern Hemisphere). Kaiser and Wolstenholme (1994) in South Africa studied the variation of lipid content and composition of Hass in two locations differentiated by climatic temperatures. Lipid content in fruit from the warmer site increased during fruit development and maturation peaking at about 30% in October after which it decreased and plateaued at approximately at 25%. The researchers suggested that the decrease in lipid content was a result of the energy demands of the tree as the spring growth flush took place. Alternatively, they suggested that the lipids might have been respired due to high temperatures.

In New Zealand, Lawes (1980) measured variation of lipid content during maturation of Hass harvested from an orchard in Gisborne. Although only two measurements were

done in the season lipids increased from 19.5% in November to 22.9% in January. Later Hopkirk (1989) evaluated the variability in lipid content for four consecutive seasons from September to March of fruit from two different regions; Kaitaia (in the Far North) and the Bay of Plenty. She found that as the season progressed dry matter content in Kaitaia increased from about 31% in September to 35% in February while lipid content varied from about 18% to 23% over the same period. Over the same period percentage dry matter from the Bay of Plenty increased from 28% to 36% while lipid content increased from 16% to 23%. Due to considerable fruit to fruit variability and technical difficulties encountered with the tasting procedures, it could only be established that there was a close relationship between total lipid and dry matter content increase as the fruit matured. Hopkirk (1989) concluded that there was a strong relationship between dry matter and lipid content and that this relationship may vary across regions. No examination of the lipid composition (fatty acids) was carried out.

Lipid composition does change throughout the season as fruit develop and mature. Davenport and Ellis (1959) reported that the major fatty acid constituent of Australian Fuerte was a monoenoic acid which was synthesised during the entire period of fruit development, unlike the polyunsaturated and saturated fatty acids that were synthesised only in the early stages of growth. Lawes (1980) examined the composition of New Zealand Fuerte avocados and found oleic acid to be the major fatty acid synthesised obtaining values of 53.5% of total lipids in March and 72.5% in June while linoleic acid decreased from 21% to 10% of total lipids respectively.

An exhaustive study of fatty acid composition during development of Fuerte fruit was done by Ratovohery (1988), (Table 1.6). On average, oleic acid increased during development as the concentration of the other fatty acids decreased.

Fatty acid changes have also been reported during the fruit maturation period. In fact, the proportion of some fatty acids tend to decrease during this period.
Inoue and Tateishi (1995) followed the changes in fatty acid composition during part of the maturation of Fuerte avocado fruit (from October to December). They found oleic acid increased from 37 to 50% of total lipids, palmitic acid remained constant at approximate 22%, linoleic acid decreased from 14 to 11%, linolenic acid decreased slightly from 0.3 to 0.1% while palmitoleic acid remained fairly constant at about 10% of total lipids. No stearic acid was reported.

Table 1. 6. Fatty Acid Composition (percent by weight) of Fuerte Avocado Mesocarp during Fruit Development (grown under Mediterranean Climate)

Fatty Acid	Stage of Development			
	Stage I mean	**Stage II Mean**	**Stage III Mean**	**Stage IV Mean**
16:0	12.8	10.2	10.9	9.3
16:1	2.6	1.9	2.2	1.5
18:0	0.9	0.6	0.5	0.6
18:1	60.8	68.4	68.6	76.8
18:2	12.3	10.2	10.8	8.3
18:3	1.1	1.1	0.9	0.6

Stage I = 20 weeks after flowering
Stage II = 25 weeks after flowering
Stage III = 31 weeks after flowering
Stage IV = 36 weeks after flowering
Ratovohery et al. (1988)

Eaks (1990) examined fatty acid concentrations during the entire maturation period of Hass fruit. On average, the major fatty acid, oleic acid, decreased from 55 to 50% of total lipids while linoleic acid increased from about 19 to 25%. Palmitic, palmitoleic and linolenic acids remained fairly constant. Kaiser and Wolstenholme (1994) only reported changes in fatty acids for part of the maturation period (July until November). Their results will be discussed in the next section.

Thus, a change in lipid content during the season is reflected in the change of lipid composition as well. In addition, it has been reported recently that ambient temperatures of the growing region might affect the concentration of fatty acids in the fruit (Kaiser and Wolstenholme, 1994).

1.3.4.6 Temperature/Growing Region

As avocado fruit is divided into three horticultural races according to their areas of origin (Mexican, West Indian, and Guatemalan) it is to be expected that they would have distinct temperature tolerances (Bergh and Ellstrand, 1989) and respond to variations in ambient temperatures.

Lee et al. (1983) when studying the feasibility of establishing picking dates based on dry weight in California, noticed that the temperature of the locality may influence maturation of the fruit. For instance it was found that the cool temperatures and the high humidity of the coastal area might have delayed fruit maturity. In turn fruit from the inland areas with high temperatures may have matured earlier. Similarly, Hopkirk (1989) found that avocados grown in the cooler area of Bay of Plenty had lower dry matter (and lipid content) during maturation than those grown in a warmer area in the Far North.

Interestingly, Bower et al. (1978) determined that optimum photosynthesis in avocado plants occurred between 20-24°C. Thus, temperatures above 25°C may slow down photosynthesis (Bower, 1978 cited by Bower and Cutting, 1988), accelerate photorespiration processes and thus decreasing dry matter production and development of the tree and of the fruit. In addition, Labay and Trochoulias (1982) noted that cool temperatures promoted root growth and dry matter accumulation in Hass plants, both of which are negatively affected at higher temperatures. They reported that heat probably had an adverse effect on CO_2 uptake and photosynthesis.

These results show that temperature does affect development and maturation (and finally the characteristic fruit composition) but it may do so indirectly through its effect on physiological processes in the plant rather than directly affecting the fruit as such.

The nutritional quality of avocado lipids is in part related to the amounts of certain types of fatty acids present. A larger proportion of monounsaturated and polyunsaturated fatty acids than saturated acids is nutritionally desirable. This is why the relationship between climate and lipid composition in avocado has been subject of considerable research with the hope of stimulating (and manipulating) the development of those desirable fatty acids. Results collected from different growing areas show differences in fatty acid composition in avocado fruit. However, these changes could be due to a combination of all the factors mentioned previously. A comparison of the lipid composition of Fuerte fruit at approximately equivalent stages of maturity (early mature) from different countries is shown in Table 1.7.

Similarly, Hilditch and William (1956) reported differences in the fatty acid composition of avocado from different regions, although the cultivars were not specified (Table 1.8).

The information presented in Table 1.7 and 1.8, represent a compilation of results from different countries and regions. As extraction efficiency varies among extraction processes (see Section 3.2.6) it is possible that differences in fatty acid concentrations shown may be less than those caused by analytical methods.

Table 1. 7. Average Fatty Acid Composition of Mature Fuerte Avocado Fruit in Different Countries (% of total fatty acids).

Country	16:0	16:1	18:0	18:1	18:2	18:3
USA- California[1]	14	5	-	69	11	0.1
New Zealand[2]	11.5	4.5	1.4	72.5	10	0.5
Chile[3]	10.9	4.5	1.1	69.6	10.2	2.3
Japan[4]	22	10	-	50	14	0.3

[1] Eaks (1990) fruit harvested in March (mid mature); [2]Lawes (1980), fruit harvested in June (early mature); [3]Luza et al. (1990) fruit harvested in July (early mature) [4]Inoue & Tateishi (1995) fruit harvested in December (early mature)

Fatty acids are vital for plant functioning since they are major components of the membrane bilayer responsible for cellular exchange processes. The performance of the bilayer relates to the viscosity of the fatty acid component.

Table 1. 8. Percentage of Total Fatty Acids in Avocado from Different Regions (% of total fatty acids)

Region	14:0	16:0	18:0	18:1	18:2
Subtropics	-	7.2	0.6	80.9	11.3
Puerto Rico	2.2	26.1	0.6	64.8	6.3
Argentine*	0.3	17.5	0.4	55.3	16.5
Argentine*	0.3	24.7	1.3	46.9	15.7

*Two different regions in Argentine

Hilditch and William , 1956.

Unlike saturated fatty acids, unsaturated fatty acids are usually liquid at cool temperatures. Moreover, an increase in temperature results in increased kinetic movement thus aiding membrane fluidity (Stryer, 1988). At low temperatures the plant membrane needs to be composed of higher levels of unsaturated fatty acids in order to perform properly (Moreton, 1988 cited by Kaiser and Wolstenholme, 1994). This was tested in South Africa by Kaiser and Wolstenholme (1994) who harvested fruit from two locations: a cooler site and a warmer site at various times during development and maturation. Including both development and maturation periods of the fruit where no exact figures were reported, the level of oleic acid at the warmer site increased from about 30% to 62% and from about 40% to 62% at the cooler site. The other monounsaturate palmitoleic acid remained fairly constant at just less than 10% of total lipids in the warmer site and about 9% in the cooler site. The saturated palmitic acid (cholesterol-raising) remained constant at about 20% in the warmer site whereas it showed a slight decrease from 20% to about 17% of the total lipids in the cooler site. In the warmer site, linoleic and linolenic acids decreased from about 30% and 12% respectively to about 5% and 2% respectively while in the cooler site these two fatty acids showed only small decreases during early developmental stages from about 20% and 7% to about 15% and 1% of total lipids.

During maturation oleic acid increased at both sites from about 59 to 63% and dropped marginally to just over 60% of total lipids. Linoleic acid showed a slight increase from about 9% to 12% at the warmer site and from about 11 to 14% in the cooler site. At the warmer and the cooler site the other fatty acids remained constant; palmitic acid at about 20% and 18% respectively, palmitoleic acid at about 7% at both sites and linolenic acid at about 1% at both sites.

On average Kaiser and Wolstenholme (1994) found oleic acid was approximately 20% lower in the warmer site than in the cooler site. Palmitic acid was 16% higher in the warmer site than in the cooler site. The sum of monounsaturates was about 10% higher in the cooler site than in the warmer site.

These differences in fatty acid composition could also occur for New Zealand fruit grown in different regions. Further research is required as a high percentage of unsaturated fatty acids in the fruit may offer significant health advantages that could be exploited from a marketing viewpoint.

1.3.4.7 Lipid Changes during Storage and Ripening

Biale and Young (1969) described fruit ripening as the processes resulting in changes in colour, taste and texture, which make the fruit acceptable for consumption. Ripening processes in avocado do not normally take place on the tree, but only after picking (Schroeder, 1953). This characteristic of remaining unripe while on the tree has been attributed to a “ripening inhibitor”. Moreover, the nature of the ripening inhibitor is not known but it continues to exert its effect for about 24 hours after harvest (Kader and Arpaia, 1992).

Davenport and Ellis (1959) determined the fatty acid concentration of Fuerte avocados in fractions according to degrees of saturation after ripening in air storage at 20°C. It was found that all categories except the triene (probably composed of linolenic acid) fraction increased slightly. On the other hand, Dolendo et al. (1966) measured the fatty acid composition throughout ripening in air storage at 15°C. They reported no significant changes in the distribution of fatty acids during ripening. Similarly, Luza et al. (1990) found that the fatty acid composition and concentration were not altered during storage at 4, 7, or 18 °C for 14, 28 and 33 days. They attributed the lack of variation in fatty acid concentration to the presence of tocopherols acting as antioxidants in the avocado mesocarp. Tocopherols are of nutritional significance in health, as it will be discussed later. Eaks (1990) also reported no change in fatty acid composition of lipids for Hass avocados either during ripening at 20 °C or after storage for 2, 4 and 6 weeks at 0°, 5° and 10°C and subsequent ripening (20 °C)
Thus, it can be concluded that the avocado nutritional value in terms of fatty acids does not change during postharvest handling.

Mazliak (1965b) studied changes in the fatty acids of avocado in response to different storage atmospheres. An atmosphere high in carbon dioxide and low in oxygen tended to cause an increase in the amount of palmitic (16:0) and palmitoleic (16:1) acid and a decrease in the percentage of oleic acid (18:1)

1.3.5 Maturity Indices and Lipid Content of Avocados

The moment of harvest is the first step in the postharvest life of a product (Reid, 1992). Therefore understanding of the meaning and measurement of maturity is crucial to postharvest technology. Most people can not distinguish between mature and ripe fruit. However in postharvest physiology mature and ripe are considered as different terms. Mature is best defined as “having completed natural growth and development while ripe as readiness for use” (Webster’s Dictionary). The U.S. Grade standard defines mature as “that stage that which will ensure proper completion of the ripening process”. However the ripening process was not defined (Reid, 1992).

Avocados do not ripen on the tree and only soften after harvest (Lee et al., 1983). The identification of maturity is particularly difficult because avocado fruit would not change in colour or firmness once it reaches maturity on tree. Moreover depending on the cultivar, no visible signs of ripening maturity could be noticed after harvest (except for Hass that progressively changes colour as it ripens). This characteristic makes it difficult for the consumer to determine a good quality fruit for cultivars other than Hass thus creating uncertainty. Consumer behavioural studies (East, 1990) show that normally the consumer perceives different levels of risk when purchasing a product. In the case of avocados this perceived risk could be enhanced by the uncertainty of the fruit quality when ripe.

In order to reduce the uncertainty with this fruit (as with many tropical fruits), researchers talk about physiological and horticultural maturity. Physiological maturity in avocado is the stage of development when a plant or plant part will continue ontogeny even if detached. Continuation of ontogeny or development includes also the ripening of the fruit. Horticultural or ‘commercial’ maturity is that stage of development when a plant or plant part possess the prerequisites for utilisation by consumers for a particular purpose (Watada et al., 1984).

Moreover, horticultural maturity is particularly subjective and difficult to determine because it mainly depends on consumer preferences. Horticulturally mature fruit could happen at any point and at more than one point of the fruit- growth and development-time line depending on the final use of the fruit (Lewis, 1978). It depends very much on fruit cultivar, rate of growth, cultural practices, environmental conditions and consumer preferences.

The harvest of mature, unripe avocado fruit enhances a number of quality characteristics, such as increased shelf life and a slow decline in firmness and other ripening changes. On the other hand, less mature fruit generally do not develop typical full-flavour and fruit characteristics when ripe. In this respect, if lipid content is considered a source of flavour (Kaiser et al., 1992), it could be implied that selling “immature” avocados, with lower lipid levels, would negatively affect the eating quality of the fruit and consequently the image of the producer.

Unfortunately, higher prices at the beginning of the season drives the harvest of early immature fruit which is the major causes of final poor eating quality that discourages consumers.

Horticultural maturity (generally termed “maturity” in the text) may vary from season to season. Thus, estimations to assess maturity from season to season should include taste panels. However taste panels, apart from being very expensive to conduct, require the analysis of ripe fruit, and avocados soften several days after being harvested. Therefore determination of maturity could take several days. For these reasons, the aim of much research has been to find one or more features of the fruit that relate closely to fruit development on the tree with least variability, in other words a maturity index. Thus, for the designing of a maturity index, physiological studies of the fruit are necessary for determination of those fruit features that best describe the development of the fruit. The present report is not intending to determine a maturity index for avocados but to highlight the necessity of further physiological studies of New Zealand-grown fruit as a foundation for designing a maturity index in the future. Thus, some approaches and research done to determine a satisfactory maturity index for avocados around the world are discussed here.

Maturity indices have been established in producer countries after physiological studies of the fruit sometimes involving taste panels. Other newly producing countries have adopted overseas maturity standards for their fruit, which may not always be satisfactory, since it has been demonstrated that a range of factors may affect the development and maturation of the fruit. A maturity standard adopted this way (not scientifically supported) creates confusion and misunderstandings among the growers to the detriment of the industry image and the economic consequences that it implies.

While it is true that the final quality of ripe avocado fruit depends on factors such as genetics, soil and nutrition, it also depends on the stage of maturity of fruit at harvest. Intensive overseas research has been done to determine a parameter (or parameters) which would indicate the minimum harvest time for avocados that would allow satisfactory ripening. In other words some indication that the fruit has reached maturity. Reid (1992) summarised in four points the strategy for developing a maturity index.

1. To determine changes in the commodity throughout its development.
2. To look for a feature that correlates well with development.
3. To use storage trials and organoleptic assays (taste panels) to determine the value of the index which defines minimum acceptable maturity. An index value can be assigned for minimal acceptable maturity.
4. To test the index system over several years and in several growing locations to ensure that it consistently reflects the quality of the harvested products. Otherwise adaptations should be made.

Attempts to determine a maturity index have included measuring changes in fruit size. When following changes in the size of fruit, research showed that when legally mature fruit were tested early in the season, larger fruit had higher flavour ratings than smaller fruit (Soule and Harding, 1955; Hatton and Reeder 1969) and these differences tended to disappear as the season progressed (Soule and Harding, 1955). Appleman (1969) showed that the fruit reaches full (physiological) maturity in December. From December until

May the fruit would increase in size but at a very slow rate. In addition it has been reported that variations in size could be influenced by cultural practices, water relations and climatic conditions (Mc Onie and Wolstenholme 1982). In conclusion, large fruit is not necessarily more mature than small fruit.

Hodgkin (1928) pointed out that “the purpose for the designing of a maturity index was to benefit the industry by protecting the consumer against the purchase of fruit that will not give reasonable satisfaction when eaten”.

As lipids are the main component synthesised during development of avocados and have been associated with flavour, maturity index- research has been dedicated to its content and composition. The fruit accumulates high amounts of lipids until the moment of harvest or until it drops mechanically with no external signs of maturity.

The first avocado legal maturity standards were established in California in 1925. They were not based on formal taste panels but on studies about the changes in lipid content and its close relationship during development of the fruit (Church and Chace, 1922, cited by Lewis, 1978). An 8% lipid content indicated the point where the fruit has reached ‘physiological maturity” and therefore attained the capacity to ripen normally developing typical characteristics after harvest.

Since then only avocados with a minimum of 8% lipid content of the edible portion were considered mature and could be sold in the market. Even now, it is generally considered that fruit picked with lower lipid levels would not ripen normally with poor final quality (Biale and Young 1969; Inoue and Tateishi, 1995).

Further research attempting to find a significant relationship between lipid content and taste have been published but only weak relationships have been found (Hodgkin 1939; Hope, 1963; Hughes 1971; Lawes, 1980). In New Zealand, Hopkirk (1989) did not obtain enough evidence in lipid content, dry matter and taste acceptability together to suggest a maturity index for New Zealand fruit.

Thus, a general maturity standard based on lipid percent has never been satisfactory because the level of lipid at acceptable taste varies among cultivars and regions (Hope, 1963). Previously, Hodgkin (1928) had found that 8% was too low for acceptable taste for several cultivars in California. More recently, Lee et al. (1983), showed that the percent lipid in California fruit varied as much as 5 percent, depending on cultivar and location. They calculated the mean lipid content value for each cultivar at minimum acceptable taste for fruit grown in different locations and showed this to be 9% for Hass and 11.2% for Fuerte. This demonstrated that the minimum lipid level of 8% is too low to serve as an indicator of good eating quality. In Australia, Hope (1963) demonstrated that Fuerte fruit had to reach 15% lipid content before being of acceptable taste. When comparing the two Guatemalan cultivars Hazzard and Anaheim, the first showed acceptable taste panel results when it attained 15% lipids while Anaheim showed unacceptable taste results in the panelists at 15% lipid.

A minimum maturity index based on percentage of lipids as such has been used in California and other parts of the world for many years (Eaks, 1990). However, this index has been unsatisfactory, mainly due to two factors: firstly, some avocados showed variability in lipid content related to organoleptic qualities (although raising the minimum lipid content standard may eliminate this variability problem) and secondly, the determination of lipid content is neither easy nor practical.

Lipid content was found to be closely correlated with the percent dry weight (Lee et al., 1983) (Figure 1.1) and since the determination of dry weight is easier to be used by the industry, the California minimum maturity standard was changed from lipid content to percent dry weight (Reid, 1992). Soon after many countries also adopted a maturity standard based on percent dry weight. Nevertheless some researchers still consider that lipid content is the most reliable maturity standard for avocados and suggest the use of dry weight lipid content as a better indicator of maturity than wet weight (Kaiser and Wolstenholme, 1994; Kruger et al., 1995; Kaiser et al., 1996).

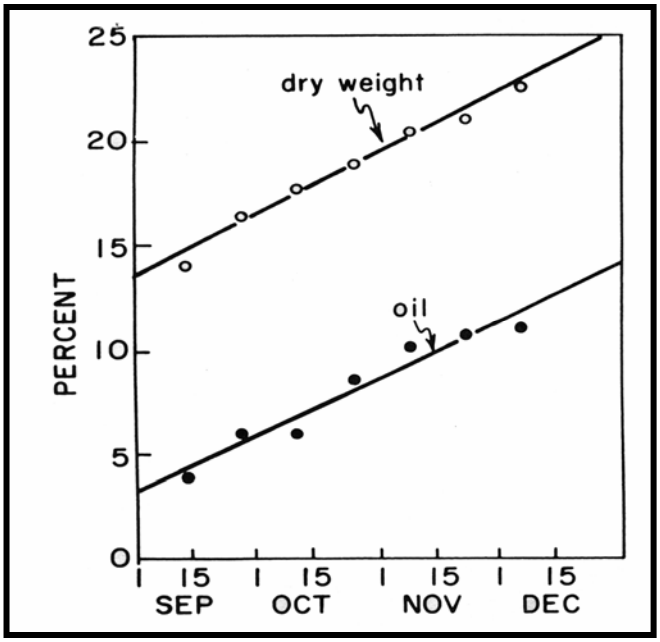


Figure 1. 1. Relationship between Percent Oil and Percent Dry Weight during Development and Maturation of "Hass" fruit (Lee et al., 1983).

To date, the correlation demonstrated between taste and lipid content (although weak) and between lipid and dry matter content serves for the prediction of the beginning of harvest (Lee at al., 1983).

Thus a fast method for the determination of dry matter using a microwave has been developed and is used by various industries. This method is quite practical and will be described here as follows:

1.3.5.1 Determination of Percent Dry Matter using a Microwave Oven (California Avocado Commission (1999).

1.3.5.1.1 Materials Needed

- Scale
- Microwave oven
- Spatula or spoon
- Petri dish or other small glass dish

- Calculator
- Food processor with chooping blade
- Knife and potato peeler
- Data sheet

1.3.5.1.2 Sampling

Select the avocados carefully. Pick them from the shady part of the tree, from different parts of the tree. The most immature appearing avocados representing the regular crop should be chosen. Off bloom fruit should not be tested. The fruit must be hard to be tested.

1.3.5.1.3 Procedure

- Fruit are first cut in half (through the seed). Next, lay the flat side down and cut a wedge out of the middle (approximately 1/8th of the fruit). Do this for the other half of fruit. Use these wedges for sampling.
- Using the potato peeler or knife, remove the skin down to flesh. Remove the seed and all traces of the seed coat.
- Cut these wedges into smaller pieces and place into the food processor with a chopping blade. Run the food processor until the avocado has been chopped into fine pieces (starts to stick to the side of the food processor container). Will have the size and consistency of grated Parmesan cheese.
- Reserve several tablespoons of sample in a plastic bag in case the sample needs to be rerun.
- Weigh an empty dish and record its weight... this is the **TARE WEIGHT**.
- Place the empty dish on the scale and add avocado sample until you have added 5 grams. Record this weight on the data sheet. (Does not have to be exactly 5 grams, but within 0.3 on either side (remember to record the exact weight). This is the **WET WEIGHT**.
- Place the dish containing the finely chopped avocado into the microwave oven.

- Since microwave ovens vary, it is critical to start at a low power setting and gradually work up to higher settings to prevent scorching. Suggested setting might be 40% power for 15 minutes. After weighing, microwave the sample again for 3 minutes at 40% power then reweigh. This process is repeated at one minute intervals until no further weight loss is observed (after several times of doing this, the proper power setting and approximate time can be determined... just be sure NOT to burn the sample).
- After no further weight loss, remove the sample and weigh. This is the **DRY WEIGHT**.

1.3.5.1.4 Calculating the Percent Dry Matter

$$\frac{\text{(DRY WEIGHT - TARE WEIGHT)}}{\text{(WET WEIGHT - TARE WEIGHT)}} \times 100 = \text{\% DRY MATTER}$$

1.3.6 Determination of Lipid Content in Avocados

Determination of lipid content is time consuming and expensive and a range of techniques have been employed to date. The refractometric index (RI) method developed by Leslie and Christie (1939) using Halowax oil as a solvent (monochloronaphtalene), was officially used for measurement of percent of total lipid in avocado in California. However, due to inconsistency of readings which are easily influenced by temperature, and equipment costs, this method was considered inconvenient for growers. RI methods are also of questionable accuracy especially when testing ripe fruit. In addition Halowax is a suspected carcinogenic and is no longer available (Lee, 1981).

A Soxhlet technique using petroleum ether (non-polar solvent) is the standard method for analysing lipid content in foods. In the Soxhlet extraction method, tissue has to be previously dried therefore extending the time of assessment. This method can take up to

12 hours and automated systems usually only run eight samples at one time. Thus, this technique is considered too slow for the industry to be used as a routine test. Moreover it appears that non-polar solvents such as petroleum ether might not remove all the lipids from avocados (Lough et al., 1966).

An adaptation of the Gerber method originally developed for the dairy industry showed accuracy in the determination of total lipids in avocados (Rosenthal et al., 1985). However, it not only uses a combination of flammable and dangerous solvents, but as it is an adaptation it uses equipment used for assessing fat levels in dairy products, equipment that is not always available in the horticulture industry. Nuclear Magnetic Resonance (NMR), although having advantages such as accuracy, simplicity and fast determination involves very high equipment costs (Barry et al., 1983; Bergh et al., 1989). Several lipid extraction methods originally developed for animal produce have been used for determination of total lipid in avocados with relative success. This is the case with the methods developed by Folch et al. (1957) and Bligh and Dyer (1959) using chloroform/methanol. However, large sample size and large volumes of solvent, a relatively high level of difficulty, and slow techniques are the main inconveniences found. Certainly, the amount of total lipids extracted in avocado depends on the extraction technique employed.

Lewis et al. (1978) compared four methods of analysing lipid content of avocados including the Soxhlet method (using petroleum ether), homogenisation with petroleum ether, the Bligh and Dyer technique and the refractometric method (using monochloronaphthalene). On average results showed that chloroform/methanol and the refractometric method gave 5-8 % higher lipid yields than the first two methods: the Soxhlet and the homogenisation with petroleum ether. They concluded that chloroform/methanol is polar enough to release some protein–bound lipids probably comprising phospholipids and glycolipids and that the similar results with monochloronaphthalene may have been due to the prolonged ball milling rather than solvent polarity.

Preliminary Observations

The avocado is a fruit of unusual high oil content. Just as the olive and its oil have a special place in the edible oil market, avocado and its oil are now recognised mainly due to its unique features such as high nutritional qualities. In contrast to olive oil, avocado oil has also a variety of applications in the cosmetic industry as a base oil or as an active ingredient is cosmetic formulations and, in the pharmaceutics industry because of its healing properties as it will be discussed in the following chapter.

Part of the success of the olive oil is due to the intensive research done about this product in all fields but especially on its composition. Many scientific publications emphasise the positive health effects of olive oil consumption. The beneficial effects of olive oil consumption appears to be the major reason for the low incidence of coronary heart disease in Mediterranean countries, traditional consumers of this oil.

Avocado oil content and its fatty acid composition are similar to that of olive oil however, as with olive oil these characteristics are variable among regions, cultivar, time in the season and environment.

Currently, there is a strong world tendency for consuming quality, more natural and healthy products, thus of avocado oil represents an industry with high potential. Of course, the nutritional benefits of avocado can also be obtained eating the whole fruit. For all these reasons better knowledge in the variations in total lipid level and composition are important for avocados grown in the New Zealand.

The following chapters refer to the characteristics of avocado oil and to further examination of this component in New Zealand-grown fruit.

Chapter 2 Commercial Avocado Oil

2. Fat, Lipids and Oil Terms

The term lipids refer to a wide range of compounds soluble in organic solvents. In foodstuffs lipids are present as: fatty acids; mono-, di- and triacylglycerols; phospholipids; sterols (including cholesterol) and lipid- soluble pigments and vitamins.
The terms fat and oils, often refer to products of commerce, crude or refined that have been extracted from animal products, plants or oilseeds. The term fat refers to extracted lipids that are solid at room temperature while oil refers to those that are liquid (Pike, 1998). Usually the three terms: lipid, fat, and oil are used interchangeably.

2.1. Growing Avocados for Commercial Oil Extraction

Avocado oil is a delicate oil derived from the fruit of the *Persea americana*. The most important characteristics of this oil are its fatty acid composition, being similar to olive oil, and its high content of vitamins, especially Vitamin E (higher than in butter or eggs), which gives it important antioxidant properties (Leung, 1980). Some of the most important characteristics of the avocado oil will be discussed.

It is well known that the lipid content of the fruit increases rapidly during development and maturation period (Biale and Young, 1969; Kaiser and Wolstenholme, 1994). Thus, at the end of the season the percentage of oil is highest for all cultivars. Consequently, if growing just for oil extraction, higher oil yields will be obtained from fruit harvested late in the season and especially during the last two months of the avocado season than from fruit harvested early in the season. For instance, oil measurements showed at the end of the season were 25 and 30% for Hass and Fuerte respectively in comparison to around 15% at the beginning of the season (Human, 1987).

Because the mesocarp is the main site of lipid storage, for commercial extraction it is important to select, if possible, those cultivars having the highest percentage of pulp as well as small seeds and low skin content. In this respect Fuerte and Hass represent good candidates but Hass cultivar has been recommended as the most suitable for oil extraction (Human, 1987). Hass is the most planted cultivar around the world (see Chapter 4) however the production is used mainly for fresh consumption and usually avocados that are not exported nor destined to the local market are destined for avocado oil extraction. There is no information about avocado plantation with only oil purposes. However, this does not mean avocado oil industry is supplied with bad quality fruit. Those avocados rejected during classification for export markets mainly due to defects in cosmetic appearance are used for avocado oil extraction. It is said for this reason that the oil industry is a by- product of the fresh fruit industry. However it is crucial that the quality of the pulp of the fruit must be first grade in order to obtain an excellent quality oil.

2.2. Commercial Extraction of Avocado Oil

As more sophisticated orchard practices are employed surpluses of avocado are expected in producer countries (Chile, Mexico, USA and South Africa) (see Chapter 4). One way of using these surpluses is by extracting the oil for commercialisation.

Traditionally, the commercial process for avocado oil extraction uses hard, mature whole fruit (no removal of the seed) and involves drying, mechanical pressing at high temperatures and oil extraction with an organic solvent. The use of solvents in a commercial scale has been questioned because of air pollution concerns. In addition, the removal of the solvent from the oil can not be 100 percent guaranteed and it may affect oil quality. The most recent technique involves ripening which allows softening of the fruit previous to mechanical pressing and centrifuging the mixture to separate the oil from the water and solids (Werman and Neeman, 1987). The ripening step is to allow softening of the lipid cell walls by natural senescence processes (Dolendo et al., 1966).

As the season progresses the lipid cells at harvest are more easily ruptured. The variation in avocado oil yields extracted monthly by means of centrifugation are shown in Table 2.1. Due to these variations over the season as a standard the industry considers 10% yield of oil out of the initial fruit weight (Smith and Lunt, 1981).

Table 2. 1. Monthly averages of avocado oil in ripe whole South African Fuerte avocados (including pips and peel) extracted by centrifugation method.

Month	Average % Oil	% Oil extracted	Recovery %
April	13.3	7.0	52.6
May	15.0	11.0	73.3
June	17.0	13.0	76.4
July	19.0	15.0	78.9
August	20.8	18.4	88.4
September	20.1	18.5	92.0
October	24.2	20.3	83.8

After Human (1987)

In addition, the centrifugation method uses only fruit pulp (no seed, no skin) and interestingly seems to better extract and keep the quality of the crude oil in terms of oleic acid content, (Table 2.2).

Oleic acid content of industrial crude avocado oil produced by centrifugation is 74.1% while industrial crude oil (organic solvent extracted) contains only 64% (Table 2.2).

Table 2. 2. Fatty acid composition of refined and crude industrial avocado oil using two different extraction methods (%of total fatty acids)

Sources	Fatty acid				
	16:0	**16:1**	**18:0**	**18:1**	**18:2**
Refined centrifugal extraction	11.8	2.2	0.7	71.2	14.2
Crude centrifugal extraction	12.2	3.5	trace	74.1	9.7
Crude organic solvent extraction	17.8	5.6	-	64.4	12.7

After Werman and Neeman (1987).

Centrifugal extraction involves pressing the avocados to a pulp which is subjected to a curing process and heat before centrifugation which removes most of the solid materials due to differences in densities with the oil and water (Smith and Lunt, 1981).
Southwell et al. (1990) obtained avocado oil by means of cold pressing with a small scale expeller using peeled and unpeeled fruit as raw material. The crude oil from the unpeeled fruit was dark brown in colour while that from the peeled fruit had a green colouration.

One of the problems in the avocado oil industry is dealing with the processing waste. This contains toxic compounds making it non-usable as animal feed. In a series of studies Werman et al. (1989, 1991) fed rats with various types of avocado oil (refined and unrefined) and avocado seed oil, extracted using different extraction methods (organic solvent and centrifugation). All the oils except for the refined caused alterations in liver metabolism such as liver enlargement, elevated levels of enzymes involved in lipid biosynthesis, reduction of triglycerides in blood and increased amount of hepatic lipids in liver. They reported the possibility of the presence of some hepatotoxic agents in the unrefined oil obtained by hot drying and organic solvent extraction of intact fruit (including the seed) and from oil from the seed. The main effect of these compounds was to cause alterations in liver metabolism of the rats. The nature of these compounds is not known but rats showed accumulation of lipids in the liver (fatty livers). Normally this phenomenon may be manifested under the following conditions: a) increased uptake of dietary fat or adipose tissue fatty acids by the liver; b) increased fatty acid synthesis, c) decreased fatty acid oxidation, d) decreased secretion of lipoproteins from the liver into the blood stream (Lyman et al., 1964). The rats presented low levels of triglycerides in the blood along with fatty livers which suggests that fat accumulation was due to the impairment of lipoproteins synthesis or its secretion (Werman et al., 1991).

In addition, in the avocado oil industry the waste water from the process contains enzymes that would decompose in about twelve hours polluting the environment (ANON, 1991). Therefore effective waste management is important in this industry.

The crude oil obtained is quite strong in flavour and odour, and (especially the centrifuged) dark in colour. The green colour of the oil is derived from chlorophyll and is an attractive benefit for gourmet and cosmetic products as it gives the product a more natural appearance. This is a desirable characteristic due to the trend of consuming products derived form natural sources. However a high chlorophyll content may enhance oxidation processes -unless stored in the absence of oxygen and light- (Werman and Neeman, 1987). Kiritsakis and Markakis (1987) reported that olive oil containing green pigments must be protected during storage from light to minimize the oxidation.

One of the ways to minimise this problem is through refining the avocado oil as is done with other edible oils. The process includes bleaching, deodorising and winterising. The bleaching process involves mixing activated earth or carbon with refined oil to remove the remaining color pigments and heavy metals. The bleaching media is then removed by filtration. Deodorising means passing refined oil over heated trays in an evacuated (under high pressure) vessel. The oil then spills from one tray to the next and in doing so loses its smell and some color. Winterising process involves the process of cooling the oil to a given temperature so that crystals that may have been formed in previous operations can be filtered out (Natural Oils International, 1999).

The refined oil is clear and odourless (Smith and Lunt, 1981). However, a deleterious effect from refining the oil processes is the removal of its natural antioxidant tocopherol.

2.3. Chemical and Physical Properties of Avocado Oil

Analysis of commercial crude avocado oil from an unspecified cultivar from South Africa identified the fatty acids present in avocado oil with oleic and palmitic acids constituting 82% of the total (Table 2.3.).

Many factors affect the chemical and physical characteristics of avocado oil. These factors can be categorised as those that act during formation of the oil in fruit on the tree, those acting during storage and ripening of the fruit, those acting during the extraction processes for instance chemical- physical characteristics vary depending on the level of refinement of the oil, (Table 2.4) and those acting during the storage of avocado oil

In addition, these characteristics also vary among different cultivars and countries, (Table 2.5). The iodine number and the low solidification points values show a high degree of unsaturation. Avocado oil is resistant to oxidation due to its low content of polyunsaturated fatty acids and because of its high content of natural antioxidants. However, due to its high amounts of chlorophyll, the rate of photo-oxidation is greater than that of other oils (Werman and Neeman, 1986). Acid value is an indication of the oxidative stability of the oil and is usually expressed in terms of oleic acid (Kiritsakis, 1990). The level of unsaponifiables is of medical and nutritional importance as it will be discussed later.

The colour of the oil is an important characteristic; consumers indicate a preference for shades according to their expectations for such a kind of oil. Crude avocado oil (from the pulp) is green, while after refining the oil is more of a yellowish tone (Swisher, 1988).

Table 2. 3. Fatty Acid Analysis of Crude Avocado Oil

Fatty Acid Type	[1]South Africa %
Palmitic acid (16:0)	11.85
Palmitoleic acid (16:1)	3.98
Stearic acid (18:0)	0.87
Oleic acid (18:1)	70.54
Linoleic acid (18:2)	9.45
Linolenic acid (18:3)	0.87
Arachidic acid (20:0)	0.50
Eliosenoic acid (20:1)	0.39
Behenic acid (22:0)	0.61
Lignoceric acid (24:0)	0.34

T= trace amounts. 1Crude Oil. After Messrs McLachlan and Lazar (Pty) Ltd. Consulting Industrial Chemists Johannesburg, South Africa. PO Box 3344. In: Human, 1987.

Table 2. 4. Properties for California Avocado Oil

Property	Crude Oil	Fully refined oil
Colour	Light to dark green	Clear yellow
Free Fatty acid	1-3%	0.03-0.5%
Iodine value (Wijs)	80-90	85-90
Specific gravity at 25°C	0.910-0.920	0.910-0.920
Refractive Index at 25°C	1.460-1.470	-
Saponification value	_	177-198

California Avocado Oil (AVOCO) files In: Swisher, 1988

Table 2. 5 Minimum and Maximum Values for the Properties of Avocado Oil

Property	Minimum	Maximum
Acid value[1]	1	7
Saponification number[2]	177	198
Iodine value[3]	71	95
Thyocianogen value[4]	(iodine value of 87.2)	71.8
Hydroxyl value[5]	8	10
R-M value[6]	1.7	15.9
Polenske value[7]	0.2	8.0
Unsaponifiable(%)	0.8	1.6
Refractive index nD, 40°C	1.461	1.465
Specific gravity 20-25°C	0.910	0.916
Solidification point (o C)	7	9

1) 2%, oleic acid, 2) mg KOH to saponify 1 g lipid, 3**)** g iodine absorbed/100 g sample. 4) g thiocyanogen absorbed/100 sample, 5) mg KOH necessary to combine with acetic acid liberated by saponification of 1 g of acetylated fat, 6) Reichert-Meissel value. Ml 0.1 N NaOH required to neutralise the volatile fatty acids obtained form 5 g of mixed triglycerides, 7) ml 0.1 N KOH required to neutralize the non-volatile fatty acids obtained from 5 g of a saponified fat or oil. After Eckey, 1954

There is not published information about flavour components in avocado oil but quantitative differences in flavour compounds in olive oil from different regions, have been observed (Lercker et al., 1973; Montedoro et al., 1978). Thus, differences in flavour are expected depending on the growing region of the avocado fruit. A characteristic flavour could be used for produce differentiation in the market. Avocado oil has a high smoke point (over 250°C) which make it suitable for cooking (Da Gama, 1998).

2.4. Uses of Avocado Oil

2.4.1. Avocado Oil in the Food Industry

Obviously the nutritional benefits obtained from a dietary intake of whole avocado fruit (from the fats intake point of view) could also be seen by consuming avocado oil as a gourmet oil. Avocado oil is clear and predominantly monounsaturated which gives it excellent oxidative stability. Normally, for its commercial use the crude oil is refined, bleached, and deodorized but during refining deodorization removes most of the oil's flavour and odour. Commercial avocado oil is light, with pleasant odour and flavour and a faint nutlike tone (SNOI, 1998). An odourless oil could be desirable in the cosmetic industry but not in the gourmet industry (Coffland, 1991). Avocado oil is commercially packed in 55-gallon steel drums of 190 kg under nitrogen to enhance stability (SNOI, 1998).

1 Nutritional Value of the Avocado Oil

In comparison to walnut oil that is rich in polyunsaturated fatty acids (71%), avocado oil is mainly composed of oleic acid a monounsaturated fatty acid (80%) (Table 2.6) In general, polyunsaturated and monounsaturated fatty acids do not promote the formation of artery-clogging deposits the way saturated fats do (See section 1.3.2.2).

Studies have shown that eating foods containing high levels of polyunsaturated fatty acids (such as safflower and corn oil), tend to lower both high and low-density lipoproteins, while foods rich in monounsaturated fatty acids (such as olive and canola oil) apart from lowering low-density lipoproteins give protection to high-density lipoproteins. High blood cholesterol concentrations, mainly low-density lipoproteins (LDLs) are a major risk factor for coronary heart disease (CHD). On the other hand high-density lipoproteins (HDP) have been proved to give protection against the development of CHD (Lichtensein, et al., 1998)

Table 2. 6. Fatty Acids Types in Different Oils (approximate average percentages)

Main types of cooking oils	Polyunsaturated Fat	Monounsaturated Fat	Saturated Fat
Almond oil	16.0	76.0	7.5
Avocado oil	3.0	80.0	10.0
Coconut oil	2.5	7.5	90.0
Corn oil	43.5	43.0	11.0
Grapeseed oil	73.5	.1	7.5
Ground-nut oil	29.5	53.5	7.10
Hazelnut oil	18.5	76.0	7.5
Olive oil	12.0	69.5	16.0
Rapeseed (Canola) oil	20.0	55.0	6.0
Safflower oil	70.5	22.5	7.5
Soya oil	43.5	37.0	14.0
Sunflower oil	59.5	28.5	11.0
Walnut oil	71.0	16.5	9.5

Oil Statistics Flavour Website, 1999.

In addition, due to its high degree of unsaturation (double bonds), polyunsaturated fatty acids are very liable to oxidation, releasing free radicals that react with the cell membranes, while monounsaturated fatty acids are more stable. (Ulbricht and Southgate, 1991). For instance, the relatives rates of oxidation of oleic, linoleic and linolenic are 1:36:180 respectively.

Thus, until recently nutritionists and specialists recommended a reduction of total fat and an increase in the consumption of fibre and polyunsaturates in the diet in order to lower blood cholesterol concentrations. However, studies have shown that is unnecessary the total reduction of fat in the diet, and that a monounsaturated- fat diet could be used to lower total cholesterol even more than the low-fat diet including large amounts of fibre (complex carbohydrates) and polyunsaturated fatty acids (see section 1.3.2.2) (Grundy, 1986).

Dietary studies done specifically on avocado oil nutrition are scarce. In 1960, Grant replaced one half of the daily intake of fat of eight male adults in hospital patients with avocado fruit. A control group received animal fat. The results from this small sample, were surprising and convincing. The cholesterol levels declined in the eight patients in comparison to those of the control group.

Later, Colguhoun et al. (1992), compared the effects of a diet high in monounsaturated fatty acids, enriched with avocado (AE) and a high-complex- carbohydrate diet (AHA III) on blood lipid concentrations. They found that AE was nearly 70% more effective than AHA- III in decreasing total cholesterol, and unlike AHA-III it did not decrease high-density lipoprotein concentrations. The study confirmed previous studies that a diet high in monounsaturated fatty acids leads to a decrease in total cholesterol, LDL cholesterol, with preservation of HDL. The results showed that avocados are an effective source for enriching the diet with monounsaturated fatty acids and improved blood lipid profiles (Colguhoun et al., 1992).

Unlike the typical seed oils, olive oil and avocado oil are extracted from a fruit. Nutrition literature is well-documented in studies mentioning the benefits of including olive oil in the diet in order to reduce the risk of heart diseases. Due to similarities in lipid composition between olive oil and avocado oil, it can be implied that the high concentration of monounsaturated fatty acids in avocado will be beneficial to lower blood lipids as olive oil does. Avocado oil has been granted the Heart Mark by the South African Heart Foundation in recognition of its positive effects on the heart.

Oils used for frying often have low smoke points, which results in them breaking up at high temperatures and forming fatty acids that may be harmful to health (hence the advice never to reuse cooking oil). Avocado oil has a high smoke point over 250 °C, which makes it able to withstand high cooking temperatures (van Heerden, 1997)

2 Vitamin E (Tocopherol)

Oxygen is essential to life processes. A by-product of the oxygen activities is the formation of dangerously reactive free radicals. Free radicals can cause harm to various body cells and organs, contribute to cell cancer or advancing the aging process, arthritis among others. There are three antioxidant vitamins that are effective against the free radicals: E (or Tocopherol), C and beta- carotene (vitamin A precursor) (Bergh, 1991). Adults should obtain at least 10 mg of vitamin E from their daily diets. A tablespoon of avocado oil contains about 10% of the daily requirement for vitamin E (van Heerden, 1997).

Avocado oil and olive oil are similar in their fatty acid composition, but they differ in that avocado oil is very high in vitamins and especially vitamin E. The tocopherol content in avocados could be up to 3700 ppm (Ricks, 199X) whereas that of olive oil varies from 12 to 150 ppm (Howard and Savage, 1994). Tocopherol content in avocado oil is considered a protective agent (natural antioxidant) or as a vitamin substance.

The levels of tocopherol in avocado oil (and in the fruit) vary depending on whether the fruit is at a mature or immature stage. Lozano et al. (1993) reported lower levels of tocopherol in the oil extracted from mature fruit (5.7-10.3 mg/100g oil) than from immature (20.1-45.6 mg/100 g oil) fruits.
In addition, it has been observed that tocopherol content in olive oil fluctuates due to its gradual destruction during processing and storage (Andrikopolous et al., 1989)

3 Bitter Compound

It has been reported that when heated avocado oil develops an unpleasant bitter taste. Ben-Et et al. (1973) identified two compounds as the most likely to contribute to the bitter taste: acetoxy-2,4 dihydroxy-n-heptadeca-16-en and 1,2,4-trihydroxy-n –heptadeca-

16-en. However, apparently these compounds are mainly found in the seed. Thus, this bitter compound would not be present in oil from the pulp.

2.4.2. Avocado Oil in the Pharmaceutics and Cosmetic Industry

At present avocado oil is mostly used in the cosmetic industry as an ingredient in a range of products (Human, 1987). The high cost of the fruit itself makes the production of avocado oil an expensive product that, at the moment only the cosmetic or pharmaceutics industry, could pay.

Usually, crude avocado oil is widely used as emollient in cosmetic products. It penetrates the skin quickly and shows unique properties in its ability to transport active substances into the skin which other oils do not posses (Human, 1987). Skin healing and penetrating properties were reported by Poucher (1974). Avocado oil demonstrated the highest rate of skin penetration (similar to lanolin), faster than corn, soybean and olive oils. Its very high unsaponifiable fraction gives the avocado oil the first place for its sunscreening properties and faster skin penetration characteristics into the skin against popular oils from almond, sunflower, peanut, olive and coconut (Ricks, 199X). Research has demonstrated the effectiveness of avocado oil as a protector against the damaging effects of solar irradiation. Table 2.7 lists the ranking of several natural oils in order of their effectiveness as sunscreens (the first ranking as the most effective).

Swisher (1988) mentioned that product information from the U.S Food and Drug Administration (1976) shows a total of 240 products containing avocado oil in concentrations ranging from 0.1 to 50%. Avocado oil is used in the formulation of cleansing creams, lipsticks, moisturizers, hair conditioners, suntan lotions, bath oils and make-up bases.

2.4.2.1. Unsaponifiable Matter

Most of the fatty acids of avocado oil are present as triglycerides. Several minor non-glyceride compounds consist of non-glyceride fatty acids, esters, hydrocarbons, sterols, triterpene alcohols, tocopherols, phenols, phospholipids, chlorophylls and flavour compounds. All these comprise the unsaponifiable matter (UM) of the oil and represents about 1.6% in the avocado oil. Avocado oil is receiving much attention from the pharmaceutics industry because of its very high unsaponifiable content.

A number of patents have been issued to the industry for extraction and use of avocado oil UM (Gaillard, 1987 cited by Lozano et al., 1993) for therapeutic and medical purposes. For instance, the UM from avocado oil is used in the treatment of connective tissue diseases (Thiers, 1971 cited by Werman and Neeman, 1987).

In the extraction of UM, avocado oil is used as a raw material. The extraction of avocado oil from whole fruit (including the seed) increases the unsaponifiable fraction of the oil. The seed oil contains 55% unsaponifiable matter (Werman and Neeman, 1987). Moreover, UM content in crude oil was higher in immature fruits than in mature fruits (Lozano et al., 1993)

The major compounds found in the UM fraction are sterols and tocopherols. While triglycerides are fatty acids esterified with glycerol (a type of alcohol), sterols are fatty acids esterified with other type of alcohols. Olive oil and avocado oil contain the same sterols. The total sterol content of olive oil is in the range of 180-265 mg/100mg (Kiritsakis, 1990).

It has been suggested that the UM content obtained from commercial avocado oil decreases during the season (Lozano et al., 1993). For instance, the sterol content was found to be higher in immature (1.1-6.2%) than in mature fruit (0.8-2.0%).

Table 2. 7. Ranking of several natural oils in order of their effectiveness as sunscreens.

Natural Oil
1) Mink oil
2) Avocado oil
3) Sweet almond oil
4) Sesame oil
5) Persic oil
6) Safflower oil
7) Peanut oil
8) Jojoba oil
9) Coconut oil
10) Olive oil

Encyclopedia of Chemical Technology, 1979.

In addition, to the unsaponifiable matter properties, a compound isolated from the seed; 4,8'- Biscatechin, has been reported to have anti-tumor activity against Sarcoma 180 (a type of cancer) in mice (Leung, 1980).

The information compiled here confirms that avocado oil compares to olive oil and can be regarded as a high- value product from the nutritional and the commercial point of view.

For all the interesting characteristics that avocado oil offers it represents an industry with good prospects. As avocado oil is commonly a by-product of the fresh fruit industry, a preliminary analysis of the fresh avocado world market is necessary in order to estimate the actual power and potential of the main country producers of such oil.

Chapter 3 Characterisation of Lipids in New Zealand Avocados

3. Introduction

Lipids are the most important component of avocado fruit. They comprise from 60 to 80% of the dry matter of the mesocarp, the edible portion of the fruit, and are responsible for the taste and mouth-feel that consumers demand in avocados (Kaiser et al., 1992; Human, 1987). Not surprisingly, lipid content of mesocarp (% of total dry matter) may be used to define avocado fruit maturity. Although there has been some work relating lipid content to fruit maturity in New Zealand-grown avocados, there has been no examination of the fatty acid makeup of the lipids, or how they might vary between regions. Nor is there any information on lipid content for New Zealand avocados harvested later in a commercial season. Such information is important from both fruit quality, health, and marketing points of view.

The leading avocado producing countries have successful marketing programs which are supported by intensive research. Thus, the market success of traditional avocado producers and exporters such as California and South Africa is partly due to the continual acquisition of information concerning the quality of their fruit, which allows confidence in the planning of marketing activities. One way of maintaining a differentiated place in the world market is by means of effective produce marketing. However, the design of an efficient and effective marketing strategy depends upon a thorough knowledge of the features of the product to be sold in order to deliver excellent quality produce to the market.

The success of the New Zealand Avocado export industry will be determined by the market strategy used and the quality of the produce it trades. In this respect, postharvest research represents an important part of the development of consistently high-quality fruit delivered to the consumer. Among the different aspects which influence final quality is the issue of harvesting the fruit at the correct stage of maturity. Harvesting only mature avocados enhances good eating characteristics at the end of the ripening process (Lewis, 1978). Thus, there is a real need to develop a simple reliable consistent means of determining when avocados are mature and ready to harvest, and will ripen to produce a fruit that is attractive to consumers.

In the past, maturity standard for avocado fruit was based on total lipid content. Since it has been demonstrated that total lipids and moisture content (dry matter) are highly correlated, this is now used by which growers to determine if fruit are ready to harvest. This method is considered practical and easy and is used by avocado industries around the world (Ranney et al., 1992, Kruger and Classens, 1996a). However, it is argued that since moisture content varies with prevailing orchard conditions and then total lipid content is the only reliable maturity standard (Stahl, 1933, Kaiser et al., 1996).

Thus, greater understanding of maturity measures such as dry matter and how they relate to total lipid content is important to industry success.
There is a range of reasons to examine avocado lipid content and its quality in relation to fatty acid composition in New Zealand grown-fruit:

1. Lipid content is the main feature of avocado fruit. In fact, of all fruits, only the olive (*Olea europea*) and the oil palm fruit (*Eleaeis guineensis*) can rival the avocado in oil content (Lewis, 1978). The types of lipids that occur in the avocado include mono-, di- and tri-, glycerides. In mature fruit, approximately, 85% of these lipids are triglycerides (Platt-Aloia and Thomson, 1981) and are normally regarded as storage material to provide carbon and energy to the plant. Additionally, minor non-glyceride (non-saponifiable fraction) compounds are present in avocado lipids. These contain flavour components and nutritionally important vitamins.

2. Lipids in avocados are synthesised only during growth and maturation of the fruit on tree and not during storage and ripening (Platt-Aloia and Thomson, 1981; Luza et al.,

1990). Lipid content and composition of avocados is affected by many factors such as fruit race, fruit position on the tree (Hatton et al; 1957) site within the fruit (Schroeder, 1987), maturity (Davenport and Ellis, 1959; Mazliak, 1965a; Kikuta and Erickson, 1968; Vakis et al., 1985; Eaks, 1990; Inoue and Tateishi, 1995), cultural practices (irrigation) (Lahav and Kalmar, 1977; Kruger and Claassens, 1996a), environmental conditions (rainfall, temperature) (Kaiser and Wolstenholme, 1994; Kruger and Classens, 1996a, 1996b; Mc Onie and Wolstenholme, 1982) and post harvest handling (atmosphere storage composition) (Mazliak, 1965b).

3. There is relatively limited information available on lipids in New Zealand avocados. Lawes (1980) analysed fatty acid composition of Hass fruit twice during development and demonstrated a relationship between lipid and moisture content for Fuerte and Zutano. Hopkirk (1989) measured lipid levels in Hass fruit and the relationship between lipid content and both maturity and consumer acceptability during four successive seasons (from 1981 to 1985). She found that as the season progressed from September to February, dry matter content of avocados from Kaitaia (in the Far North) increased from about 31% to 35% while lipid content increased from about 18% to 23%. In the same period, Bay of Plenty fruit increased in dry matter from 28% to 36% and in lipid content from 16% to 23%. However, because of large fruit variability and technical difficulties encountered with the tasting procedures, it could be established only that total lipid content and dry matter content increased concomitantly as fruit matured. Hopkirk (1989) concluded that there was a strong relationship between dry matter and lipid content and that this relationship may vary across regions. Only a weak relationship between total lipid content or dry matter, and taste acceptability could be established. No attempt was made to analyse the nature of the fatty acids in the lipid component.

4. Lipids are composed of fatty acids. The fatty acids found in the avocado mesocarp are long chain, with 16 carbon atoms or more (Kikuta and Erickson, 1968). In general, the combination of fatty acids in lipids determine their physical and nutritional

characteristics. To date no examination of the lipid composition (fatty acids) has been done for New Zealand fruit.

5. Due to the rapid growth of the avocado industry in New Zealand, there is an urgent need to undertake research in compositional changes in fruit during development and maturation. Such research will provide information to assist in determining maturity indices to ensure that fruit are harvested at a maturity that will enable to achieve good quality and thus, minimise the possibility of inferior fruit being placed on the market.

6. Kaiser et al. (1992) reported that the lipid component in avocado fruit, provides a unique and desirable taste to the fruit. Unsaturated fatty acids, especially polyunsaturated ones are very unstable and easily react with oxygen (Berger and Hamilton, 1990) developing off-flavours which cause the oils to become rancid. In this respect, flavour and rancidity issues have been claimed to be threatening the New Zealand avocado industry. The issue of rancidity will not be examined this season, but the relationship of fatty acids to the development of flavour and off-flavours in avocados represents a major research area that is most applicable to consumer appreciation of the fruit.

7. Lipid is a major component of the human diet contributing up to 40% of the calories in the diet of people from developed countries (Enser, 1995). For many years the nutritional benefits of such a high lipid consumption has been questioned, particularly the consumption of a high proportion of saturated (S) fatty acids (cholesterol-promoting fatty acids) and lower proportions of unsaturated (U) fatty acids. Nutritional studies have shown that diets high in monounsaturated fatty acids (of which oleic acid has been the only fatty acid so far investigated in vegetable foods) may be more favourable to health than polyunsaturated fatty acids in imparting resistance to atherosclerosis (Christakis et al., 1980). Oleic acid has been reported as the major monunsaturated fatty acid present in avocados (Eaks, 1990, Luza et al., 1990). Thus, there is potential for promoting avocados as an anti-atherosclerogenic food.

8. Avocado oil is widely used in the cosmetic industry due to its properties as a natural antioxidant and its ability to penetrate the skin (comparable to lanolin) (Human, 1987). Moreover, avocado oil composition compares favourably with olive oil by having a high oleic acid content thus, avocado oil can also be promoted as cholesterol-reducing as olive oil. Usually the avocado oil industry uses surpluses or undergrade fruit as a raw material for extraction. Thus, in the future, the extraction of avocado oil may represent an alternative for adding value to the industry in New Zealand.

9. Since synthesis of fatty acids may be influenced by ambient temperatures during fruit development (Moreton, 1988, and Kaiser and Wolstenholme, 1994) it is likely that differences in fatty acid composition among growing regions will occur. The extent and direction of these differences would make fruit from one region more nutritionally desired than fruit from other regions. Results could suggest significant health advantages that could be exploited from the marketing strategy point of view. This needs to be further studied in New Zealand where Hass avocados are successfully grown in a range of climatically different regions. If such differences are found for New Zealand grown-fruit these could also mean a disadvantage as, an avocado oil processor might have to take fruit from all areas to source their plant.

From the above exposed it is clear that better knowledge in the variations in total lipid content and composition is necessary for New Zealand avocados.
The main objective of the present report is to determine the qualitative and quantitative changes in lipid content and composition in New Zealand avocados throughout maturation from September to April.

3.1. Materials and Methods

3.1.1. Sample Collection

3.1.1.1. Orchards Location

Avocado fruit (cv. Hass) were obtained from two orchards sited in the Far North and Te Puke regions, selected on the basis of different climatic effects. The warmer site was in Awanui, Far North located at Lat. S. 35° 03’; Long 173 ° 16’. The cooler site was in Te Puke, Bay of Plenty region, located at Lat.S. 37° 47’; Long. 176° 20’.

3.1.1.2. Avocado Tree Characteristics

On twenty ten-year old Hass avocado trees, clusters of 10-20 fruit in the East-Northeast quadrant of the tree at 1-2 m height, were tagged in both orchards. At the time of tagging, Sapac dataloggers (Sapac TempRecord, Argus Distributers Ltd, Auckland) were placed in the tree canopy shaded by a plastic container and temperature was recorded hourly.

3.1.1.3. Fruit Collection

Fruit from these orchards was harvested on seven occasions at approximately monthly intervals between September 1998 (beginning of the harvest season) and April 1999 the main commercial season in New Zealand. From each tagged tree, the largest two fruit were selected, clip-picked and one fruit placed into each of two trays; one for measurement of dry matter/lipids, and the other for weight loss determination. The tray of fruit for dry matter/lipids assessments was wrapped in a plastic bag with 3 small holes to minimise water loss during transport. Fruit were green and did not show purple/black discolouration that can be caused by excessive sunlight.

Unless otherwise stated the avocados were picked early in the morning (thus avoiding water stress) and transported overnight by courier to HortResearch Auckland, arriving at the laboratory within 30 hours of harvest.

3.1.2. Fruit Assessments

On arrival in the laboratory, fruit were weighed and firmness measured using the Anderson Firmometer.

3.1.2.1. Dry Matter

The fruit in tray one from each orchard was divided into groups of five giving four replicates per tray. Two types of dry matter test where carried out as follows.

3.1.2.1.1. Commercial Dry Matter

This is the method regularly used by the industry. A quarter of each fruit (sliced vertically) was peeled, seed coat removed and the flesh grated in a food processor. A subsample of 20 grams was then taken and dried in a petri dish for 36 hours at 60ºC (until constant weight) and then re-weighed. Average dry matter for fruit from the Far North and Te Puke was 24.1% and 24.6% respectively at the beginning of the sampling period (September).

3.1.2.1.2. Plug Dry Matter

A plug from the equatorial part of each fruit was taken using a brass cork borer (5mm id). The plugs were cut longitudinally weighed and then dried in a petri dish until constant weight for at least 36 hours at 60ºC after which they were re-weighed.

3.1.2.2. Sample Preparation for Total Lipid Extraction

For determination of total lipid concentration a second plug, taken from each fruit in each of the four replicates. The plugs were sliced thinly (approximately 5mm diameter, 0.5-1.0 mm width) then weighed in tared KMax glass test tubes. Ten mL of a chloroform-methanol solution (1:1 v/v) was added to each test tube, which were then homogenized using a Vortex blender for 10 seconds ensuring that slices were fully immersed in the solvent. The homogenates were left at room temperature for 36 hours with occasional shaking, after which time, slices of tissue were clear and had sunk (the water in the tissue had been replaced by the methanol). Samples were then stored at –20°C until required for quantitative lipid extraction and fatty acid analysis.

3.1.2.3. Firmness and Weight Loss

3.1.2.3.1. Weight Loss

In some harvests, weight loss was measured by differences in weight from initial values during 14 days of ripening at 15°C.

3.1.2.3.2. Firmness Assessments

Fruit firmness was determined using an Anderson Firmometer (as described by Woolf et al., 1997), that measures the resistance offered by the fruit to a compression force of 300g weight through a 17mm diameter convex button over a 10-second period. The Firmometer value registered, is the Firmometer reading (displacement of the fruit in mm.) multiplied by 10. This Firmometer value increases to a maximum of 110 as fruit softens.

3.1.2.4. Quantitative Determination of Total Lipids

The technique used for quantification of the total lipid content in the samples was a modification of that described by Bligh and Dyer (1959) for total lipid extraction. Lipids were extracted with a mixture of chloroform, methanol and water (1:1:0.9 v/v/v). Following thorough mixing and brief centrifugation, two clear layers were resolved. The lower layer was predominantly chloroform and contained lipids from the original tissue while the upper layer was composed of methanol and water and contained water soluble material from the original extract. Thus, when the chloroform layer was isolated, a purified lipid extract was obtained.

For simplicity and convenience it was anticipated that total lipids would be extracted from thin slices of mesocarp into chloroform/methanol without resorting to homogenisation means. Therefore to test extraction efficiency, different methods for extracting total lipids from hard mesocarp into chloroform/methanol were trialed and compared: sample slicing, sample grinding with liquid nitrogen and sample grinding using an overhead blender (Polytron) (Appendix 1).

Avocado samples collected during the season were sliced, weighed and immersed in 10 volumes of chloroform-methanol solution and stored at -20°C until the most efficient technique was developed. The technique finally developed for extraction of the avocado samples collected during the season was as follows:

The frozen sliced samples in chloroform-methanol were thawed for at least one hour at room temperature. Following addition of 5 mL of (1:1v/v) chloroform/methanol solution, samples were homogenised and totally ground using a Polytron (model CH- 6010 Kinematica Kriens-Lu, PT 10-35 cm., head diameter 1.5 cm., with a universal speed controller) for approximate 30 seconds. After standing for 15 minutes, samples were homogenized with a Vortex blender and immediately filtered through Miracloth. The remaining tissue in the filter paper was rinsed with 5 mL of chloroform/methanol solution and pressure applied, squeezing the paper to ensure maximum solvent recovery.

Ten mL of the filtrate was transferred to a new KMax test tube, and 4.2 mL of 1% v/v NaCl solution added before centrifuging at 2500 rpm for 30 seconds. The salt solution was added for partitioning, and to correct the proportion of water in the system. The final system should contain chloroform:methanol:water (1:1:0.9 v/v/v) to form the biphasic system. The mixture was vigorously shaken and centrifuged to allow better separation and clarification of the lipid-containing chloroform layer, which was then aspirated with a glass syringe. A small volume of the chloroform layer was left behind to avoid removal of the methanol-water layer. The remaining mixture was re-extracted adding 2.5 mL of petroleum ether (boiling point 40-60°C), Vortex-blended and centrifuged. The lipid-containing petroleum ether layer was aspirated and combined with the first chloroform extract. The solvents were evaporated at 40°C under a continuous stream of oxygen-free nitrogen (to prevent oxidation of the fatty acids in the sample) to a constant weight. The dry weight of the lipids was recorded. On one occasion, the Soxhlet method using petroleum ether as a solvent (bp 40-60°C) was carried out manually and the results of the two methods compared.

3.1.2.5. Fatty Acid Analysis of Lipids

3.1.2.5.1. Conversion of Triglycerides to Fatty Acid Methyl Ester (FAME)

The weighed lipids were immediately resuspended in 5 mL of chloroform and stored at -20°C. To determine its fatty acid composition, a 50 μL subsample of the lipid-in-chloroform was treated with 100 μL of 0.5 N sodium methoxide in methanol (prepared with a solution of dimethoxypropane and methanol (95:5, v/v). Esterification of fatty acids to fatty acid methyl esters (FAME) was complete after standing at room temperature for 15 minutes. Sulfuric acid (400 μL of 0.125 N) was added and fatty acid methyl esters were recovered in 7.5 mL of petroleum ether (boiling point 60-80°C).

3.1.2.5.2. Gas Chromatography Analysis

One μL of fatty acid methyl esters in petroleum ether was injected into the gas chromatograph (Hewlett Packard model 5890A), equipped with a Supelco fused silica capillary column No. 11484-02A, catalogue No. 2-4019 (30 m x 0.25mm ID x 0.2 μm film Mfg.) and a flame ionisation detector (FID). The temperature was 100°C initially, then increased by 15°C per minute to 190°C and held at 190°C for 25 minutes. Injector and detector temperatures were at 200 and 220°C respectively. The carrier gas was

Nitrogen flowing at 22 cm per second. For this study an extra fatty acid component, stearic acid methyl ester (18:0) was added to each sample immediately prior to injection as an internal standard. The detector response was calibrated with a standard fatty acid methyl ester mixture (supplied by Sigma-Aldrich) containing five fatty acids which commonly occur in significant concentrations in avocado fruit; palmitic acid (16:0), palmitoleic acid (16:1), oleic acid (18:1), linoleic acid (18:2), linolenic acid (18:3) and the stearic acid (18: 0). The fatty acid peaks in lipid samples were identified by comparison with the retention times of fatty acids in the standard mixture, and the amount calculated as a percentage of the total lipids and as grams of fatty acid per 100 grams of fruit (fresh weight).

3.2. Results

3.2.1. Lipid Extraction Technique

Although slices of ripe mesocarp were extracted adequately, slices of unripe (hard) tissues apparently were not. When extracting unripe hard avocados (day 0 after harvest), grinding with Polytron equipment achieved the highest lipid extraction efficiency of all the methods trialed (Appendix 1). Reducing the sample to a powder using liquid nitrogen (in a morter with a pestle) extracted 76% more lipid than cutting the tissue to slices. Moreover, blending the tissue with the Polytron extracted 131% more lipid than that from sliced tissue. In the case of ripe-soft tissue (day 8 after harvest) liquid nitrogen grinding and Polytron blending extracted 13.6% and 14.6% more lipid than sliced tissue. The difficulties in maximising extraction may be due to the complex three-layered cell walls surrounding the idioblasts mentioned by Platt-Aloia et al. (1983) and Kaiser et al. (1992). This grinding method was reasonably practical with no major difficulties.

Lipid content of avocados remained constant during ripening from harvest (day 0) through ripening at 15°C until day 8 (Appendix 1) when fruit was soft and eating ripe. This was reported before by Platt-Aloia and Thomson (1981) and Luza et al. (1990). The new technique was able to extract on average 5% more lipids than the extraction using the Soxhlet technique.

3.2.2. Fruit Firmness and Weight Loss

Fruit was harvested on seven occasions from orchards in the Far North and the Te Puke regions at approximately monthly intervals between September 24th 1998 and April 28th, 1999. At harvest, fruit from Te Puke had an average weight of 252.1 g and an average firmness value of 14.3, while fruit from the Far North had an average weight of 261.7 g and average firmness of 13.9 during the season (Table 3.1). Usually immediately after

Table 3. 1

harvest Firmometer readings are between 10 to 15, depending on the time of the season Woolf et al. (1997). Results showed firmness at harvest was between 12.26 and 16.23.

Far North and Te Puke fruit harvested in November and January lost approximately 2.7% and 3.8% of their weight respectively during 14 days of ripening at 15°C (data not shown). The rate of weight loss during ripening was fairly constant being approximately 0.2%/day for Far North and 0.3%/day for Te Puke. The differences in weight loss may be due to differences in size of fruit from the respective orchards.

3.2.3. Dry Matter and Lipids

Average dry matter increased from September to April. Dry matter for Te Puke fruit increased from 24.6% to 36.4%, while dry matter from the Far North fruit increased from 24.1% to 32.3% over the same period of time. Along with the standard commercial technique for determining dry matter, the use of a single small plug sample was also examined (Appendix 2). The determination of plug dry matter was significantly quicker than the commercial dry matter technique. However, there was more variability in the results obtained using the single plug method (Table 3.1). Considering the time savings possible using this technique, further trials should be carried out before it can be recommended as an industry standard test.

Over the period of study, percentage dry matter value was higher for Te Puke fruit than for Far North fruit. Although percentage dry matter in both orchards started at a similar value in September (≅24%), dry matter of Te Puke fruit increased at a faster rate than that for Far North fruit (Table 3.1 and Figure 3.1). At Te Puke, dry matter content increased rapidly from September (24.6%) to a peak in mid January (35.2%) after which there was little change during February and a tendency to increase through March and April. In Far North fruit dry matter increased rapidly from 24.1% in September to a peak of 33.5% at the end of February, (a month later than Te Puke) and then remained at approximately this level (32.4%) through April.

Figure 3. 1

Total lipid content (% fresh wt) measured in September was on average 17.2% and 16.4% in Te Puke and the Far North respectively. Lipid content of Te Puke fruit remained higher, increasing rapidly to a peak of 29.6% in January after which it increased slowly to 31.3% through April. Far North fruit showed a more gradual increase to a peak of 26.7% in March, two months later than the Te Puke peak, after which it levelled- off at 26.4% through April. Total lipids in the Far North peaked a month later than its corresponding dry matter value (percent dry matter peaked in February and percent lipids peaked in March).

Linear regression analysis between percent dry matter and percent total lipids showed that there is a close relationship between these factors in fruit from both locations (Figures 3.2a and 3.2b). The correlations resulted in an 'R^2' for Te Puke of 0.99, and of 0.9 for the Far North. Previous research has shown that percent lipid (on a fresh weight basis) and percent moisture content generally sum to a constant value for a particular cultivar and region. If this constant is known, then lipid content can be easily calculated from water content. In this study, the sum of total lipids and water content of the fruit for each region remained constant through the season at about 94% for Te Puke and 93% for the Far North.

Analysis of the extracted lipids by gas chromatography indicated that lipids were similar in fruit from both regions. Fatty acids identified using commercial standards showed that the lipids were predominately composed of oleic (18:1), palmitic (16:0), linoleic (18:2), palmitoleic (16:1) and linolenic (18:3) acids with monounsaturated oleic acid being the most abundant fatty acid in fruit from both sites.
Through September and October the daily rate of synthesis of oleic acid in fruit from Te Puke was faster (72mg fatty acid/100g/day) than in fruit from the Far North (32mg/100 g/day) (Figures 3.3a and 3.3b). In fruit from Te Puke the daily rate of oleic acid decreased from November through February reaching 4mg/100g/day after which increased to 21mg/100g/day through April. From November, oleic acid synthesis rate in fruit from the Far North, decreased through January to 8 mg/100g/day after which it

Figure 3. 2

Figure 3. 3

increased again to 27 mg/100g/day through February after which it decreased through March and April to a rate of 18mg/100/day.

Accumulation of oleic acid in fruit from Te Puke increased markedly from about 3 g/100g fruit from September to 5.5 g/100g fruit in October (2.5g in approximately one month) after which it increased slowly to reach a value of 8g/100gfruit (2.5g in approximately 6 months) through April (Figure 3.4a). Accumulation of oleic acid in fruit from the Far North increased markedly from about 3g/100gfruit in September to 6.5g/100g in February (3.5g in approximately 4 months) after which it started to decrease to reach a value of 5g/100gfruit through April (Figure 3.4b). Slight but consistent increases in palmitic (16:0), linoleic (18:2), palmitoleic (16:1) but not linolenic (18:3) acid were recorded in fruit from both sites throughout maturation on tree.

In fruit from Te Puke, oleic acid (18:1) concentration, as a percentage of total lipids rose from 67% in September to 71% in October after which it decreased slowly and finally plateaued at 62% in April (Figure 3.5a). Palmitic acid (16:0) was the second most abundant fatty acid, remaining fairly constant at about 15% of the total lipids. Concentrations of palmitoleic acid (16:1) remained fairly constant at about 6% during the season. Concentrations of the linoleic acid (18:2) remained constant at 11% until about January after which it increased slowly to 15% in April whereas, linolenic acid (18:3) increased slightly from 0% in September to 1.4% in March after which decreased to 0.9% through April.

In fruit from the Far North, oleic acid increased slightly from 62% of the total lipids in September to 63% in November after which decreased slowly to remain at 57% through March and April (Figure 3.5b). Again palmitic acid (16:0) was the second major fatty acid present remaining fairly constant at about 18%. Palmitoleic acid (16:1) remained fairly constant at about 6% until mid January then increased slightly to 9% towards April. Linoleic acid (18:2) remained fairly constant at about 13% in January after which it

Figure 3. 4

Figure 3. 5

increased slightly until 16% in April whereas linolenic acid (18:3) increased slightly from 0% in September to 1.2% in March where it plateaued.

On average oleic acid levels were approximately 10% lower in Far North fruit (60%) than in Te Puke fruit (66%), while palmitoleic acid was 17% higher in Far North fruit (7%) than in Te Puke fruit (6%). Palmitic acid was 20% higher in fruit from the Far North (18%) than in Te Puke fruit (15%). Linoleic acid was 17% higher in Far North (14%) fruit than in Te Puke fruit (12%). In both regions, linolenic acid remained fairly constant for most of the season at about 0.8%.

3.2.4. Air Temperature

Average and minimum daily temperatures were generally higher for the Far North site than for the Te Puke site (Figure 3.6). However, maximum temperatures were similar for both orchards (Appendix 3 for detailed temperature records). The rate of lipid synthesis may not be determined by temperature alone, but maybe by other factors as well.

Figure 3. 6

3.3. Discussion

This study confirmed the high relationship between lipid content and dry matter in avocado fruit previously reported in New Zealand by Lawes (1980) and Hopkirk (1989), and in overseas studies by Stahl (1933), Biale and Young (1969), Appleman (1969), Kikuta and Erickson (1968), Lee et al. (1983) and Ranney et al. (1992). Thus, for both Te Puke and the Far North, fruit water content decreased steadily as lipid content increased (R^2 = 0.96) during the time of assessments. The equations presented in Figures 3.2a and 3.2b, mean that the percentage of lipids in fruit at a given a percentage dry matter or vice-versa can be predicted, although with higher accuracy for fruit from Te Puke than for fruit from the Far North.

In comparison to previously reported methods for the determination of lipids in avocados, this optimised technique offers advantages such as small sample size, low expense of operation, simplicity, accuracy and relatively fast determination (particularly for a large number of samples). This new technique was able to extract on average 5% more lipids than extraction using the Soxhlet technique. Lewis et al. (1978) working with avocados also demonstrated that polar solvents such as chloroform/ methanol extracted on average 5-8% more lipids than did the Soxhlet method (using petroleum ether). They suggested that chloroform/methanol is polar enough to release some protein-bound lipids, probably phospholipids and glycolipids. In this study both techniques (the new and the Soxhlet technique) were found positively correlated (R^2 = 0.7), but it is recommended that the two techniques be compared further using the Soxhlet technique at least twice in the season. As different lipid extraction methods and conditions can give different results, care should therefore be taken in making comparisons between results reported here and elsewhere.

Overall, two stages of lipid production could be distinguished. An initial stage of rapid lipid increase, occurring from September until January for Te Puke, and from September until March for the Far North, followed by a second stage with a slow increase in lipid content in both regions for the rest of the season. Eaks (1990) reported that a reason for the decrease in total lipid content through May (about October in Southern Hemisphere), could be that lipid synthesis has slowed or stopped although the fruit are still increasing in weight.

In addition, the late peak in total lipids in fruit from the Far North may be due to a change in temperatures. Kaiser et al. (1992) suggested that lipids may have been respired due to high temperatures thus, delaying its accumulation. Orchard temperature records during this period (Appendix 3) show that the maximum temperatures of the two regions are similar, but that Te Puke has lower average and minimum temperatures. Results showed that fruit from the Far North may take longer to achieve maturity ie. the ability of the fruit to ripen properly. However further research, examining for instance changes in a wider range of environments, is necessary to correlate these results found with climatic temperatures.

The Far North region recorded higher average temperatures than Te Puke. Nevertheless, fruit from Te Puke always showed higher values for dry matter and lipid content. Lawes (1980) found similar values for lipid content (19.5% in early November and 22.9% mid January) to those found in this work for the Far North (19.5% end of October and 23% in mid January). Nevertheless, Lawes (1980) only studied fruit from one area (Gisborne) in New Zealand and at just two occasions during the season. Conversely, Hopkirk (1989) found higher values of dry matter and lipid content for fruit from Kaitaia (in the Far North) than for fruit from the Bay of Plenty. In Kaitaia, dry matter content increased from 31% to 35% while lipids increased from 18% to 23% from September to February. In the Bay of Plenty, dry matter increased from 28% to 36% while lipids increased from 16% to 23%. Hopkirk’s results agree with those of Kaiser and Wolstenholme (1994) in South Africa who also found higher lipid content in fruit from the warmer site than in those from a cooler site during part of the development period they were studying. These contrasting results may imply that the temperature of the growing region is not the only factor that affects the maturity of avocados. Therefore further research including fruit from more regions and more orchards within a region is necessary to assess the different factors that may affect the maturation of the fruit.

The sum of lipids and water content remained fairly constant for each region over the period of study (September until April). This implies that the rate of increase in the percentage of lipids is the same as the rate of decrease in the water content in the fruit. Although there may be some slight variation between growing regions and cultivars, this constancy has been reported previously both in overseas (Pearson, 1975; Swarts, 1976; Kruger et al., 1995) and in New Zealand by Lawes (1980) and Hopkirk (1989). However, Hopkirk suggested this relationship from the point of view of the non-lipid fraction in avocados. He stated that because of the close relationship between dry matter and lipid content, therefore the non-lipid dry matter fraction remains constant. Thus, for instance he found that for fruit from the Bay of Plenty the non-lipid dry matter value was calculated to be 10.5%. Even though, Stahl (1933) considered that water content could vary with rainfall, this calculation whereby the sum of water plus lipid content, or the non-lipid dry matter remains fairly constant during maturation, is easy and practical enough to be used by growers and packers.

Fatty acid profiles of avocado mesocarp lipids reported by several authors varied with the nature of cultivars, growing conditions and stage of development of fruits. Thus, it is difficult to contrast the results found here with theirs. Nevertheless oleic acid was always the major fatty acid reported followed by palmitic, linoleic, palmitoleic and linolenic acids. In this study oleic acid was also the main fatty acid being synthesised and deposited as triglyceride in the mesocarp tissue of the fruit. Thus, the increase in total lipids appears to be due primarily to the synthesis of oleic acid. These results agree with those of Eaks (1990). The five fatty acids that occurred in significant amounts were oleic (18:1), palmitic (16:0), linoleic (18:2), palmitoleic (16:1) and linolenic acid (18:3) These fatty acids were also identified in similar amounts for part of the maturation period in California by Eaks (1990), in Chile by Luza et al. (1990), in South Africa by Kaiser and Wolstenholme (1994) and in Japan by Inoue and Tateishi (1995).

Concentrations of oleic acid, the cholesterol- reducing fatty acid, were 10% lower in the Far North than in Te Puke. In addition, the cholesterol-promoting palmitic acid was 20%

higher in the Far North fruit than in Te Puke fruit. On average, the sum of beneficial monounsaturates found (oleic and palmitoleic acid) was about 7.5% higher in fruit from Te Puke (72%) than in fruit from the Far North (67%). A similar distribution of fatty acids in fruit from both orchards to that of Kaiser and Wolstenholme (1994) was found. In their study oleic acid was approximately 20% lower at the warmer site than at the cooler site, palmitic acid was 16% higher at the warmer site than at the cooler site, and the sum of monounsaturates was about 10% higher at the cooler site than at the warmer site. Even though, Far North avocados had lower levels of monounsaturated oleic acid than did Te Puke fruit, the levels of oleic acid (60%) and palmitoleic acid (7%) are similar to those of olive oil (56- 83% oleic acid and 0.3-3.5% palmitoleic acid) (IOOC, 1984 summarised by Kiritsakis, 1990). The nutritional properties of olive oil as a cholesterol-reducing food are well known and are shown by the low indexes of coronary diseases in countries with high consumption rates of this product (Andrikopolous, 1989).

In addition, the polyunsaturated to saturated ratio (*P*:*S*) has been suggested as an indicator or measure of whether the diet promotes coronary heart disease (or index of atherogenicity). Over the period of study (September to April) the *P:S* ratio varied approximately from 0.7 to 1 in both regions (Table 3.2), increasing with maturity. However the averages for the season at both sites are about the same, 0.9 for Te Puke and 0.8 for the Far North. In California, Slater et al. (1975) reported for Hass avocados an average *P:S* ratio of 0.75 from April to June (about September to November in the Southern Hemisphere). Far North ratio is similar to that of California found by Slater et al. (1975) whereas Te Puke ratio is higher than California Hass.

Olive oil *P:S* ratio is in the range of 0.14- 1.19 depending on the growing region (IOOC, 1984 summarised by Kiritsakis, 1990). However, recent developments in nutrition reported better health benefits from a high dietary ratio monounsaturated (especially oleic acid) to saturated fatty acids (*M*:*S*) than from a diet with a high *P*:*S* ratio. For instance for olive oil *M:S* ratio is in the range of 3.1- 9.2 (depending on the growing region). In this study it was found an *M:S* average ratio of 4.7 for Te Puke fruit and 3.8 for the Far North.

Table 3. 2

Comparing the values found for New Zealand fruit in this study, and the values compiled in overseas research (Table 3.3) it is clear that in all the cases the major saturated fatty acid is palmitic acid and the main unsaturated fatty acid is oleic. Straight comparisons among these results are difficult because of the different stages of maturity that the fruit might have been at the time of the research. Nevertheless, fruit has been regarded as mature therefore all achieved horticultural maturity. Thus, fruit from Japan presented the highest levels of palmitic acid (22%) and the lowest level of oleic acid (50%). South African avocados show the highest level of oleic acid (87.9%). However, fruit from Chile seems to have the highest ratios of *U:S*, *P:S* and *M:S* where high values for these ratios are regarded of nutritional benefit.

Values for fruit from Te Puke (in New Zealand) are very similar to those from the USA, (with the exception of linolenic acid). Therefore, New Zealand fruit- from Te Puke- could be marketed of the same nutritional quality, in terms of fatty acids, as fruit from the USA, California.

On the whole, during the season total unsaturated (polyunsaturated plus monounsaturated) fatty acids are higher in fruit from Te Puke than in fruit from the Far North. However as the season progressed this difference becomes smaller. Average seasonal values of oleic acid for both regions indicate that Te Puke fruit would be preferable than Far North fruit due to higher oleic acid (oleic acid, has been reported to reduce blood cholesterol levels).

Oil processors might want to use only fruit from Te Puke as its nutritional quality could be used as a marketing advantage over oil produce from other regions. In addition, Te Puke fruit showed to contain higher levels of oil than Far North fruit, therefore higher yields could be obtained during commercial oil extraction.

However, if oil processors source their avocados from both regions, the nutritional advantage of Te Puke fruit would disappear and a standard country oil would be obtained.

Table 3. 3

3.1.1. Fruit Assessments

On arrival in the laboratory, fruit were weighed and firmness measured using the Anderson Firmometer.

3.1.1.1. Dry Matter

The fruit in tray one from each orchard was divided into groups of five giving four replicates per tray. Two types of dry matter test where carried out as follows.

3.1.1.1.1. Commercial Dry Matter

This is the method regularly used by the industry. A quarter of each fruit (sliced vertically) was peeled, seed coat removed and the flesh grated in a food processor. A subsample of 20 grams was then taken and dried in a petri dish for 36 hours at 60ºC (until constant weight) and then re-weighed. Average dry matter for fruit from the Far North and Te Puke was 24.1% and 24.6% respectively at the beginning of the sampling period (September).

3.1.1.1.2. Plug Dry Matter

A plug from the equatorial part of each fruit was taken using a brass cork borer (5mm id). The plugs were cut longitudinally weighed and then dried in a petri dish until constant weight for at least 36 hours at 60ºC after which they were re-weighed.

3.1.1.2. Sample Preparation for Total Lipid Extraction

For determination of total lipid concentration a second plug, taken from each fruit in each of the four replicates. The plugs were sliced thinly (approximately 5mm diameter, 0.5-1.0 mm width) then weighed in tared KMax glass test tubes. Ten mL of a chloroform-methanol solution (1:1 v/v) was added to each test tube, which were then homogenized using a Vortex blender for 10 seconds ensuring that slices were fully immersed in the solvent. The homogenates were left at room temperature for 36 hours with occasional shaking, after which time, slices of tissue were clear and had sunk (the water in the tissue had been replaced by the methanol). Samples were then stored at –20°C until required for quantitative lipid extraction and fatty acid analysis.

3.1.1.3. Firmness and Weight Loss

3.1.1.3.1. Weight Loss

In some harvests, weight loss was measured by differences in weight from initial values during 14 days of ripening at 15°C.

3.1.1.3.2. Firmness Assessments

Fruit firmness was determined using an Anderson Firmometer (as described by Woolf et al., 1997), that measures the resistance offered by the fruit to a compression force of 300g weight through a 17mm diameter convex button over a 10-second period. The Firmometer value registered, is the Firmometer reading (displacement of the fruit in mm.) multiplied by 10. This Firmometer value increases to a maximum of 110 as fruit softens.

3.1.1.4. Quantitative Determination of Total Lipids

The technique used for quantification of the total lipid content in the samples was a modification of that described by Bligh and Dyer (1959) for total lipid extraction. Lipids were extracted with a mixture of chloroform, methanol and water (1:1:0.9 v/v/v). Following thorough mixing and brief centrifugation, two clear layers were resolved. The lower layer was predominantly chloroform and contained lipids from the original tissue while the upper layer was composed of methanol and water and contained water soluble material from the original extract. Thus, when the chloroform layer was isolated, a purified lipid extract was obtained.

For simplicity and convenience it was anticipated that total lipids would be extracted from thin slices of mesocarp into chloroform/methanol without resorting to homogenisation means. Therefore to test extraction efficiency, different methods for extracting total lipids from hard mesocarp into chloroform/methanol were trialed and compared: sample slicing, sample grinding with liquid nitrogen and sample grinding using an overhead blender (Polytron) (Appendix 1).

Avocado samples collected during the season were sliced, weighed and immersed in 10 volumes of chloroform-methanol solution and stored at -20°C until the most efficient technique was developed. The technique finally developed for extraction of the avocado samples collected during the season was as follows:

The frozen sliced samples in chloroform-methanol were thawed for at least one hour at room temperature. Following addition of 5 mL of (1:1v/v) chloroform/methanol solution, samples were homogenised and totally ground using a Polytron (model CH-6010 Kinematica Kriens-Lu, PT 10-35 cm., head diameter 1.5 cm., with a universal speed controller) for approximate 30 seconds. After standing for 15 minutes, samples were homogenized with a Vortex blender and immediately filtered through Miracloth. The remaining tissue in the filter paper was rinsed with 5 mL of chloroform/methanol solution and pressure applied, squeezing the paper to ensure maximum solvent recovery.

Ten mL of the filtrate was transferred to a new KMax test tube, and 4.2 mL of 1% v/v NaCl solution added before centrifuging at 2500 rpm for 30 seconds. The salt solution was added for partitioning, and to correct the proportion of water in the system. The final system should contain chloroform:methanol:water (1:1:0.9 v/v/v) to form the biphasic system. The mixture was vigorously shaken and centrifuged to allow better separation and clarification of the lipid-containing chloroform layer, which was then aspirated with a glass syringe. A small volume of the chloroform layer was left behind to avoid removal of the methanol-water layer. The remaining mixture was re-extracted adding 2.5 mL of petroleum ether (boiling point 40-60°C), Vortex-blended and centrifuged. The lipid-containing petroleum ether layer was aspirated and combined with the first chloroform extract. The solvents were evaporated at 40°C under a continuous stream of oxygen-free nitrogen (to prevent oxidation of the fatty acids in the sample) to a constant weight. The dry weight of the lipids was recorded. On one occasion, the Soxhlet method using petroleum ether as a solvent (bp 40-60°C) was carried out manually and the results of the two methods compared.

3.1.1.5. Fatty Acid Analysis of Lipids

3.1.1.5.1. Conversion of Triglycerides to Fatty Acid Methyl Ester (FAME)

The weighed lipids were immediately resuspended in 5 mL of chloroform and stored at -20°C. To determine its fatty acid composition, a 50 μL subsample of the lipid-in- chloroform was treated with 100 μL of 0.5 N sodium methoxide in methanol (prepared with a solution of dimethoxypropane and methanol (95:5, v/v). Esterification of fatty acids to fatty acid methyl esters (FAME) was complete after standing at room temperature for 15 minutes. Sulfuric acid (400 μL of 0.125 N) was added and fatty acid methyl esters were recovered in 7.5 mL of petroleum ether (boiling point 60-80°C).

3.1.1.5.2. Gas Chromatography Analysis

One μL of fatty acid methyl esters in petroleum ether was injected into the gas chromatograph (Hewlett Packard model 5890A), equipped with a Supelco fused silica capillary column No. 11484-02A, catalogue No. 2-4019 (30 m x 0.25mm ID x 0.2 μm film Mfg.) and a flame ionisation detector (FID). The temperature was 100°C initially, then increased by 15°C per minute to 190°C and held at 190°C for 25 minutes. Injector and detector temperatures were at 200 and 220°C respectively. The carrier gas was Nitrogen flowing at 22 cm per second. For this study an extra fatty acid component, stearic acid methyl ester (18:0) was added to each sample immediately prior to injection as an internal standard. The detector response was calibrated with a standard fatty acid methyl ester mixture (supplied by Sigma-Aldrich) containing five fatty acids which commonly occur in significant concentrations in avocado fruit; palmitic acid (16:0), palmitoleic acid (16:1), oleic acid (18:1), linoleic acid (18:2), linolenic acid (18:3) and the stearic acid (18: 0). The fatty acid peaks in lipid samples were identified by comparison with the retention times of fatty acids in the standard mixture, and the amount calculated as a percentage of the total lipids and as grams of fatty acid per 100 grams of fruit (fresh weight).

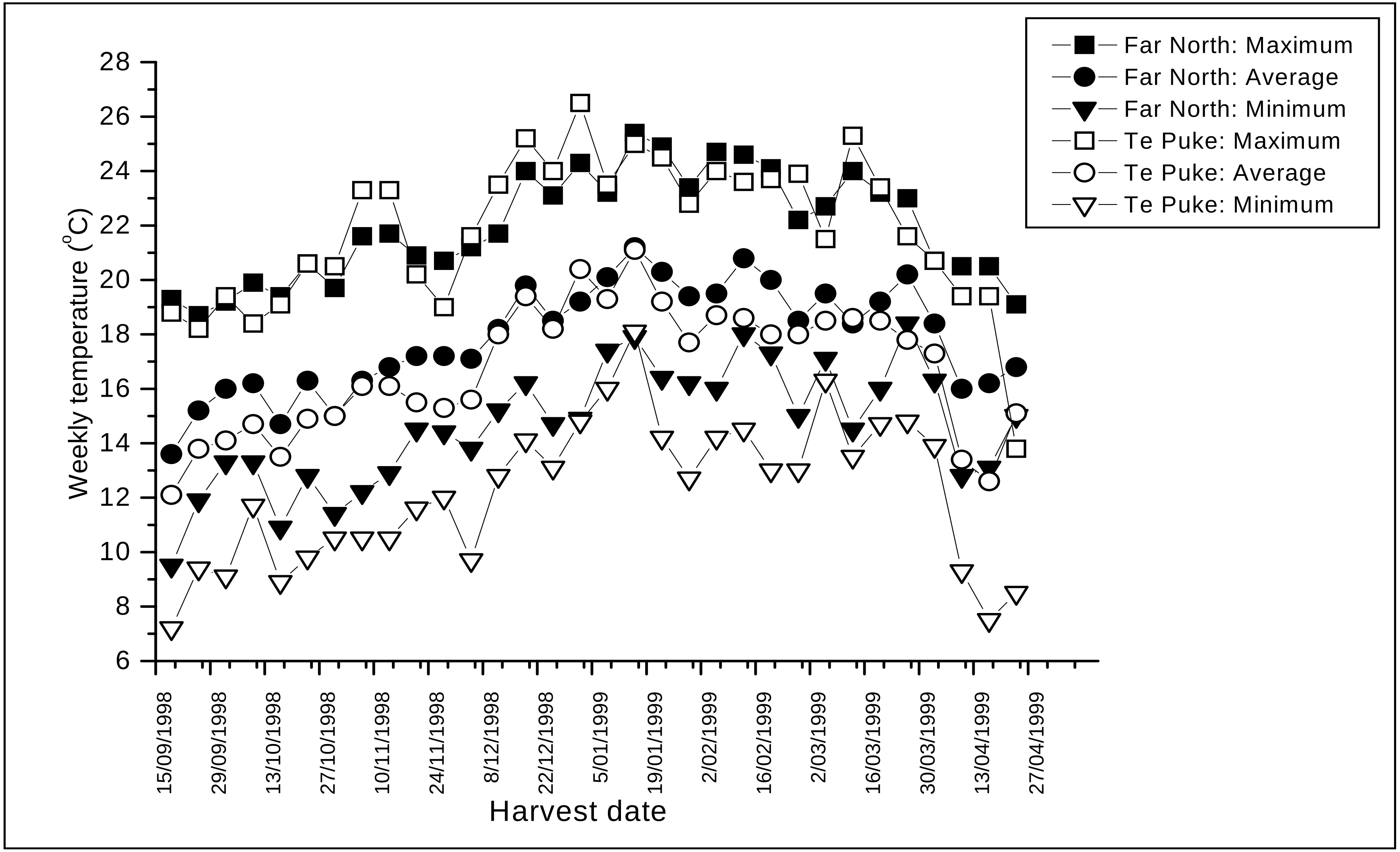


Figure 3.6. Average weekly temperatures (minimum, average and maximum) for Far North and Te Puke orchards from September 1998 to April 1999. Temperature was logged every hour (see Appendix 3 for raw data).

Table 3.1. **Mean Fresh Weight, Firmness and Dry Matter of "Hass" Avocados from the Far North (FN) and Te Puke (TP) from September 1998 to April 1999 at Harvest.**

Harvest Date	WEIGHT g.				[1]FIRMNESS		MEAN COMMERCIAL DRY MATTER %				MEAN PLUG DRY MATTER %			
	Mean		Range		FN	TP	FN	SEM	TP	SEM	FN	SEM	TP	SEM
	*FN	*TP	FN	TP										
24 Sept 1998	268.8	241.1	211-321	192-344	13.5	15.4	24.1	0.7	24.6	0.7	27.9	4.6	23.8	0.6
30 Oct. 1998	261.3	241.6	243-312	174-299	13.6	14.5	26.1	0.7	27.5	0.6	26.7	1.2	27.7	1.2
27 Nov. 1998	256	228.4	236-283	186-303	12.3	12.8	28.3	0.6	30.5	0.8	29	0.5	32	0.9
15 Jan. 1999	274.3	-	241-313	-	14.6	-	31.4	1.0	-	-	31.4	0.8	-	-
19 Jan. 1999	-	239.8	-	169-310	-	14.8	-	-	35.2	0.5	-	-	37.2	0.9
26 Feb. 1999	241.2	-	193-299	-	12.9	-	33.5	0.4	-	-	35.3	0.8	-	-
02 Mar. 1999	-	271.1	-	209-363	-	12.9	-	-	35.1	0.8	-	-	35.9	0.6
31 Mar. 1999	279.4	281	221-354	211-353	14.4	13.6	32.1	0.4	35.4	0.8	31.5	0.3	35	0.8
28 Apr. 1999	251.8	261.4	200-348	179-352	15.8	16.2	32.3	1.2	36.4	0.6	33.2	1.4	38.6	0.6
MEAN	261.8	252.1	-	-	13.9	14.3	-	-	-	-	-	-	-	-

*FN= Far North
*TP= Te Puke
1 Firmometer value
SEM= Standard Error
Source: Own elaboration

Table 3.2. Fatty acids of New Zealand Hass Avocados from the Far North and Te Puke Regions

% Fatty Acid	Harvest Month/ Region/ Percentage Fatty Acid															
	Sept		Oct		Nov		Jan		Feb		Mar		Apr.		AVERAGE	
	[4]FN	[5]TP	FN	TP	FN	TP	FN	TP	FN	TP	FN	TP	FN	TP	FN	TP
Saturated																
Palmitic	19.8	16	16.9	14.3	19.1	14.4	17.5	14.7	17.6	15.7	17.6	15.5	16.9	15.4	**17.9**	**15.1**
Unsaturated																
Palmitoleic	5.5	5.5	7.7	4.5	5	5.4	7.4	5.6	8.8	7.1	8.6	7.5	9.2	6.2	**7.4**	**6**
Oleic	61.9	67.3	61.7	70.6	62.8	68.3	60.4	67.6	58.4	62.2	57.2	61.5	57.2	61.3	**59.9**	**65.6**
Linoleic	12.9	11.1	12.9	10	12.6	11.3	13.7	11.3	14	13.8	15.4	14.1	15.7	14.7	**13.9**	**12.3**
Linolenic	0	0	0.83	0.59	0.51	0.58	1.04	0.74	0.79	1.13	1.21	1.36	1.18	2.37	**0.8**	**1**
SUBTOTAL	**80.3**	**83.9**	**83.1**	**85.7**	**80.9**	**85.6**	**82.5**	**85.2**	**82.5**	**84.2**	**82.4**	**84.5**	**83.3**	**84.6**	**82**	**84.9**
Ratio U : S[1]	**4.1**	**5.2**	**4.9**	**6**	**4.2**	**6**	**4.7**	**5.8**	**4.7**	**5.4**	**4.7**	**5.4**	**4.9**	**5.5**	**4.6**	**5.6**
Ratio P : S[2]	**0.7**	**0.7**	**0.8**	**0.7**	**0.7**	**0.8**	**0.8**	**0.8**	**0.9**	**0.9**	**0.9**	**1**	**1**	**1.1**	**0.8**	**0.9**
Ratio M : S[3]	**3.4**	**4.5**	**4.1**	**5.3**	**3.6**	**5.1**	**3.9**	**5**	**3.8**	**4.4**	**3.7**	**4.4**	**3.9**	**4.4**	**3.8**	**4.7**

1 Unsaturated to Saturated fatty acids ratio
2 Polyunsaturated to Saturated fatty acids ratio
3 Monounsaturated to Saturated fatty acids ratio
4 FN= Far North, 5 TP= Te Puke
Source: Own elaboration

Table 3.3. Fatty acids of New Zealand Hass Avocados and other Countries*

% Fatty Acid	Region/ Percentage Fatty Acid					
	NZ		USA[6]	South Africa	Chile	Japan
	FN[4]	TP[5]				
Saturated						
Palmitic	17.9	15.1	14	18.8-21.7	10.9	22
Unsaturated						
Palmitoleic	7.4	6	5	7.3-11.1	4.5	10
Oleic	59.9	65.6	69	50.4-60.3	69.6	50
Linoleic	13.9	12.3	11	10.7-15.3	10.2	14
Linolenic	0.8	1	0.1	1.1-1.2	2.3	0.3
SUBTOTAL	82	84.9	85.1	69.5-87.9	86.6	74.3
Ratio U : S[1]	**4.6**	**5.6**	**6.1**	**3.7-4.1**	**7.9**	**3.4**
Ratio P : S[2]	**0.8**	**0.9**	**0.8**	**0.6-0.8**	**1.1**	**0.7**
Ratio M : S[3]	**3.8**	**4.7**	**5.3**	**3.1-3.3**	**6.8**	**2.7**

*For mature fruit

1 Unsaturated to Saturated fatty acids ratio, **2** Polyunsaturated to Saturated fatty acids ratio, **3** Monounsaturated to Saturated fatty acids ratio, **4** FN= Far North, **5** TP= Te Puke, **6** USA, California.

Source: Requejo et al., 1999; Eaks, 1990; Kaiser and Wolstenholme, 1994; Luza et al., 1990; Inoue and Tateishi, 1995.

Chapter 4 World Avocado Market Overview

4. World Production of Avocados

The avocado, is the fruit of the *Persea americana*, of the family Lauraceae. Avocado trees usually begin producing fruit within 3 to 4 years and may produce for up to 50 years. With the exception of West Indian race cultivars, avocados take approximately one year to develop and mature.

Normally the avocado harvest season (depending on the Hemisphere) starts late or mid way in the year and extends until the following year. This is the reason why, in the industry, a season is usually considered as covering two years, eg. 1997/98. In this review, for simplicity and convenience years and not seasons will be used.

Avocado fruit is globose similar to a pear with a large stone. Avocado originates from the regions of Mexico extending to Peru but excluding the West Indies where it was introduced later.

Avocado is an unusual fruit and differs from other fruits in that it possesses high oil and protein content. Moreover is the only fruit known that contains all the nutrient elements; sugars (as carbohydrates), proteins, lipids, vitamins, minerals, salts and water (Bioplus, 1998). It supplies from 150 to 300 calories per 100 grams. Not surprisingly it represents an important nutritional food source in producing countries.

Although a range of avocado cultivars are grown, Hass is the world's most widely-grown and exported cultivar. One of the reasons for the popularity of Hass is that it produces high yields of rich fruit with excellent storage and shipping conditions.

Avocados are usually hand- picked, therefore the harvesting operation requires the use of intensive labour resources. Fruit selection depends on either oil content or dry matter content, or release-date/size maturity requirements, depending on the producer. Pickers are encouraged to use gloves and canvas picking bags to prevent physical damage and protect the quality of the fruit. In addition, pickers should be able to select and harvest only desirable fruit, clipping the stem as close as possible without injuring the fruit (FAS, 1998).

Avocado flesh is hard at harvest but after several days ripens to a soft buttery texture with a faint nutlike flavour. It is consumed mainly as either fresh fruit in salads or as a puree known as ‘guacamole’. These consumption habits make it possible to utilise all the nutritional benefits of the fruit when eating including the vitamins, which otherwise will be destroyed during cooking.

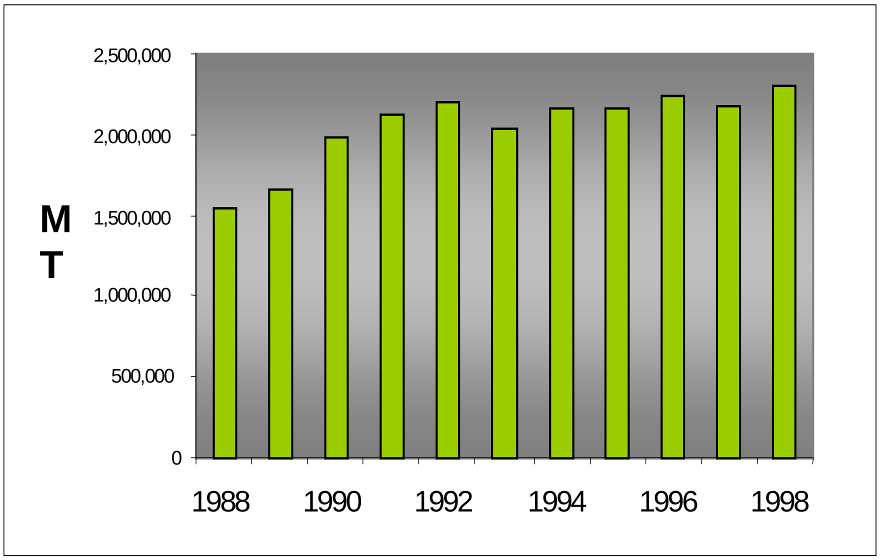
The food industry makes use of its avocado oil to prepare concentrated foods, while the cosmetics industry prepares lotions and soaps for hair and skin treatments. Lastly, prestigious laboratories are also analysing the properies of the flesh and oil for medical purposes.

The avocado trade had its origins in colonial times in Latin America, when the Spanish carried the fruit for the first time across the sea to Spain. These trips allowed expansion of the growing areas of avocados, which had previously been concentrated in Mexico and Central America.

Intensive cultivation of avocados for commercial purposes began in California and Florida in 1932 and later in Israel, South Africa and Chile. These countries along with Mexico constitute the main producers of the fruit today.

Avocado fruit has shown good commercial prospects and planted areas demonstrate a tendency to increase. World production of avocado has grown on average 4.3% (over 760,000 MT) between 1988 and 1998. It totalled over 2.3 million tonnes in 1998 (Figure 4.1.).

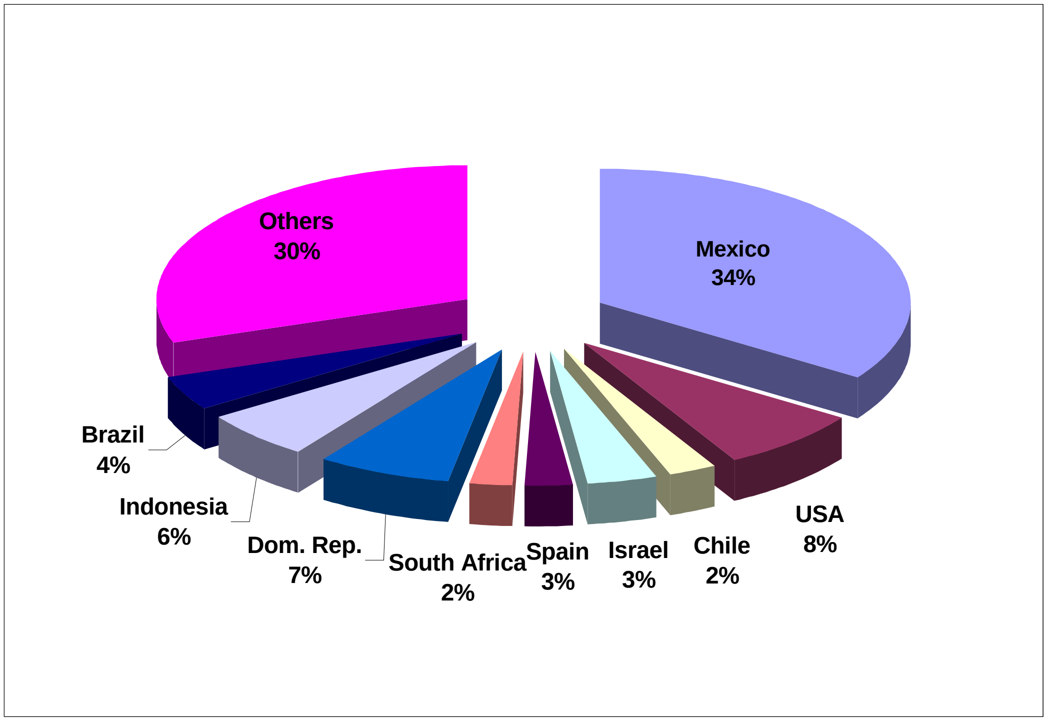
On average, the Americas, North and Central America account for nearly 60% of world production while, South America accounts for 18% of world production and Africa and Asia account for 10% each. However in these continents production is concentrated in only a few countries. Avocado production figures by country producer are shown in Table 4.1.



Source: FAO, 1999 Databases

Figure 4. 1. World Avocado Production

The main producers of avocado are Mexico (34%), USA (8%), Dominican Republic (7%), Indonesia (6%) Brazil (4%) and Israel (4%), Chile (2.4%), Spain (3%) and South Africa (2%) which, during 1997, contributed together to just over 70% of the world production. Avocados are grown in other countries such as Colombia, Peru, Venezuela, Ecuador, Costa Rica, Guatemala, Australia, El Salvador and Philippines basically for local consumption, with no export industry yet developed. These countries, along with others, accounted for 30% of the world production (Figure 4.2). Countries such as Brazil, Indonesia and the Dominican Republic produce large amounts of avocados however have not developed an export industry. These countries will be mentioned only briefly, as the focus will be on countries, which are the principal traders of avocados namely, Mexico, USA, South Africa and Israel. In addition, a special review of the avocado industry in New Zealand will be given.



Source: FAO, 1999 Databases

Figure 4. 2. World Avocado Production by Main Producer Countries in 1997.

4.1.1 Dominican Republic

During 1997, Dominican Republic avocado production was around 155,000 tonnes and accounted for 7 percent of the world's total production. Production has risen almost 7% since 1992 but only around 4% of the produce is exported every year. The Dominican Republic is after Chile the second largest supplier of avocados to the United States. Fruit from the Dominican Republic enters the U.S. duty free under the Caribbean Basin Economic Recovery Act. Small amounts are also exported to Canada and other Caribbean countries. At present the Dominican Republic has no governmental, production marketing, or export policy for avocados (FAO, 1999; FAS, 1997a).

4.1.2 Indonesia

Indonesia produced 6% of the world's total avocado production. During the 1997 season Indonesia's produced 109,000 metric tonnes of avocados which accounted to 6% of the world's total avocado production. Although it is a large producer of avocados and exported 30 metric tonnes in 1988 and 2 tonnes in 1997, Indonesia does not produce export quality produce. All the produce is basically consumed internally.

4.1.3 Brazil

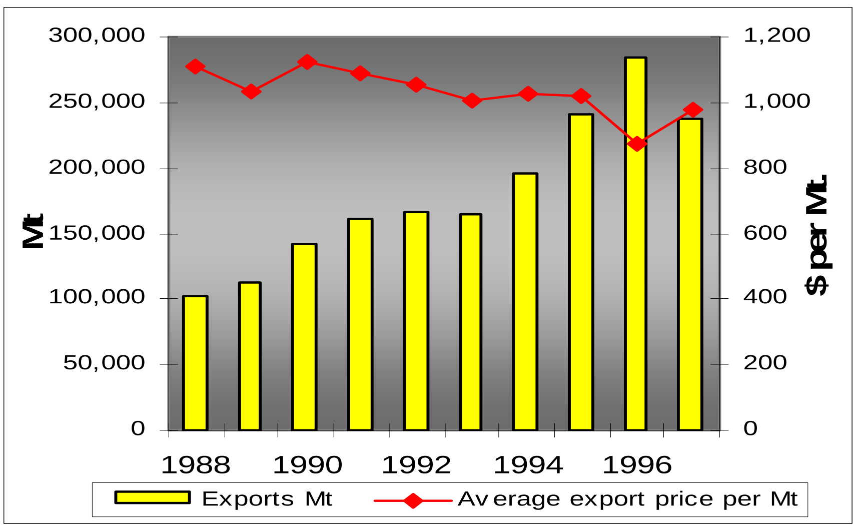
Due to its extensive territory and diversity of climates, Brazil is able to produce many tropical and subtropical fruits. Not surprisingly Brazil is also a large producer of avocados. Four percent of the world's avocados are produced in this country. However as in the case of Indonesia, Brazil has not developed an important avocado export industry. The main reason for this is that avocado cultivars produced in this country are not known in importing countries. In 1997 Brazil produced over 93,000 tonnes of avocados, of which only 0.3 percent were exported. Similar export figures are reported every year.

Table 4. 1. Avocado Production by Main Country Producers (Mt)

4.2. World Avocado Trade

Avocado world trade has increased greatly from 57,576 tonnes in 1980 to 238,306 in 1997.

The main players in the export market in 1980 were South Africa, Israel and the United States. With only a few suppliers, average world prices paid in the export market were over $1,000 per metric ton. However, average prices have decreased during the years as higher volumes of fruit have been traded and new exporters have entered into the business. The average world price per metric ton during 1997 was $980 down 11% since 1988, while export volumes increased 135% over the same period of time, Figure 4.3.

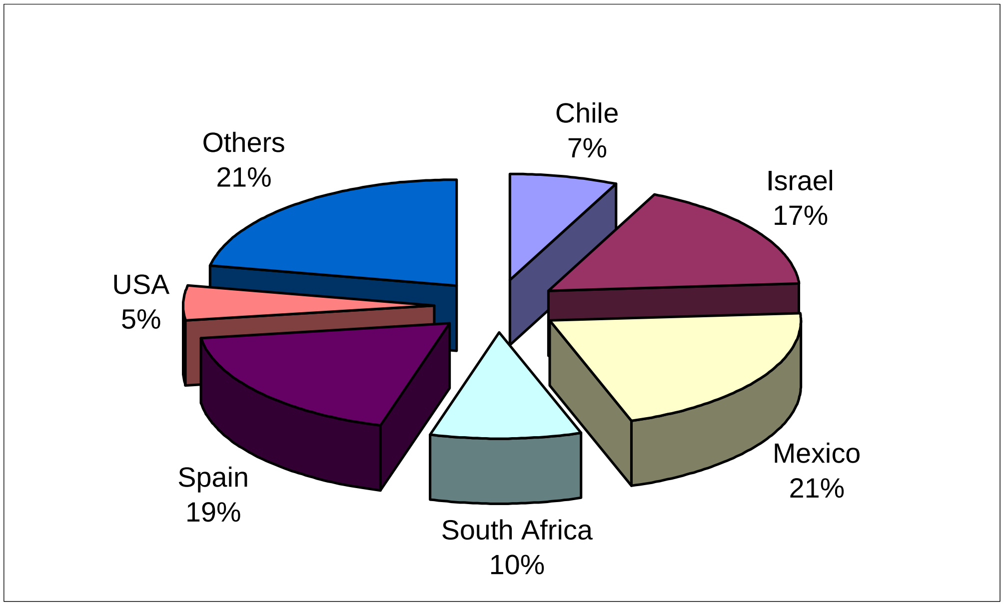


Source: FAO, 1999 Databases

Figure 4. 3. World Export Volumes and Value in Dollars per Mt.

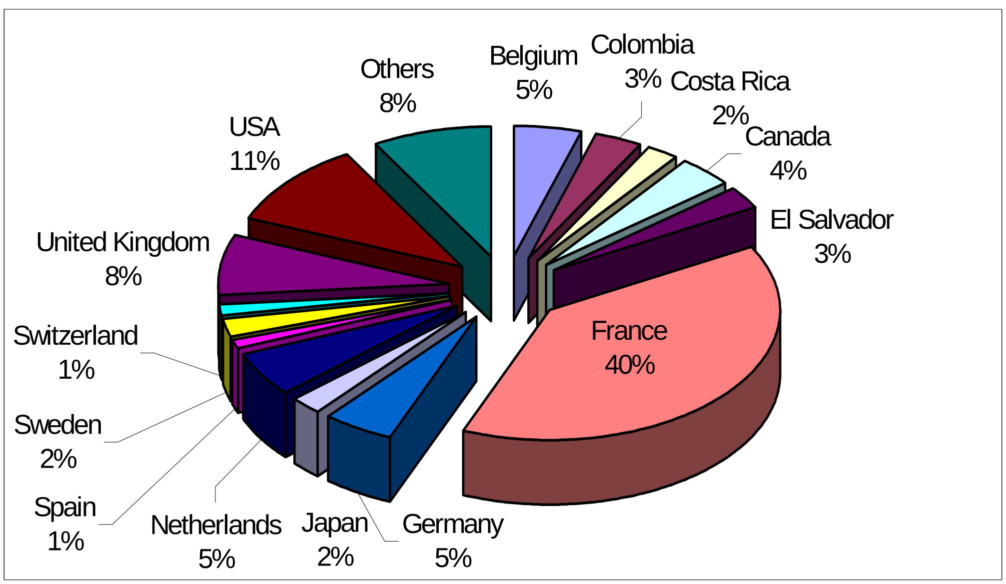
Much of the increase in export volumes, though, has been limited primarily to increases in demand from the United States and European markets. Japan has recently entered the avocado market as an importer, but this is the only Asian country which has yet started a regular demand for the fruit. Chile, Israel, Mexico, South Africa, Spain and the USA were the main exporters of avocado in 1997, (Figure 4.4) while the main importers of this fruit were in Europe: Belgium, France, The Netherlands, Sweden, Switzerland, the

United Kingdom, Germany and Spain, and in America: the USA, Canada, Costa Rica, El Salvador and Colombia and in Asia, Japan has emerged as a strong market since 1995, (Figure 4.5). From the figures it is noticeable that there are only a few suppliers but various buyers of avocados.



Source: FAO, 1999 Databases

Figure 4. 4. Main Avocado Exporters for 1997



Source: FAO, 1999 Databases

Figure 4. 5. Main Avocado Importers for 1997

When analysing Figures 4.2 and 4.4 it can be confirmed that although some countries are characterised by their large production, they are not always those which are known as the main exporters of avocados. This is the case for Mexico, Indonesia, Brazil and the United States. There are two main reasons for this: either they have not developed a product which meets all export quality requirements, which is the case for Indonesia and Brazil, or they show large consumption of the produce in the domestic market, thus leaving only small quantities to be exported, as occurs in the US, Mexico falls in both of these categories. Therefore, the largest producer is not always the largest supplier of avocados to the world market. Interestingly, international trade from 1993 to 1997 was led by South Africa, Israel and Spain even though their combined annual production is still only 24% that of Mexico.

4.2.1 The European Market of Avocados

Total imports in Europe according to country of destination, increased at an average of 11% per annum from 1988 to 1992 (Table 4.2). In 1992 European market analysts forecast that future total avocado imports to Europe would increase 23% from 1992 to 1998 reaching 167,000 tonnes (Market Asia, 1995). However current statistical information (FAO, 1999) indicates that 174,885 tonnes of avocados entered Europe during 1997, a 31% increase over 1992. If it is considered that the total world trade of avocados increased 43% from 1992 to 1997 then it may be concluded that the majority of the world export avocados are traded in Europe where France, the UK, the Netherlands and Germany are the top four avocado importers in this market.

France is the largest importer of avocados. In 1992, 64% of total imports of avocados to Europe were traded in France. However in 1997 France imported only 57% of European avocados. This, does not mean that there was a reduced consumption of avocados in France; rather, it means that an increase in the consumption of avocados occurred in other European countries.

Per capita consumption in France is 1.1 kilogram followed by Spain with 0.42 kg, UK 0.41 kg, Netherlands 0.2 kg and Germany 0.15 kg.

Table 4. 2. European Imports of Avocados by Main Country of Destination.

Country	1992	1993	1994	1995	1996	1997
France	84,661	72,781	78,677	86,353	100,524	99,857
UK	15,985	14,041	15,259	12,277	16,752	19,581
Germany	10,012	7,963	9,863	11,235	15,602	12,718
Netherlands	7,957	9,138	11,695	12,564	11,419	13,771
Italy	1,283	1,716	2,152	1,617	1,746	1,798
Denmark	2,768	2,368	1,968	1,562	2,554	2,579
Belgium	2,333	2,579	3,583	16,394	16,673	11,733
Others	8,262	7,095	8,473	5,750	7,165	7,184
Total	**133,261**	**117,681**	**131,670**	**152,193**	**178,393**	**174,885**

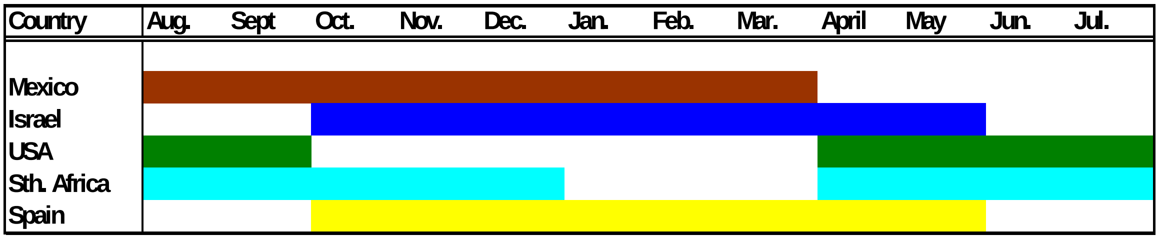
Source: FAO, 1999 Databases.

Consumer preference in France is for the dark skin cultivar Hass of average size (count 20 avocados per tray). France re-exports some avocados to Germany and the UK (Galinsky, 1995; van Zyl and Ferreira,1995).

Approximately 11% of avocados imported into Europe are traded in the UK. In this country, as in the other European importers of avocados, green-skinned cultivars of large to medium size fruit (count 16 per tray) are preferred. However, traders have reported that demand for Hass has risen recently.

Further increases in per capita consumption of avocados are expected in most of the European importing countries. For instance, the Netherlands increased its import volumes of avocados by 70% from 1992 to 1997. Belgium also represents an important market for avocados as it has shown a large increase in imported volumes from 2,333 tonnes in 1992 to 11,733 tonnes in 1997. The main suppliers of the European market are Spain, Israel, South Africa, the U.S, and Mexico, where seasons in Spain, Israel and Mexico to a very great extent, overlap. (Table 4.3). Other smaller suppliers are Kenya and Dominican Republic, (Market Asia, 1995; Galinsky, 1995).

Table 4. 3. Months of Supply and Country Suppliers of Avocados to Europe



Source: Market Asia, 1995

4.2.1.1 Marketing Channels

Generally avocados reach the consumer through supermarket chain stores. Such stores constitute the main outlet of avocados in Europe, as they trade 60% of the produce. Although wholesalers are also an important factor in the marketing chain, they do not control as much of the fresh produce as supermarkets do (Market Asia, 1995).

Supermarkets in the U.K. have begun promotional efforts to increase the consumption of avocados, and especially to encourage the change from Hass to Fuerte.

4.2.2 The Asian Market for Avocados

4.2.2.1 Japan

Japan, the most westernised of all Asian countries, is emerging as an important market for avocados. As Japan does not produce avocados, its consumption depends entirely on imports. This country is the only Asian nation that imports large volumes of avocados, and since avocados were introduced in Japan in the 1980s, the internal consumption of avocados has gradually increased. Japan’s imports of avocados have risen almost 70% from 3553 tonnes in 1992 to 6,040 tonnes worth US$13.5 million in 1997 (Table 4.4).

Many exporters regard Japan as a high quality market with very strict phytosanitary regulations. Avocados are supplied year round into Japan, where they are considered an exotic fruit which receives premium prices. Only the Hass cultivar of large size is traded in Japan, as large size is associated with high quality.

Table 4. 4. Imports of Fresh Avocados into Japan.

Year	Imports Volume by Country of Origin		Imports Value ($1000)
	USA	MEXICO	
1992	2,160	1,399	7,751
1993	3,185	1,388	7,537
1994	2,443	1,298	9,528
1995	1,803	2,922	10,620
1996	2,609	3,846	14,318
1997	1,624	4,415	13,545

Source: GAIN/Japan, 1998; FAO, 1999 Databases.

Historically, the United States has been the main supplier of avocados to the Japanese market; however now the United States and Mexico are their only suppliers. United States and Mexican avocados used not to compete in the Japanese market in the same season; Mexican avocados used to arrive in large amounts from September to December, while U.S avocados used to arrive from February to September. However, now the Mexican avocado season is extending and overlapping with the U.S. season, especially from January to March and in August.

Avocados imported to Japan from the United States and other industrialised World Trade Organisation Members (WTO) face a 4% *ad-valorem* tariff (on a CIF basis). Mexico is favoured under the General System of Preferences (GSP), the aim of which is to provide duty-free treatment for eligible items imported from certain developing countries. Mexico is favoured with a 3% import *ad-valorem* duty compared to 4% for the U.S. In addition, favourable exchange rates of the dollar against the yen had helped U.S. importers before the Mexican devaluation of the peso. Devaluation of the Mexican currency helped increase imports of avocados to Japan. Thus, U.S produce usually faces stiff competition from Mexico. Nevertheless, U.S avocados are regarded as being higher quality produce than those from Mexico and thus, receive much higher prices (Market Asia, 1995;Van Zyl and Ferreira, 1995; FAO, 1999) (Table 4.5)

Nevertheless, due to the improving quality of Mexican avocados, which now equals that of U.S produce, Japanese traders expect the Mexican market share to increase in the next few years. Market sources expect record sales of 8,100 tonnes for the 1999 season. Year round availability, together with competitive prices for Mexican avocados, have made them the preference of traders in Japan. The CIF price of Mexican avocados averaged $2.19 per kilo in 1998, while the U.S. price product averaged $3.58 per kilo.

The California Avocado Commission has a marketing programme demonstrating how to use avocados in Tokyo's supermarkets in Harajuku, a fashionable district in Tokyo (GAIN/Japan, 1998). The focus is on the education of the Japanese consumer and local handlers in the health benefits of avocados, when to deliver, eat and how to use them.

Table 4. 5. Japanese Import Prices (CIF) of Fresh Avocados by Month

Month	*Price 1997 (Yen/kg)		*Price 1998 (Yen/kg)	
	US.	MEXICO	U.S	MEXICO
Jan.	-	193	-	239
Feb.	-	216	-	227
Mar	344	254	519	234
Apr.	348	278	624	245
May	348	280	311	265
Jun.	347	265	418	282
July	340	243	481	303
Aug.	460	264	-	314
Sept.	-	259	-	290
Oct.	-	239	-	250
Nov.	-	221		na
Dec.	-	225		na

*Average monthly CIF prices, na = not available. Source: Customs Bureau, Japanese Ministry of Finance (MOF), 1998; GAIN/Japan, 1998.

Now the timing of the avocado marketing campaign is a matter of concern to the U.S industry as a considerable amount of Mexican avocados are overlapping with the U.S season's supply (GAIN/Japan, 1998). This means that the US. industry marketing efforts in Japan could also be encouraging the consumption of Mexican avocados.

4.2.2.1.1 Marketing Channels

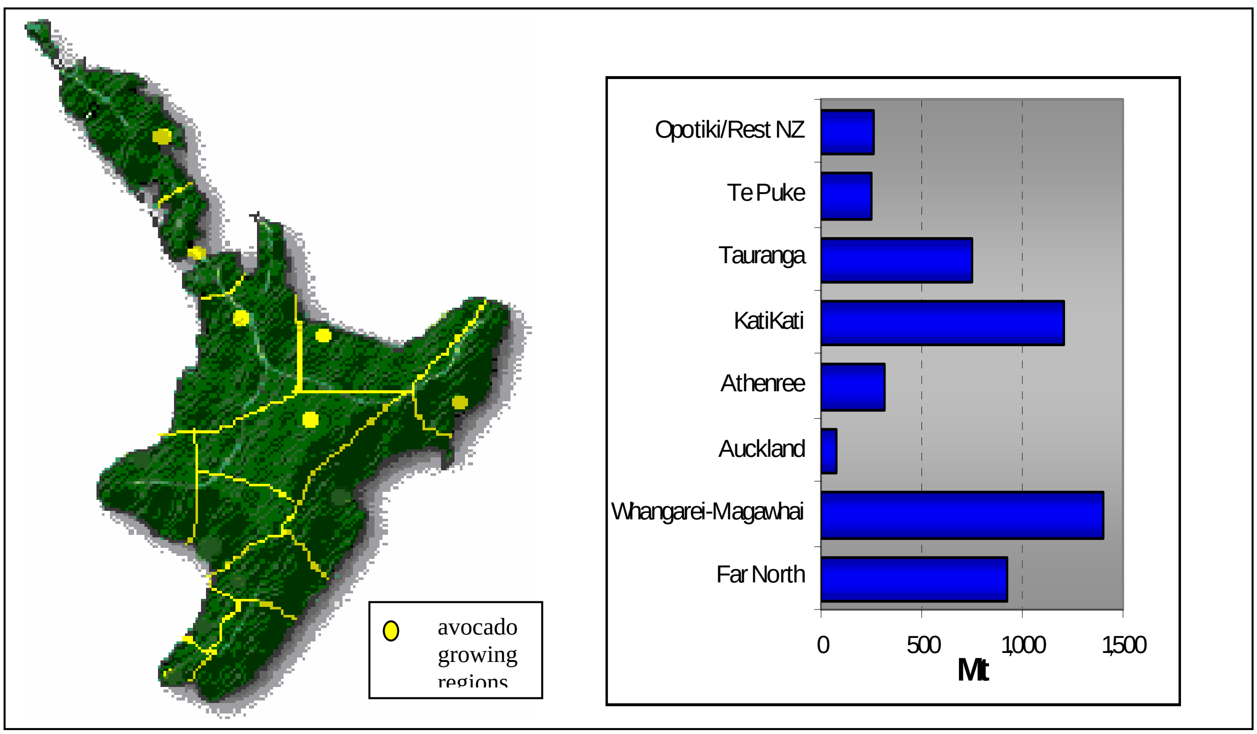
Avocados in Japan are sold mainly through retail outlets for home consumption, while a small percentage (20%) is consumed in restaurants and hotels. Tokyo, Osaka and Nagoya are the major cities of consumption of avocados. Tokyo traders report that the potential for growth in avocado consumption is significant, but that awareness of avocados remains comparatively low in regional markets (GAIN/Japan, 1998). In general, the consumption of fresh avocado has been increasing gradually since the fruit was introduced into Japan (FAS, 1999).

4.2.2.1.2 Future Trends

Japan's total imports of fruits during 1998 amounted to 2,355,719 metric tonnes, worth U$2,889,508 (350,873 million yens), twenty percent more than in 1997 (MOF, 1998). Currently Hass is the only variety sold in Japan. Total avocado sales in 1997 were 6,000 tonnes and are expected to increase 35% to 8,100 tonnes in 1999. Increasing awareness of the nutritional benefits of foods is likely to raise the consumption of fruits (FAS, 1999).

4.3. The New Zealand Avocado Industry

The avocado industry in New Zealand is currently undergoing a steady expansion. Avocados are mainly cultivated in the North Island of New Zealand specifically in the Bay of Plenty and Northland areas. There are seven producing regions: The Far North, Whangarei-Mangawhai, Auckland, Katikati, Tauranga, Te Puke, and Opotiki. The largest producing areas are Tauranga in the Bay of Plenty and Whangarei in Northland (Figure 4.6). In the last two seasons Whangarei production has surpassed that of Tauranga and today this region is one of the major suppliers of this fruit. Rainfall in the growing regions is fairly consistent at around 1,500mm to 2,000mm spread throughout the year (Bailey, 1994).



Source: NZ Avocado Growers Association, 1998; Barber and Lyford, 1998
Figure 4. 6. Main Avocado Growing Regions and Production in 1997/98 in New Zealand.

The actual area planted has increased rapidly. During 1995-1996, 30,000 new avocado trees were planted, increasing the planted area by 100 ha. From approximately 1,000 ha in 1993, there were 1,221 hectares planted in avocados in 1998 (Barber and Lyford, 1998). Currently there are 141,667 trees planted and 701 registered growers (Bailey, 1994; Barber and Lyford, 1998). Almost 40% (472 ha) of plantings are less than 10 years of age, which means that they have not reached full maturity, leaving potential for further increases in production. Traditionally 4 regions in the Bay of Plenty have had the largest percentage of mature trees in New Zealand as, in this district about 60% of the avocado area is planted with trees older than 10-years. However, the majority of recent plantations with trees under 6 years of age are concentrated in 3 regions, the Far North, Whangarei and Auckland (Table 4.6).

The average national yield for 1998 was 7.6 tonnes per hectare, up from 6.3 in 1997 (Avo News, 1999). However, yields as high as 20 tonnes per hectare can be obtained from well managed trees (Cutting, 1999, personal communication).

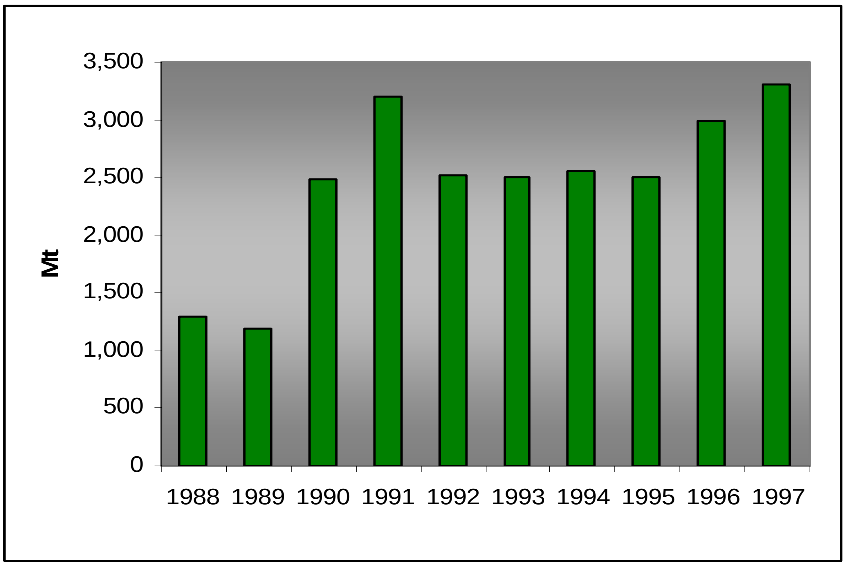
Table 4. 6. Avocado Areas and Tree Plantings

Region	**Areas (ha)**		
	Age 0-5	**Age 6 +**	**Age 10+**
Far North	21	85	71
Whangarei	48	46	162
Auckland	6	12	22
Athenree	32	18	31
Katikati	41	36	183
Tauranga	31	41	154
Te Puke	11	18	82
Opotiki/rest NZ	5	21	44
Total	195	277	749
TOTAL	**1221 ha.**		

Source: Barber and Lyford, 1998.

Avocado trees continue to be widely planted in New Zealand and with the entrance of new growers the orchard area will continue to increase in the future (Barber and Lyford, 1998). The New Zealand avocado Industry is based on the Hass cultivar with approximately 80% of the total planted area being planted with this cultivar. Other cultivars such as Fuerte, Reed and Zutano are used primarily as pollinators for Hass. The picking season for Hass is between August and April and fruit is harvested when it has reached at least 26% dry matter content.

New Zealand avocado production has increased by 150% over the past 10 years, (Figure 4.7). Since 1995 national avocado production has grown at an average annual rate of 15%. Due to the young age of the trees and the increasing number of avocado trees planted every year, this rate is expected to increase in the next 5 years. Industry sources have estimated that production values will reach 18,000 tonnes in the year 2005 (New Zealand Fruit Industry, 1998).



Source: FAO, 1999 Databases.
Figure 4. 7. New Zealand Avocado Production

As in other producer countries, avocado yields are affected by climatic changes therefore accurate predictions of production are almost impossible. This is especially true for avocado as it is a subtropical fruit very sensitive to extreme weather conditions.

In the 1998 season it was predicted that a long dry summer would adversely affect the crop. In addition, other climate factors, such as strong winds or hail, were predicted to also affect final crop yield causing fruit drop and injury that can reduce the amounts and quality of fruit (Barber and Lyford, 1998). However, as the season progressed through January it was estimated that the 1998 crop would be bigger than predicted, as unexpectedly favourable summer and spring conditions produced heavy fruit set and continued fruit sizing (Avo News, 1999).

4.3.1 New Zealand Avocado Industry Structure

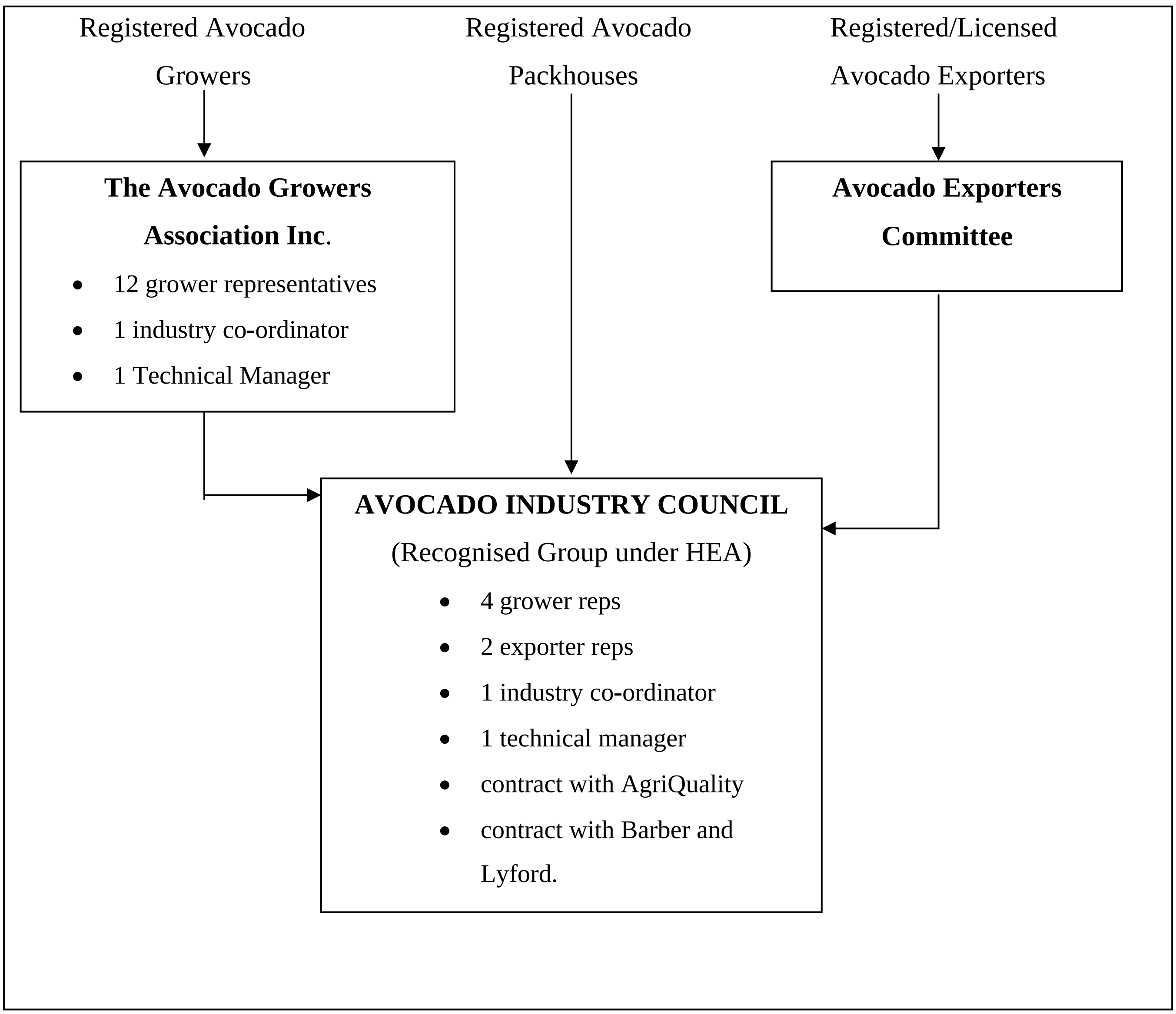
Growers are associated with the New Zealand Avocado Growers Association Inc (NZAGA) and the Avocado Industry Council (AIC) Ltd.
The Growers' Association deals with political issues and local market issues. Funding of the NZAGA is by way of a commodity levy on local fruit set at 3% at first point of sale. Research, promotion and administration of the Association are funded out of this levy as well.

The Avocado Industry Council (originally called the Export Council) meets 4 or 5 times a year. It licenses exporters and pack- houses and is a recognised Product Group under the Horticulture Export Authority, (Figure 4.8). The Industry Council implements quality standards, export grade standards and rules and procedures that must be followed by growers, packhouses and exporters. These are well documented in the Avocado Quality Manual and the Avocado Export Marketing Strategy. The AIC is funded by an export management fee, which is paid on a per tray basis at a rate of 10 cents per 5.5 kg. export tray by the exporter, and 50 cents per export tray paid by the grower. This contribution is collected by the exporter and sent to the Industry Council every month. The AIC management fee pays for the following activities:

- Management,
- Administrative activities,
- Maintaining and managing the research programme,

- Providing a quality management programme for the benefit of all growers of avocados,
- Market access,
- Management of the AIC Pre-clearance programme to Australia, and
- Pursuing the industry objectives as set out in the Export Marketing Strategies.

The AGA is an incorporated society, totally separate from the Industry Council, although both meet and work together for the entire industry (AIC, 1999).



Source: New Zealand Avocado Industry Council, 1999.

Figure 4. 8. New Zealand Avocado Industry Structure

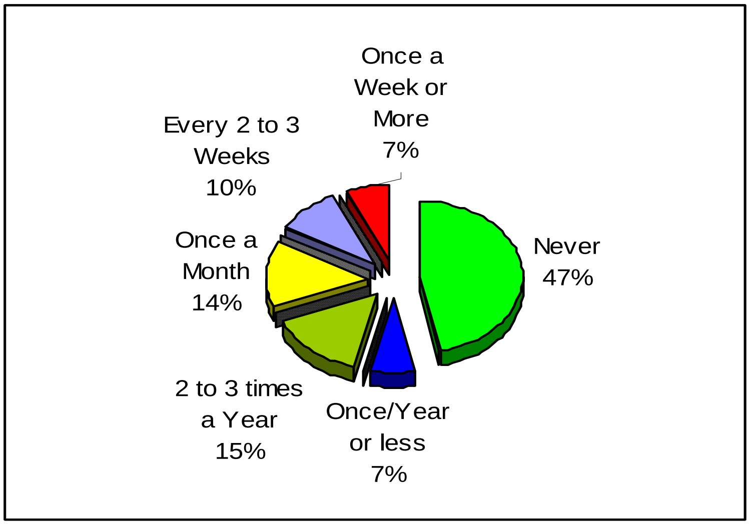
It is of industry concern that, with the contemplated increases in production this industry structure may become inefficient. Therefore the Council is considering the possibility of employing a management consultant to see if this is the best structure to face future challenges (Avo News, 1999).

4.3.2 Local and Export Markets

Although avocados are successfully produced in New Zealand they are not consumed in large quantities. The annual consumption per capita is about 0.5-0.7 kg (Cork, 1999 personal communication) which is low compared to 9 kg in Mexico and almost 1 kg in the USA.

As in the case of South Africa and Israel, the avocado industry in New Zealand is export driven and generally, the local market is supplied with produce that is not suitable to export. This is reflected in the poor consistency of quality and produce size found in retail outlets. Nevertheless some retailers and supermarket chains have requirements of the produce needed for their business. For instance there is specific demand for pre-ripened avocados by some supermarket chains (Cork, 1999 personal communication). During the 1998 season around 1,960 tonnes of avocados were forecast to be sold in the local market i.e. 38% of the total production (Barber and Lyford, 1998). Returns to growers for local market fruit is low, remaining constant during 1998 at $0.4/tray (Gush, 1998 personal communication).

At present the industry's aim is to increase domestic consumption in line with expected production increases. For this reason intensive consumer research is being undertaken in order to identify consumer purchase habits and barriers towards avocados. Recent research shows that nearly half of New Zealanders (47%) never buy avocados, while less than a third buy them once a month or more and only 7% buy avocados once a week or more (QZONE, 1998), (Figure 4.9). Therefore there is significant potential to increase purchase frequency of avocados.



Source: QZONE report to the NZ Avocado Growers Association, 1998.

Figure 4. 9. Purchase Frequency of Avocados in New Zealand

Moreover, local market research identified the main barriers to increasing avocado consumption in New Zealand as: lack of familiarity with avocados, ripeness of the fruit i.e. knowing how to select the ideal avocado, and quality of the fruit.

In New Zealand avocados are perceived as being an “indulgent” and extravagant food, and most people are unable to associate nutritional benefits with avocados. Interestingly, New Zealand consumers are interested in new and innovative products. Moreover, among them there is an increase in health consciousness, which is making them more aware of the nutritional value of foods (USDA, 1994). Thus, it seems necessary to communicate the message about the nutritional value of avocados in order to increase local market sales.

In addition, New Zealanders generally perceive the avocado as a “difficult fruit” as it is hard to find an ideal one, they are often messy to use, they seem limited in their use, they go off quickly and seem fattening (QZONE, 1998).

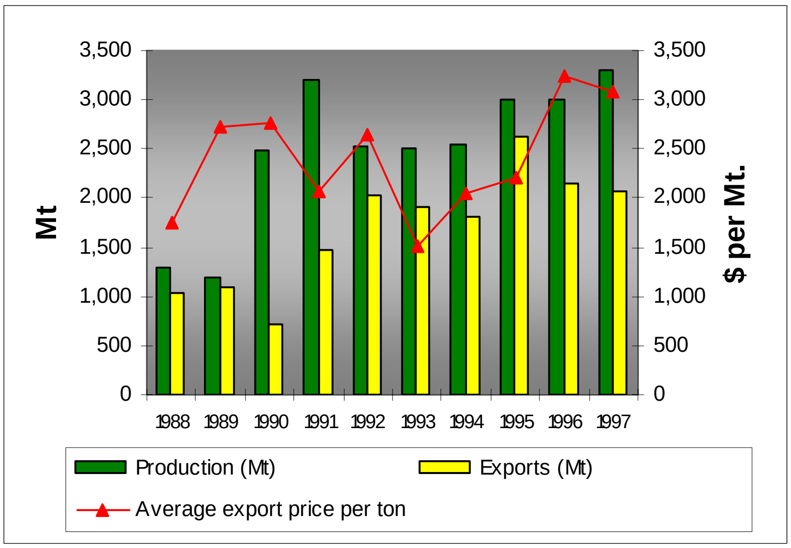
Because of these identified factors, the marketing plan developed for the domestic market involves educating consumers as to the proper way to handle avocados, in order to overcome barriers to purchase increasing the size of the avocado market.

However, educating the consumer alone will not increase sales. Price is also a barrier to sales and higher frequency of purchase of avocados. In this respect, the retailer also plays an important role in the marketing chain. High retail prices for avocados might be a consequence of the high perishability of the product, which involves the risk of losses to the retailer. Thus, the marketing mix involves training programmes directed for the handlers of avocados in grocery shops and supermarkets (Cork, 1999 personal communication). For instance, temperature management programmes are being introduced (unripe avocados should not be stored under 6ºC) to avoid internal and external chilling injuries that are detrimental to the final quality of the fruit. However once the fruit have reached full ripeness they can be best stored at temperatures just above freezing without suffering chilling injury (Arpaia et al., 1992).

Retailers and handlers should have ongoing training so as to be able to identify ripening stages of the fruit to ensure that they can be sold before they have deteriorated too far. Better handling would result in a reduction of fruit loses. In addition, the expected abundance of produce that will occur as production increases might lower market prices, making avocados more affordable and popular among New Zealand consumers.

Statistical information shows that New Zealand exported approximately 86% of its total production of avocados during 1995 and about 63% during 1997 (Barber and Lyford, 1998, FAO Databases, 1999) (Figure 4.10). This indicates that the industry is mainly export driven. For instance, since 1994, exports have increased almost 100% from 328,779 trays (5.5 kg/tray) to 600,080 trays in 1997. Increasing volumes reflected increases in the value of exports as well. Export prices paid per metric ton have increased steadily from $1,748/Mt. in 1988 to $3,090/Mt. in 1997. In 1997 the avocado industry was worth around $10 million per year (Fruit Research Council of New Zealand, 1997) however industry sources reported that the value of the avocado industry has doubled in 1998.

The export return to growers remained fairly constant during 1998 at about $1NZ per tray (Gush, 1998 personal communication). Export volumes have been estimated to reach 880,000 trays for the 1999 season (4,840 tonnes) more than double the amount since 1994/95 (Avo News, 1999).



Source: FAO, 1999 Databases

Figure 4. 10. New Zealand Avocado Production, Export Volume and Average Value.

New Zealand's main export markets are Australia and (recently) the United States; while only small and inconsistent amounts of produce are exported to other countries (Table. 4.7).

Traditionally, New Zealand exported almost 95% of its total exports of avocado to Australia; to New South Wales, Queensland, Victoria, South Australia and Western Australia. The risks of a high reliance on one single market led the industry to form the Avocado Export Council in 1989 (Bailey, 1994); this was later called the Avocado Industry Council. This organisation has enabled the industry to concentrate efforts on development of export strategies and new markets.

It is predicted that actual Australian market dominance by New Zealand will be reduced in the future due to a constant increase in Australian domestic avocado production. New

Zealand supplies to the Australian market over a short window from December to February and occasionally in March. New Zealand supplies to the Australian market during February had been the subject of quality problems during 1999. The main reasons were probably the advanced stage of maturity of fruit that translated into rapid ripening, thus reducing the shelf life of the fruit. The New Zealand Avocado Industry Council has planned an avocado promotional programme in Australia for 1999 to reinforce the position of the New Zealand fruit (Avo News, 1999). During 1998 New Zealand exports to Australia were 4,180 tonnes an increase of just over 100% respecting 1997 (AIC, 1999).

Table 4. 7. New Zealand Export by Country of Destination

Country of Destination	Exports (Mt)			
	1994	**1995**	**1996**	**1997**
Australia	1,809	1,764	2,499	2,068
Fiji	2.2	3.91	0.2	0.02
Hong Kong	36.2	1.72	26.5	8.5
Japan	3.6	-	14.2	-
Korea	0.6	6.61	8.9	0.08
Malaysia	1.47	-	-	-
New Caledonia	6.1	5.1	1.6	0.9
Singapore	42.6	23.4	5.2	3.2
Taiwan	0.15	-	-	0.3
USA	0.71	2.51	73.9	67.9
Others	0.4	0.9	0.6	0.3
Total	1,903	1,808	2,630	2,149

Source: Statistics New Zealand, 1997

Although the US. is one of the world's largest producers of avocados it also consumes large quantities of this fruit. The large population and ethnic diversity of the US. have caused it to be identified as the market with the most potential for New Zealand avocados.

At the beginning when exploring the possibility of exporting New Zealand avocados to the U.S. there were various concerns. For instance, could the produce quality be maintained during the 19-day sea freight journey from Auckland to Los Angeles?. The solution to this concern was to export avocados using controlled atmosphere technology. This technology involves carefully regulating the atmosphere of fruit and vegetables to retard the ripening process and thus extend the products' shelf life.

Additionally, pricing was also a concern for New Zealand growers. The long journey meant that the market would have more time to fluctuate and, because New Zealand was practically unknown, U.S. traders would not set prices three weeks in advance (Carrol, 1998). This situation changed over the seasons as New Zealand avocados have become well known in the US. and are regarded as quality fruit; thus traders are comfortable with the importing and have reliance on New Zealand fruit. In 1994, New Zealand exported less than a metric ton to the United States but this increased to almost 68 tonnes in 1997 and 379 tonnes in 1998 (AIC, 1999). Today, the U.S. has become an important market of destination for New Zealand avocados since 1996 (Table 4.7).

The large Hass avocado production in the US. has caused the U.S consumer to develop a taste for this cultivar. In New Zealand, as in the US., the main cultivated variety is Hass. California's harvest season for Hass is from April to August, whereas in New Zealand it is from August to April. This gives New Zealand a window to supply the U.S market during October to November i.e. during California's off- season.

The traditional supplier of the U.S. market has been Chile, which is therefore, New Zealand's main competitor. For instance during 1997, 57% of U.S. imports of avocados came from this country. However, Chilean fruit is, in general terms, smaller than New Zealand fruit (Wolf, 1999 personal communication) which represents an advantage to New Zealand. In addition, Chile is trying to export its avocados before November so as not to overlap with New Zealand's exports. While the opening of the US. market to Mexican produce increases competition which could cause prices to drop, this might affect only suppliers to that same north-eastern region of the United States. However, international pressure claiming for a free trade world (such as the North America Free Trade Agreement: “NAFTA”) could result in the future entrance of Mexican produce to all the US. territory.

4.3.2.1 Marketing Channels

In New Zealand avocados are commonly sold through the wholesaler to Fruit and Vegetable shops, and from supermarkets to a lesser extent (Avo News, 1999). In order to increase internal consumption, promotional campaigns are frequently undertaken. Usually, in-store demonstrations, participation in food expo-shows and fairs, and advertising (e.g. in supermarket trolleys) are the main tools used to market avocados. The principal objective is to familiarise the consumer with avocados (Cork, 1999 personal communication).

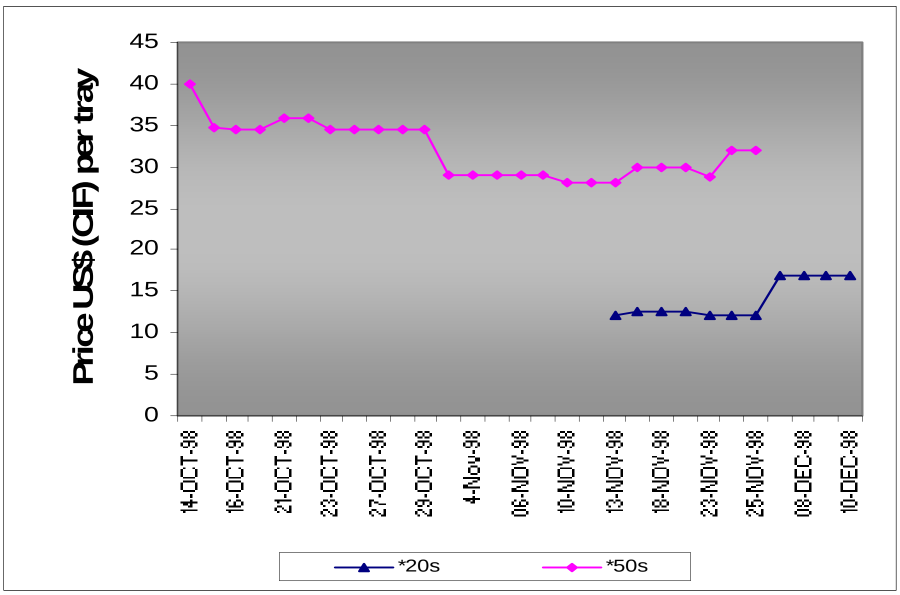
All New Zealand exporters sell avocados to importers in the main centres of consumption: in Australia: Sydney, Melbourne, Brisbane, Adelaide and Perth. From the importer, two situations could happen; either the fruit is sent directly to the retailer (i.e. supermarkets or vegetable shops), or it is sent to various market wholesalers, who usually specialise on the market of a particular fruit. Generally, New Zealand importers send the fruit to people who also wholesale kiwifruit (perhaps due to either fruit similarities i.e. both kiwifruit and avocados need to be pre ripened, or due to pre- established relationships as avocado growers are often kiwifruit growers) (Cork, 1999 personal communication).

4.3.3 Market Prices

New Zealand exports fruit to California in the U.S., where the main ports of destination are Los Angeles and San Francisco. Prices fluctuate according to the volume of fruit imported into the country. New Zealand exports to the US. mostly count 20s, i.e. trays of 5.5 kg of 20 avocados per tray, which are exported from November to December, and 50s, i.e. trays of 5.5 kg of 50 avocados per tray, which are exported from October to

November. During 1998, count 20s prices fluctuated from about US$12 to 17, while count 50s ranged from about US$40 to 26 (CIF) (Figure 4.11).

Chile is New Zealand's main competitor in the US. market as their harvest season occurs at the same time of the year (October and November). A drop in prices during October and November reflects the entrance of Chilean produce, which creates an oversupply in the market.



*20s = tray containing 20 fruit ; 50s = tray containing 50 fruit. Source: Today's Market Prices, 1999

Figure 4. 11. Prices of Imported New Zealand Fruit in, USA- San Francisco.

4.3.4 Future Trends

Large increases in production are expected over the next few years. Crop estimates indicate that 5 million trays (5.5 kg./tray) may be produced in the year 2010 (Table 4.8). Even though most fruit will be destined for export, the local market will also receive large volumes of fruit. Therefore local market strengthening is crucial.

Apparently due to their unfamiliarity with the fruit, i.e. how to choose a good avocado, many consumers have suffered disappointment. Restoring their confidence may be a very difficult marketing task. In order to encourage and increase consumption the consumer should be presented with a product of excellent quality.

Usually avocados should be ethylene treated (pre-ripened) in order to accelerate the ripening process, and to ensure that a higher percentage of fruit will ripen evenly and to a better final quality than fruit which has not been pre-ripened. A few supermarkets demand only pre-ripened avocados, but others purchase non treated fruit because of cheaper prices. This is detrimental to the industry. Treatment of the fruit is important because it will deliver better quality fruit to the consumer, and will assist the retailer in better handling, as the fruit will ripen more uniformly. The New Zealand avocado industry as a union, should institute regulations for the sale of only pre-ripened avocados in order to deliver standard quality avocados and protect the consumers. If it is handled under the correct conditions, the consumer will receive quality produce, which will result in repeated, and perhaps more frequent, purchase of avocados.

New Zealand’s first projections indicate that it could continue to supply the Australian market for approximately five more years at which time Australian national production would be self sufficient to cover its own domestic demand (Cork, 1999 personal communication).

Meanwhile, the industry is looking to increase sales to the US. As part of the industry vision, New Zealand is aiming to produce and export larger avocados than Chile to the US. market (Cork, 1999 personal communication) in order to obtain differentiation.

Table 4. 8. Crop Estimates and Projected Industry Growth

Production	2001	2005	2010
Number Mature trees[1]	930	1,345	2,205
Number bearing [2]	413	860	1,000
Not bearing trees[3]	710	1,000	n.e
Production (tonnes)	14,300	18,000	22,000
Export ($million FOB)	n.a	20.0	25.0
Domestic ($million)	n.a	10.0	12.0
Total Industry Value ($million)	-	30.0	37.0

Crop Estimates Industry Sources, 1998. [1]more than 10 years of age; [2] Not mature between 6-10 years; [3] under 6 years of age; n.a= not available; n.e = not estimated. Source: New Zealand Fruit Industry- An investment in the Future-1998.

A question arises as in the future, Mexican, or perhaps US. Produce, could be exported into New Zealand. Industry sources commented that this possibility is unlikely in the short term (next 2-3 years) (Cutting, 1999 personal communication) presumably because New Zealand consumption is currently low to justify export costs. However, in the long-term import produce might be seen in New Zealand market (Cutting, 1999 personal communication).

In addition to continuing the expansion of the U.S market, New Zealand is seeking to develop new export markets that could absorb the increasing production volumes. Although New Zealand already exports small amounts of fruit to Asian countries, the industry is very interested in the development of strategies to increase sales in Singapore, Hong Kong, Korea, Taiwan and Japan (Bailey, 1994).

4.3.4.1 Industry Vision and Key Success Factors

The industry vision for 2006 is that "The New Zealand Avocado Industry will be the premium supplier of large, good looking, environmentally friendly avocados that taste great, to selected markets segments in the Pacific Rim".

The industry is considered as well co-ordinated and efficient. It is steadily expanding and is committed to strategic planning. The key success factors, threats and industry opportunities identified are mentioned below (New Zealand Fruit Growers Federation, 1998)

4.3.4.1.1 Key Success Factors

- Efficient and sustainable production
- Product innovation intensive research to get differentiation in the market place
- Trade access

4.3.4.1.2 Industry Threats

- Increase in summer production of avocados in Australia
- Increase "quarantine risks" if new pests established in New Zealand.
- Access to Australian market by other large scale producers in the summer period.
- Access of other suppliers into the U.S market.

4.3.4.1.3 Opportunities

- Raise yields to 20 tonnes /ha
- Reduce postharvest rots and ripening problems
- Increase exports to USA and develop Asian markets.
- Improvement of Quality Assurance Programs.
- Improved export marketing and marketer co-operation.

- Expand the consumption of avocados in New Zealand

The alternative of an avocado processing industry has not yet been considered by the New Zealand avocado industry. It is presumed that this option might be considered soon, as more and more avocados become available to supply a processing industry.

Table 4. 1Table 4. 2Table 4. 3Table 4. 4Table 4. 5Table 4. 6Table 4. 7Table 4. 8

Figure 4. 1Figure 4. 2Figure 4. 3Figure 4. 4Figure 4. 5Figure 4. 6Figure 4. 7Figure 4. 8Figure 4. 9Figure 4. 10Figure 4. 11

4.4. The Mexican Avocado Industry

Mexico is by far the world's largest producer of avocados. In 1998 Mexican production accounted for 39% of the world production, (Table 4.10). National avocado production has increased from almost 400,000 tonnes in 1987 to an average of over 700,000 tonnes since the 1990s, (Figure 4.12). Production has remained fairly constant since 1991, but the opening of the US. market in 1997 is encouraging more production of avocados towards future years.

Avocado orchards in Mexico have expanded all over the country in the form of either family or commercial orchards. Production is concentrated in the state of Michoacan, which accounts for 72 percent of the entire national production (San Agustin, 1995). The major cultivar produced is Hass, accounting for 80 to 90 % of the total production. Michoacan State produces more avocados per year than California and Florida combined (Ramirez, 1995).

The planted and harvested area for 1999 season are estimated to increase because of smaller growers returning to their orchards and additional trees coming into production. Favourable weather and new market export opportunities also are encouraging more and more growers to enter the industry. For instance, in 1996/97, 85% of the planted area was harvested and yielded approximately 8 tonnes of fruit per hectare (Table 4.9). The majority of the trees in Michoacan are under 10 years of age, which leaves potential for expanding production (FAS, 1998a). The actual average yield in Michoacan is 10 tonnes of fruit per hectare, however mature orchards can produce 15 tonnes or more.

Mexico's avocado production has increased steadily since 1993 however, the 1996/97 crop (usually referred to as the 1997 crop, harvested August 1996 through July 1997) decreased 5% to about 762,336 tonnes due to excessive rainfall, hail and low temperatures during the flowering season in Michoacan. This adverse weather caused early fruit drop, low quality fruit and lower yields.

Table 4. 9 . Mexican Avocado Area Planted, Harvested and Yield

Year	Area Planted (Ha)	Area Harvested (Ha)	Yield per Hectare (Mt)
1991/92	91,274	82,926	9.4
1992/93	98,965	87,508	8.3
1993/94	98,098	82,792	8.6
1994/95	98,130	87,200	9.2
1995/96	92,584	89,705	8.8
1996/97	98,000	83,000	7.7
1997/98*	96,000	90,000	8.9

*Forecast. Sources: U.S. Agricultural Attache Reports, 1998.

As a result, national production and harvested area decreased in 1997 in relation to the previous year's season. (FAS, 1998a).

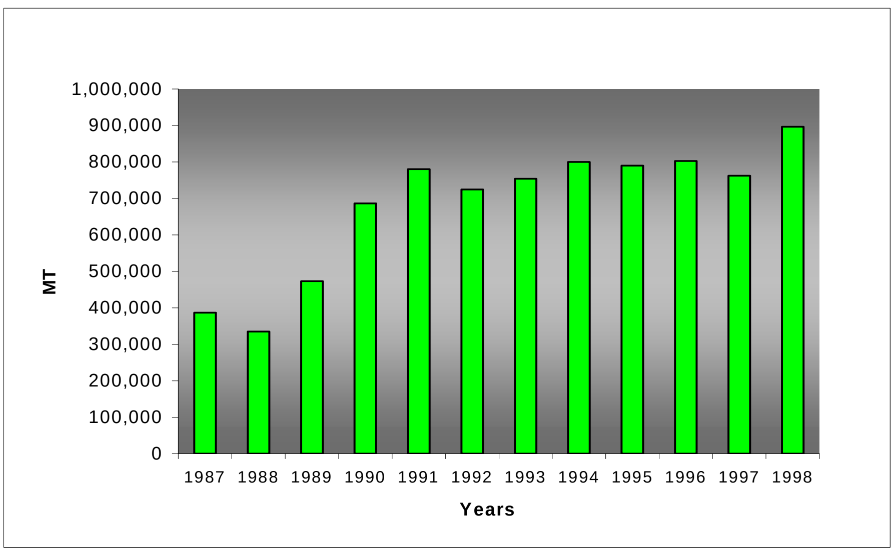
Industry analysts reported that the State of Michoacan has limited land suitable for expanding avocado cultivation. Converting marginal areas into cultivated ones would be costly (FAS, 1998a). Therefore, it is said that Michoacan has reached its maximum cultivation capacity.

For 1998, it was forecast that Mexico would produce over 800,000 metric tonnes. Early reports (not officially confirmed) indicate that production is 896,563 tonnes, almost an 18% increase from the previous year and almost 30% more than the combined production of the next eight largest producers for the same year.

Table 4. 10. Mexican Share in the World Production of Avocados

Year	Mexico (MT)	World (MT)	World Share (%)
1992	724,523	2,199,325	33
1993	709,296	2,022,443	35
1994	799,929	2,150,295	37
1995	790,097	2,160,077	36
1996	802,625	2,250,634	36
1997	762,336	2,213,848	34
1998*	896,563	2,324,788	39

*Forecast. Source: FAO, 1999 Databases and USDA Attache Reports, 1998.



*1998 data forecast. Source: FAO, 1999 Databases

Figure 4. 12. Mexican Avocado Production (Mt)

4.4.1 Mexican Avocado Industry Structure

The avocado industry in Mexico does not have a single organisation for the entire country as do those in other countries such as New Zealand or South African. Avocado orchards in Michoacan are characterised by a large number of small producers and a small number of large and medium sized producers. The majority (almost 80%) are small producers who own 10 hectares or less, while only a few producers (5%) own more than 1,000 hectares.

More than 100,000 of the 2 million residents of Michoacan are directly involved in the avocado industry (Ramirez, 1995). Avocado growers in Michoacan are organised into 16 local associations, nine co-operative societies, and a group of independent growers all belonging to the regional Agricultural Union of Michoacan State's Avocado Growers. In addition, there are many avocado growers who do not belong to this organisation (Aguilera and Salazar, 1991).

Each member of the union pays an annual fee plus a small fee per kilogram of avocados for marketing promotions. The aim of the Union is to meet their goals of working for better prices for growers and to reduce the costs of inputs (FAS, 1998a). A board of directors oversees the interests of the growers. There are no direct government support policies for avocados.

4.4.2 Local and Export Markets

The avocado industry in Mexico is approximately 4.3 times larger than that of the United States (Ramirez, 1995). Besides Michoacan, avocados are grown also in Nayarit, Puebla, Morelos and Mexico states although their production cannot compete with the volumes and quality of fruit produced in Michoacan (Bioplus, 1998). The peak harvesting season for Mexican avocados is between October and February, but they are harvested year round.

Mexico is the largest consumer of avocados too, where Distrito Federal and Monterrey cities consume almost 60 percent of the total production, followed by Torreon, Guadalajara and Aguascalientes (Aproam, 1999). A comparison between production, and both domestic and export volumes for Mexico are shown in Figure 4.13. Internal consumption is the highest in the world, being about 9 kg of avocado per capita, per year. Therefore the majority of the produce is consumed internally, and only about 8% of the production is exported every year, (Table 4.11). Internal demand for avocados includes the consumption of the fresh fruit and its use as raw material for the manufacturing industry. Domestic consumption decreased during 1996 and 1997 due to smaller harvests and high retail prices (FAS, 1998a). Consequently, the industry conducted advertising campaigns on TV, radio and in the press to increase domestic consumption. The volume of avocados consumed internally has remained fairly stable from 1991, with a tendency to decrease towards 1997.

On the other hand exports have tended to increase since 1988. Export volumes reached a maximum value during 1996, with almost 80,000 metric tonnes traded. Further increases are expected. It has been reported that less than 15 percent of recent production is judged to be of export quality (Paz-Vega 1989). Industry sources, however, indicate that 15 to 30% of its crop could be of export quality. Mexico exports to 20 countries where its largest export destination markets are France, the United Kingdom, Canada and Japan (Table 4.12). Avocado traders from Europe, South Africa and the United States have begun active involvement in Mexico's avocado exporting industry (FAS, 1998a).

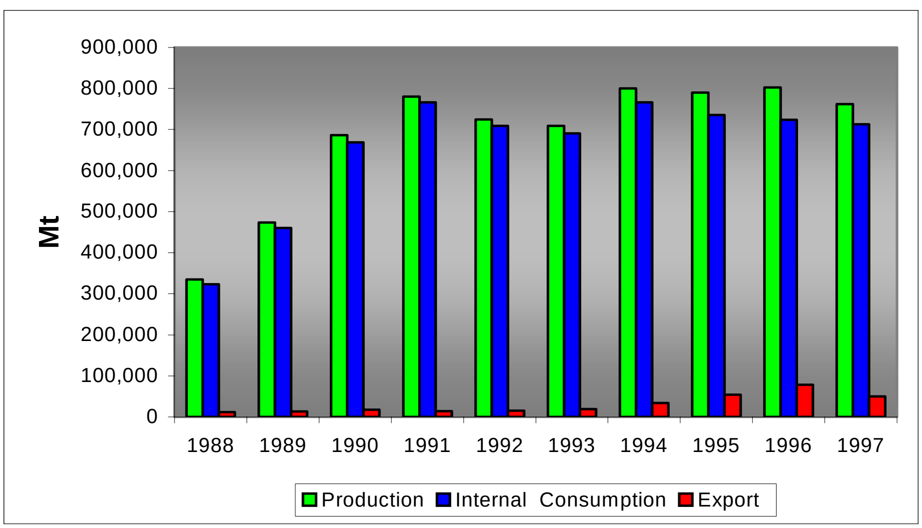
4.4.2.1 Marketing Channels

Due to the limited means of transport, growers generally sell to a "field collector". The domestic commercial channel also includes wholesalers, distributors, and packing plants who then sell to local supermarkets, hotels and restaurants (FAS, 1997b). This characteristic commercial chain (including a middle-men) in the distribution of avocados, affects final prices and the returns to the growers.

Table 4. 11. Mexican Production, Internal (Domestic) Consumption and Exports of Avocados

Year	Production (MT)	Exports (MT)	Exported Percentage of avocados	Export Value ($1000)	Internal Consumption (MT)
1988	334,741	11,857	4	9,853	322,884
1989	473,156	13,101	3	11,007	460,055
1999	686,301	17,427	3	14,865	668,874
1991	780,000	14,314	2	17,914	766,089
1992	724,523	15,676	2	19,909	708,847
1993	709,296	18,829	3	18,548	690,467
1994	799,929	33,750	4	29,534	766,179
1995	790,000	54,595	7	34,314	735,405
1996	802,625	78,556	10	42,777	724,069
1997	762,336	49,824	7	42,945	712,512

Source: FAO, 1999 Databases; U.S, Agricultural Attache reports US, 1998.



Source: FAO, 1999 Databases; U.S, Agricultural Attache Reports US, 1998.

Figure 4. 13. Production, Internal Consumption and Export Volumes of Avocados in Mexico.

Table 4. 12. Mexico's avocado export by country destination (Excel horiz)

4.4.2.2 The U.S. Avocado Ban Over Mexican Produce

Mexican avocados have been banned from the United States since 1914 due to the presence of pests that could devastate the Californian Avocado Industry. Mexican farmers argue that the ban was aimed to keep high prices in the U.S. market and not for phytosanitary control. For instance, a box of Mexican avocados sells for around $8 in Canada, which allows imports, compared with a price of $30 for U.S.-grown avocados (USDA News, 1997).

Avocado growers in both California and Florida have been consistently and intensely opposed to the entry of Mexican avocados under any circumstances. They have argued that the importation of avocados presents a pest risk invasion to the U.S. avocado industry. On the other hand, U.S. agricultural exporters increasingly fear that USDA's position and possible continued prohibition of Mexican avocados, will result in a regulatory standard that will be adopted by Mexico, and perhaps other countries, thereby affecting access for U.S. products (APHIS, 1997).

Between 1990 and 1992, Mexico submitted three different work plans under which avocados grown in Michoacan could be imported into the United States. One of those work plans resulted, in July 1993, in APHIS allowing the entry of Mexican avocados into Alaska under certain conditions (APHIS, 1997).

After long periods of discussion with growers’ representatives, scientists and government officials, on January 31st 1997, the Animal Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture approved the import of Mexican Hass avocados from 1,500 hectares of orchards in Michoacan State into 19 northeastern U.S. states and the District of Columbia during the months of November, December, January and February, provided growers meet pest-control safeguards specified by APHIS under a systems approach (FAS,1998a). This period from November to February represents the low production period of avocado in the United States.

The systems approach consists of nine safeguards designed to operate sequentially to progressively reduce risk to an insignificant level. The components of the systems approach are: field surveys, trapping and field bait treatments, field sanitation practices, host resistance, post-harvest safeguards, winter shipping, packinghouse inspections, port-of-arrival inspections, and limited U.S. distribution. This approach operates as a "fail-safe" system; if one mitigating measure fails, other safeguards are in place to ensure that the risk continues to be reduced and managed (APHIS, 1997).

Thus, approximately 65 Mexican growers and 5 exporters have been approved by APHIS to export to the USA. Imports are allowed to those northeastern states where climatic conditions would prevent pest survival in the event that any pests happened to accompany a shipment.

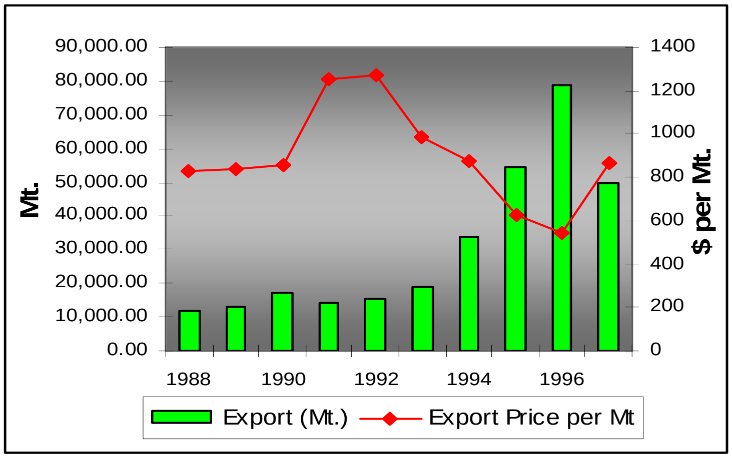
Finally, the economic impact of the final import approval on U.S. producers is considered limited. Only about 8% of the total U.S. avocado production is sold in the 19 Northeastern states, where Mexican avocados will be imported. In addition, a positive net economic benefit to consumers of as much as $19 million is anticipated as a result of this rule (APHIS, 1997).

Thus, the first Mexican avocados were shipped to USA between November 1997-February 1998. Over 6,000 tonnes entered the market, this quantity surpassed the original export estimates by 20%.

4.4.3 Market Prices

Even though Mexican avocados are harvested year round, low prices are obtained during the peak-harvesting season from October to February. High prices are obtained during off- season; from May to September. The average farm-gate price for avocados in 1997 was about US$ 156 per metric ton. during peak season. During the off-season growers may receive US$ 325 per metric ton.

Export prices fluctuate according to availability of produce in the market. The average avocado grower in Mexico receives 19 pesos per kilogram (about $1 per pound) of avocados sold to the United States - half the prevailing price in many American markets - and nearly double what the fruit brings in Mexico (Stevenson, 1997). Average prices for the export volumes recorded from 1988 to 1997 are shown in Figure 4.14.

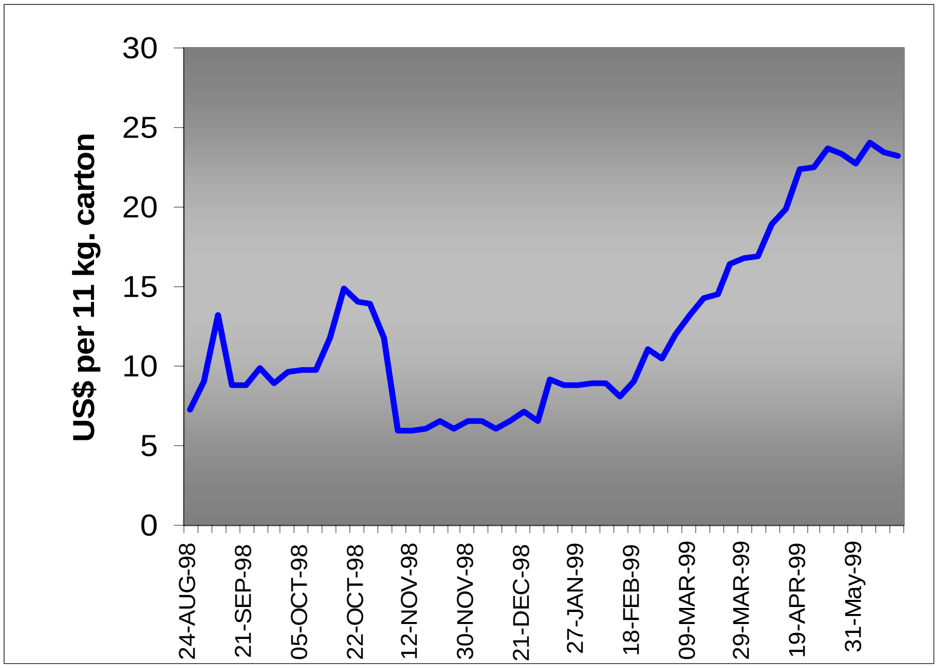


Source: FAO, 1999 Databases

Figure 4. 14. Export Volume and Average Annual Price (per Mt.) for Mexican Avocados.

High prices per Mt. were achieved during 1991 and 1992 due to a world shortage of avocados. However increases in export volumes have brought decreases in prices in the export market. During the 1995/96 season, bad weather conditions negatively affected the production in major production areas in Israel, South Africa and Spain and allowed larger exports of Mexican produce. It was during this period that prices were lowest. Since then prices have recovered, with a tendency to remain stable at approximately $860 per Mt towards 1997.

Export prices are affected year by year and also within the year during the season. For instance, actual prices for the 1998/99 season (for an 11-kilogram carton of avocados) are shown in Figure 4.15. The highest prices during the season were recorded in August and in April, whereas the lowest prices were recorded during November (where $5.98 was the lowest price recorded for the season). This is because of oversupply in the market at this time and overlapping of harvest seasons from November until February with produce from Israel, South Africa, Chile and US. After this period of time prices tended to recover towards the end of April. Due to this market variability in prices, some growers prefer to harvest later in the season so as to obtain higher prices for their produce. This strategy is possible thanks to the characteristics of this particular fruit which can be stored on the tree for longer periods of time after maturation without detriment to the quality.



Source: Today's Market Prices, 1999.

Figure 4. 15. Seasonal Market Price received in USA for Mexican Export Hass Avocados during 1998/99 (for 11 kg. carton).

Although Mexico permits the importing of avocados, because of current prices, avocado imports are not generally competitive in Mexico. Under NAFTA, fresh avocado imports from the U.S. are subject to a U.S. $0.066/kg duty for 1998 although this tariff is scheduled to be phased out by 2004. Imported avocados are also subject to phytosanitary and sanitary inspections by SAGAR, the Mexican Ministry of Agriculture Livestock and Rural Development (FAS, 1999).

4.4.4 Future Trends

Industry experts expect that, given the significant number of trees planted in the late 1980s and early 1990s, total production will increase until the year 2000 when those trees will reach full maturity (FAS, 1998a). The average yield in Michoacan is 10 tonnes per hectare, but mature tree orchards can have yields of 15 tonnes or more and produce for up to 50 years. In addition, the harvested area is expected to increase 8% to 90,000 hectares based on more growers returning to their orchards (FAS, 1998b).
Mexican avocados are rapidly gaining popularity and share in export markets, such as Japan and Europe because of greater availability and lower prices than their competitors. Moreover, sophistication of growing techniques and the formation of unions among Mexican producers for better price-impact in the market, are expected to increase the export potential of Mexican avocados. However, if plantings and production do not increase, then there is concern that this could put pressure on domestic avocado prices as growers would prefer to export rather than to sell in the local market (FAS, 1997b). Nevertheless internal consumption is forecast to rise by 26% in 1998 based on the expected larger harvest (FAS, 1998a).

The opening of the US market has raised many speculations and concerns especially on the part of U.S. producers and traders. The U.S. constitutes an attractive market because of its size and diversity, and because of its Hispanic population (with strong avocado consumption habits) which is highly significant. However there is concern about their limited knowledge of the north-eastern U.S. market. In these states avocados are viewed only as a summer fruit, which may create difficulties in marketing during winter months. (FAS, 1997b). Nevertheless, among U.S. consumers there is a tendency to believe that Mexican Hass avocados taste better because of the terrain and climate in Mexico (Ramirez, 1995) which favourably affects the marketing of the produce.

In addition, the APHIS approval requires strict compliance with phytosanitary procedures and standards as well as passing a series of APHIS inspections during growing, packing and exporting processes. The cost of meeting these requirements is high, however, the

Mexican industry hopes that revenues from avocado export sales to the United States will eventually more than offset the APHIS costs. Moreover, due to the opening of the U.S market, Mexican Banks are more interested in helping producers with credits programmes to cover their costs (FAS, 1998a).

For 1998/99, Mexican exports to the United States are forecast at 10,000 - 12,000 tonnes. Due to the partial lifting of the phytosanitary ban, the United States has the potential to become a major market for Mexican avocados. Mexican exporters have expressed hopes of exporting 25,000 tonnes to the United States in the near future.

Overall because of the different factors discussed (increasing growers, interest, production and the opening of the U.S market) total Mexican avocado exports in 1998/99 were forecast to increase to 44,000 tonnes, an increase of 29 percent from last year, due mainly to higher export-quality supplies (FAS, 1999).

Table 4. 1

Table 4. 2

Table 4. 3Table 4. 4Table 4. 5Table 4. 6Table 4. 7Table 4. 8Table 4. 9Table 4. 10Table 4. 11Table 4. 12

Figure 4. 1Figure 4. 2Figure 4. 3Figure 4. 4Figure 4. 5Figure 4. 6Figure 4. 7Figure 4. 8Figure 4. 9Figure 4. 10Figure 4. 11Figure 4. 12Figure 4. 13Figure 4. 14Figure 4. 15

4.5. The South African Avocado Industry

Although, compared to Mexico or the U.S., South Africa is a minor producer of avocados, nevertheless, is one of the world's leading exporters.

A recent census carried out by the South African Avocado industry reports that 10,800 hectares are planted in avocados in South Africa. These are mainly situated in the Lowveld areas of the Northern and Eastern Transvaal region (van Zyl and Ferreira, 1995). These regions account for 55% of the total national planted area. The second largest production region is Nelspruit-Burgershall, accounting for 23% of the national planted area (FAS, 1997a) and the remaining 22% of the land is distributed around the country. Farming units vary in size and the typical farm could vary from 20 to 30 hectares.

The production of avocados in South Africa has potential for further increases because around 30% of the planted area has not yet come into production. New plantings have been made since 1991 and, as a result, the industry is expanding. At the moment only about 6,000 hectares are harvested every year. Moreover, 48% of the planted area has not yet reached full production, Table 4.13. (FAO, 1999).
On average the harvested area has remained fairly constant since 1992, as have yields of fruit per hectare. Average yield for the past few years has been about of 7 tonnes per hectare, which is considered low. The main reasons for this are: unsuitable land (25% of total area is planted under dry land conditions), incorrect application of cultural practices and spraying programmes and continuous drought conditions in avocado producing areas. On the other hand, efficient farmers have been reported to have achieved yields of 15 tonnes per ha.

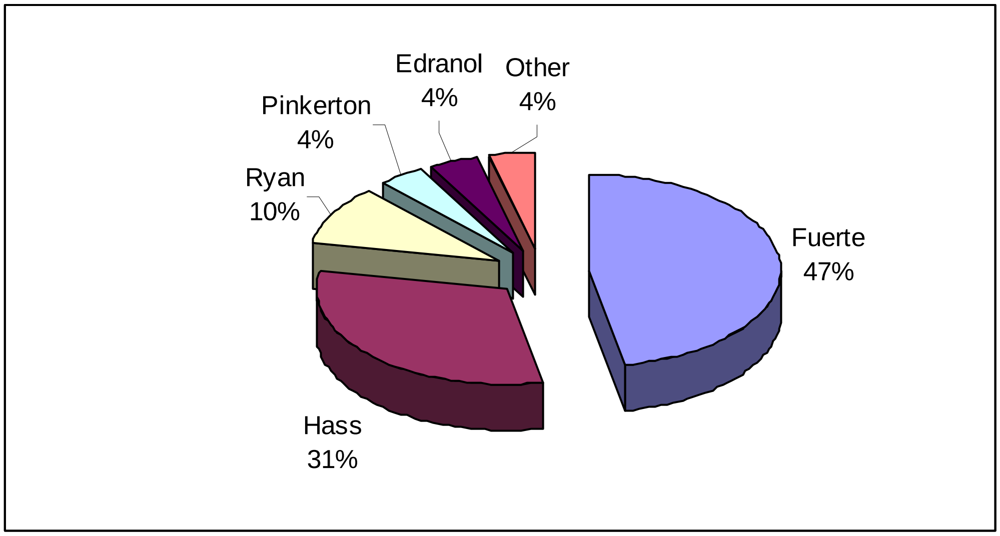
Table 4. 13. South African Production Harvested Area and Yield per hectare of Avocados.

Year	Production (MT)	Area Harvested (Ha)	Yield Per Hectare (Mt)
1992	45,710	5,600[e]	7.5
1993	36,921	5,300[e]	7.1
1994	37,748	6,000[e]	8.1
1995	45,428	6,000[e]	7.6
1996	53,801	6,000[e]	8.9
1997	44,586	6,000[e]	7.4

na= not available; e= FAO estimates
Source**:** FAO, 1999 Databases

The avocado industry in South Africa is considered very sophisticated. For instance, approximately 75% of the planted area is irrigated. At the nursery trees are grafted with root rot (Phytophtora) resistant rootstocks. In addition, there is intensive research at all levels of the production and distribution chain; cultivation and irrigation, harvesting techniques, transportation and postharvest handling. All the product planning and marketing strategies are designed to meet the requirements of its main customer, the EU, (FAS, 1997b).

In contrast to Mexico and the U.S., a variety of cultivars are grown in South Africa. On an area basis Fuerte cv. constitutes the most popular and the most planted cultivar, accounting for 47% of the crop, while Hass cv. accounts for about 31% (FAS, 1997b). The remaining plantings are composed of Ryan (10%) and other cultivars such as Edranol, and Pinkerton (Figure 4.16). An increased number of Hass cv. trees have been planted since 1991 (van Zyl and Ferreira, 1995). Basically the highest volume of trade is in green skinned cultivars, with Hass being the only dark-skinned cultivar traded. Avocados are harvested year round in South Africa, depending upon the variety, with most of the crop being harvested from November to October. The peak season is from March to September.



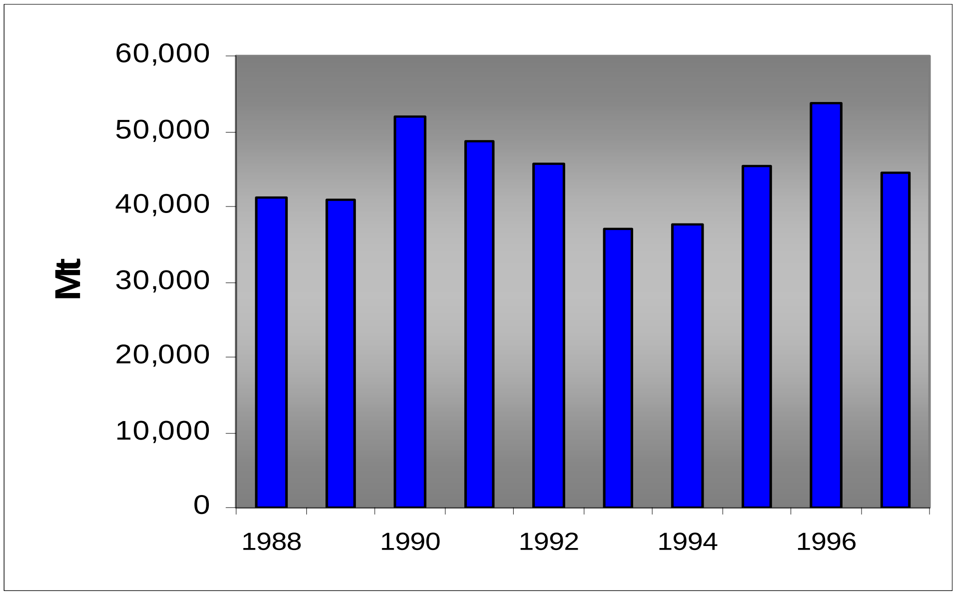
Source: van Zyl and Ferreira, 1995; FAS, 1997b.

Figure 4. 16. Percentage of Trees planted in South Africa by Cultivar.

Aside from the ups and downs in production numbers, due mainly to unfavourable climatic conditions and the bearing cycles of the trees, South African production has varied with no particular pattern (Figure 4.17).

Over the past 5 years, South Africa has contributed approximately with 2% of the world's total production. In 1997 South Africa produced 46,369 metric tonnes from which

about 53% were exported. Production for 1998 was initially forecast at 53,000 tonnes, however adverse weather conditions affected the final harvest yield. Consequently production estimates have gone down to 43,000 tonnes of produce for that year (FAS, 1997b). Official data for 1998 season are not available yet.



Source: FAO, 1999 Databases
Figure 4. 17. South African Avocado Production

4.5.1 South African Avocado Industry Structure

Approximately 550 growers are associated under the South African Avocado Growers' Association (SAAGA). SAAGA's mission is to look after the interests of members of the industry and to co-ordinate research and negotiation with government officials. SAAGA's activities are financed through a voluntary duty on exports. The industry has not receive any government assistance since the formation of the Uruguay Round (FAS, 1997b).

During 1997 the SAAGA board was restructured and Regional Committees were introduced (Vorster, 1997). The new structure sought for greater grower involvement. Thus the objectives of the SAAGA were redefined as:

- Assisting members to become more productive
- Creating an information basis on the viability and productivity of the industry.
- Ensuring flow of information between co-ordination and distribution of market information.

- To create a forum for exporters to co-ordinate exports.

The domestic avocado industry in South Africa is composed of four segments:

1. Growers and Packers:
    - Large growers, Small growers
    - Estate packers, Co-op packers, Central packers
2. Marketers:
    - Large grower marketing
    - Small grower marketing
    - Central Marketing
3. Distributors
4. Consumers

The final role of SAAGA is to communicate, co-ordinate, and ensure co-operation amongst the levels involved in the domestic market.

4.5.2 . Local and Export Markets

The local market has not received much attention since almost all of the industry is export-oriented. However, SAAGA has undertaken a marketing plan to promote the internal consumption of avocados. Thus, in 1993 SAAGA collaborated with a professional research company to find the key success factors for improving avocado marketing in South Africa. The aim of the research was to develop an integrated market strategy and an action plan for its implementation (Hilton-Barber, 1995).

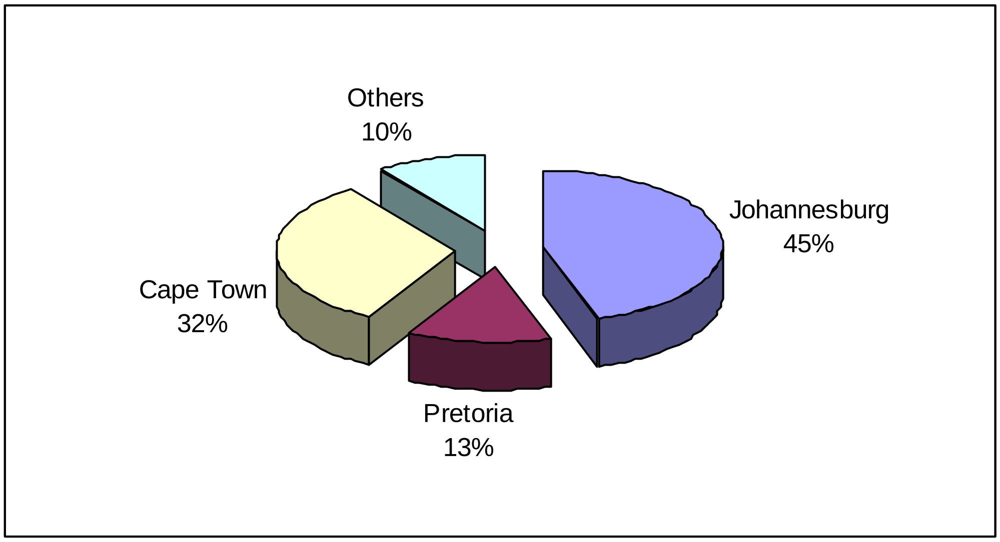
Industry consultants describe the domestic market as being well disposed towards avocados. However, due to the preoccupation with exports, the local consumer is poorly educated regarding knowledge of cultivars (especially towards Hass), fruit quality, nutrition and ripening status. Moreover, as the industry’s main focus is the export market, fruit of only “second best” status is marketed locally. There is a national strategy underway to improve the situation of the local market, which basically involves consumer education, extension of season supply, and the appointment of a promotion's co-ordinator (Hilton-Barber, 1995).

The SAAGA is trying to increase domestic consumption by restoring the confidence of the local consumer. It is basically a "Quality drive" programme, which conveys the message that "*what you buy, you can eat*". In order to achieve the objectives, SAAGA has looked back to the factors that certainly play a major role in the final quality of the ripe fruit. Thus, members of the distribution chain are involved in the current local marketing strategy.

This means that growers and packhouses are certifying that the fruit went through the required pre and post-harvest treatments, and met the minimum maturity standards and quality at harvest. The programme is complemented with grading and packing recommendations for the local market in order to deliver consistency of quality (GAIN/South Africa, 1998).

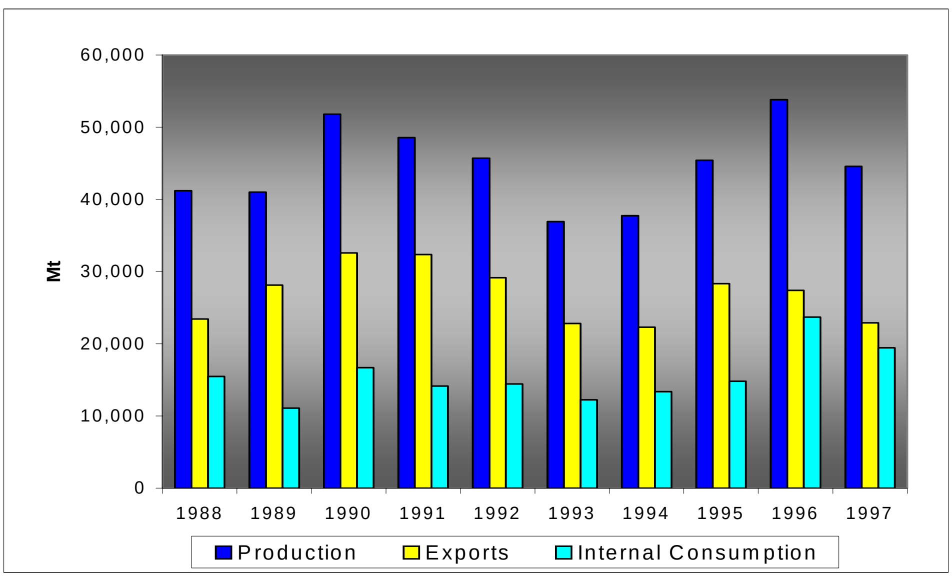
According to official statistics approximately 50% of the crop is exported and 35% of the crop is consumed domestically (Figure 4.19), and the remainder of the crop is traded through other outlets (not official). Although, in 1997 internal consumption of fresh avocados decreased 20% relative to 1996 due to a smaller crop, it is expected to increase in the future. Internal consumption of the avocados is either as fresh or processed. In addition, it is estimated that minor quantities of fresh avocados are traded locally by 'hawkers' (van Zyl and Ferreira, 1995). Average figures for the last five years indicate that about 2% of the crop is also destined as raw material for further processing such as oil extraction (Table 4.14).

The main consumption areas of fresh avocados in South Africa are Johannesburg, Pretoria and Cape Town (South African Department of Agriculture, 1995). These regions absorb approximately 90% of the total supply to the local market (Figure 4.18). The peak supply months to the domestic market are from March to September.



Source: South African Department of Agriculture, 1995

Figure 4. 18. Main consumption markets of avocados (as fresh) in South Africa.



Source: South African Department of Agriculture, 1995; van Zyl and Ferreira, 1995; FAO, 1999 Databases.

Figure 4. 19. Production, Internal Consumption and Export of Avocados in South Africa.

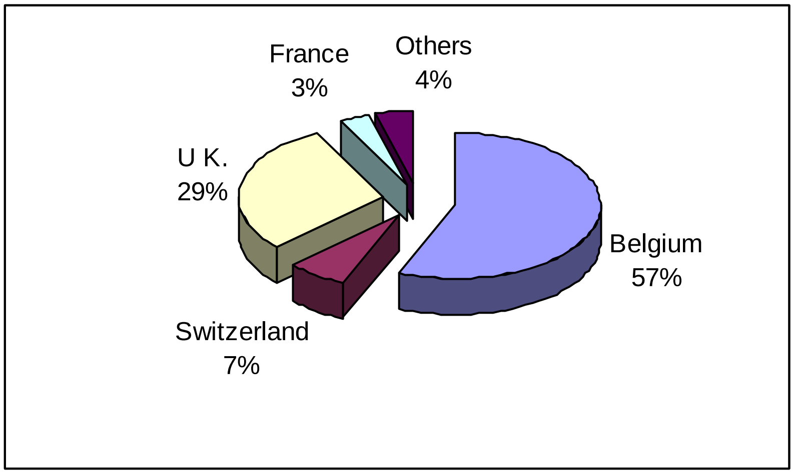
Table 4. 14. South African Production, Internal (Domestic) Consumption and Exports of Avocados.

Year	Production (MT)	Exports (MT)	Internal Consumption as Fresh (MT)	Fruit for Processing (Mt)	Other Outlets (Mt)
1988	41217	23,432	14,339	1,138	2,308
1989	41,004	28,114	11,097	n.a	1,793
1990	51,808	32,590	16,005	685	2,528
1991	48,565	32,355	13,158	1000	2,052
1992	45,710	29,166	12,980	1,468	2,096
1993	36,921	22,814	11,583	654	1,870
1994	37,748	22,303	12,847	524	2,074
1995*	45,428	28,339	13,909 [oe]	909[oe]	2,271[oe]
1996*	53,801	27,416	22,619 [oe]	1,076[oe]	2,690[oe]
1997*	44,586	22,921	18,544 [oe]	892[oe]	2,229[oe]

n.a= not available, oe= own estimates for: fruit for processing at 2% of total production, for other outlets 5% of total production, for internal consumption by difference.
Source: South African Department of Agriculture, 1995; *FAO, 1999 Databases.

The South African export season is from March to August, with 95% of the export crop usually being sent to European markets such as Belgium, Switzerland, Germany, France and the U.K (Figure 4.20). In 1997 exports totalled 22,921 tonnes, 16% below the previous year. This was largely due to cold weather in spring which affected the availability of export quality fruit (Milne, 1996).

Nevertheless, South African exports are subjected to a tariff rate in order to enter the European market. After long negotiations during 1997, a reduction from 4 to 3.5% (December 1st to May 31st) and from 8 to 6% (from June 1st to November 30th) in the tariff rate was granted under the General System of Preferences Agreement (GSP). During 1998 negotiations were still underway as South African attempted to obtain a zero percent tariff rate granted to all other GSP countries except South Africa (FAS, 1998b).



Source: GAIN/South Africa, 1998.

Figure 4. 20. South African Exports by Country of Destination

South Africa generally does not import avocados. The country imposes a 5% duty on imports, which basically limits the entrance of imported fruit.

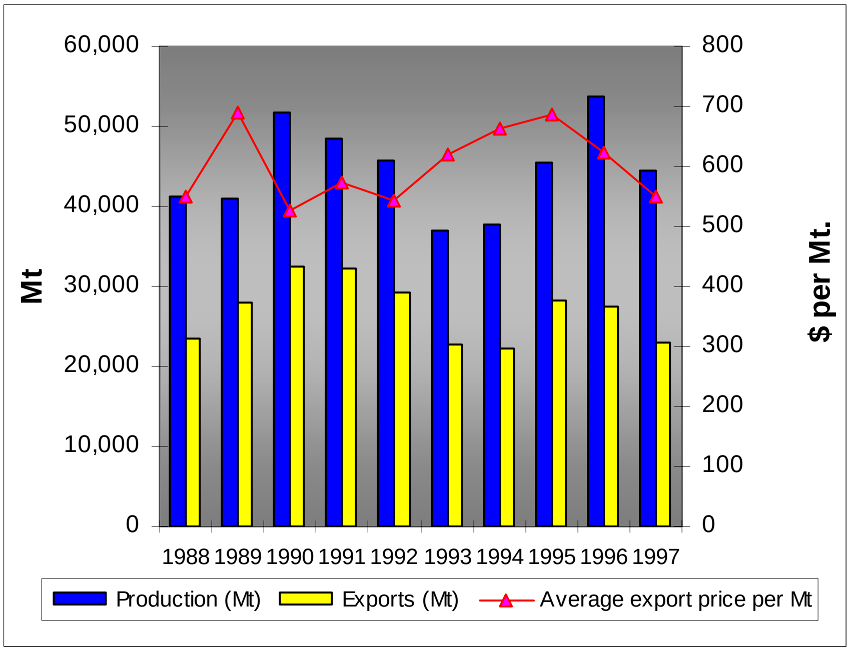
4.5.2.1 . Marketing Channels

The common distribution channel of avocados in the domestic market is through municipal markets however, direct contracts with retailers are becoming more and more popular.

Private traders are contracted for exports. Labels such as Bella Nova and UNIFRUCO, a major fruit exporter, trade the largest volumes (Market Asia, 1995).

4.5.3 Market Prices

It is observed that the variation pattern in the export volumes traded since 1989 coincided with the variation pattern in the export prices (Figure 4.21). Thus, it seems that the prices obtained by South Africa for exported fruit influence the export price in general. This may be because South Africa is the largest producer and supplier of avocados in Europe and thus exerts a large influence on the European market. Among the different South African varieties exported, Fuerte usually obtains higher prices than Hass (van Zyl and Ferrreira, 1995).



Source: FAO, 1999 Databases

Figure 4. 21. Volume and Value of Exports of South African Avocados

4.5.4 . Future Trends

With only 70% of the planted area in actual production at almost 50% of its production capacity, there is great potential for increasing the national output of avocados in future years, even if the rate of new planting slows. In fact, industry sources expect that avocado production in South Africa will double within the next five years (provided favourable climatic conditions prevail). Hass will become more important than Fuerte as more trees of this cultivar have been planted (Patridge, 1995 interviewed by van Zyl and Ferreira, 1995).

For 1998 production was estimated to reach 78,000 tonnes. Domestic consumption of avocados during 1998 was forecast to rise from almost 22,000 tonnes during 1997 to 40,000 tonnes. It is estimated that the major part of this increase in consumption will be as fresh avocados (Embajada de Sudafrica, 1998) with a small portion going to processors.

A record export crop of 50,000 tonnes (12.5 million export carton of 4 kg.) was predicted for the 1998 season, up almost 100% from 1997 (24,800 tonnes). The industry also expects to increase future supplies to traditional importing European countries, which may mean a drop in export prices for South African fruit due to intense competition. To prevent this, the South African industry started in 1996 a marketing programme with direct promotions to increase sales to the United Kingdom. The main problem was that the low crop in 1997 could not supply the market (Vorster, 1997). This programme is still underway and is aimed at developing the United Kingdom as its primary export market. The main issues for increasing sales in this market have been identified as: lack of knowledge of avocados, U.K. consumers emphasised quality above price, and a real need for promotion to stimulate demand ahead of supply (Francis, 1997). With this promotional campaign the industry expects to double the export volume to the U.K. during 1998 (Embajada de Sudáfrica, 1998).

South Africa’s main competitors in the European market are Israel and Spain. Due to its closeness, Spain’s main export market is Europe and mainly France. Primarily avocado cultivars grown in Spain are Hass, Bacon and Fuerte. Hass accounts for 80% of the total production and is the most popular. Spanish fruit is regarded as high quality. Avocado producers use high quality seed imported mostly from California. Spanish avocados overlap with the South African supply from October to December and from April to June (FAS, 1997a). Spanish exports for 1999 are forecast to decrease by 14% from last year, due to decreasing production forecast (FAS, 1999). Spain and Israel ship during the same export season every year. South Africa also supplies the Spanish market and because Spanish production is declining, this could also mean greater opportunities for increasing quantity of South African avocados to be exported to Spain.

4.6. The Israeli Avocado Industry

Commercial growth of avocados in Israel started in the 1960s. The area planted reached its peak during 1986-87 with 11,000 hectares (Gafni, 1998) which later declined due to low and unstable yields (6-7 tonnes /ha). Actual (1998) planted area is about 7,100 hectares and the country's average yield is slightly above 10 tonnes /ha but the aim is to reach 20 tonnes per hectare (Lahav, 1997), (Table 4.15).

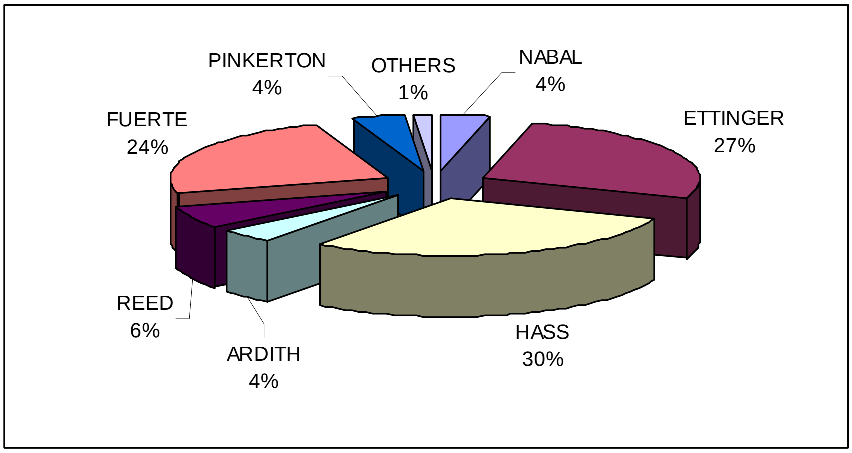
Table 4. 15. Area Planted and Yield per Hectare of Avocados in Israel

Year	Area Planted Ha.	Yield per Hectare Mt/Ha.
1990	8,466	5.7
1991	7,991	6.6
1992	8,337	8.9
1993	7,320	6.5
1994	7,852	6.9
1995	7,495	7.6
1996	7,349	10
1997	7,100	9.9

Source: FAO, 1999 Databases; GAIN/Israel, 1998.

Industry experts say that, in order for the avocado production to be a profitable business, the yield must increase to at least 15 tonnes per hectare. However, an acute scarcity of irrigation water and the use of unsuitable soils in the past, together with recent heat-waves have been the main reason for low average yields and the abandonment of orchards (GAIN/Israel, 1998).
Nevertheless, a slight resurgence in the industry is noticeable. From the lessons learnt from the past, production areas are being relocated into regions with appropriate climate and water availability. These areas are Western Galilee and the Central Coastal plain, which in the future, will contain 75% of Israel's avocados. (GAIN/ Israel, 1998).

Hass is the most planted cultivar, accounting for approximately 30% of the total area. Other cultivars planted are Ettinger, Fuerte, Nabla, Pinkerton, Ardith and Reed. The area planted with the commercially-popular cultivar Fuerte is decreasing significantly, due to low yields, which means that is a non- profitable cultivar (Gafni, 1998) (Figure 4.22).



Source: Gafni, 1998

Figure 4. 22. Avocado Area by Cultivars in Israel

It is interesting to note that, while the Ardith is a rejected cultivar in California, which is not even popular in the local market, in Israel it represents an important 4% of the total area planted. This is because the Israeli breeding program is very active, with constant improvement and introduction of cultivars in the industry. For instance, Fino, Iriet and Galil are recent introductions, with Galil being grown for the local market only (Lahav, 1997).

Cultivar percentages vary by region (Figure 4.22). For instance ‘Hass’ in Western Galilee represents 35- 40% of the total area planted, while in the hot region of the Sea of Galilee ‘Hass’ is not commercially grown (Hofski, 1996).

In the business of cultivation of avocados in Israel, the high cost of water is a limiting factor. Moreover, the rapidly growing population impacts on the availability of water for agriculture. Obviously, all good quality water will be used for drinking, and recycled water will be the only water available for irrigation. The salinity of the irrigation water is a major issue, especially for salinity-sensitive avocado cultivars (Hofski, 1996)- however, intensive research and selection over many years have identified numerous avocado rootstocks with salt tolerance that can be grown in Israel. The majority of these rootstocks belong to the West Indian race, therefore these are the preferred types of rootstock in Israel.

For the past 5 years, Israel's production has represented about 3% of the total world's production. Avocado production during 1996 and 1997 has been 70,000 and 64,000 tonnes respectively (Figure 4.23) but for 1998, production was estimated to drop to 55,000 tonnes due to dry conditions during flower set.

4.6.1 Israeli Avocado Industry Structure

In 1997 about 66% of the avocado farms were organised in large communal units which had previously belonged to family farms (kibbutz) and private companies. The tendency is to merge several avocado 'kibbutz' (agricultural communities) to form co-operatives under one single manager.

Both local and export marketing of avocados have been traditionally managed through a single body: the Fruit Production and Marketing Board of Israel (FPMB) (GAIN/Israel, 1998).

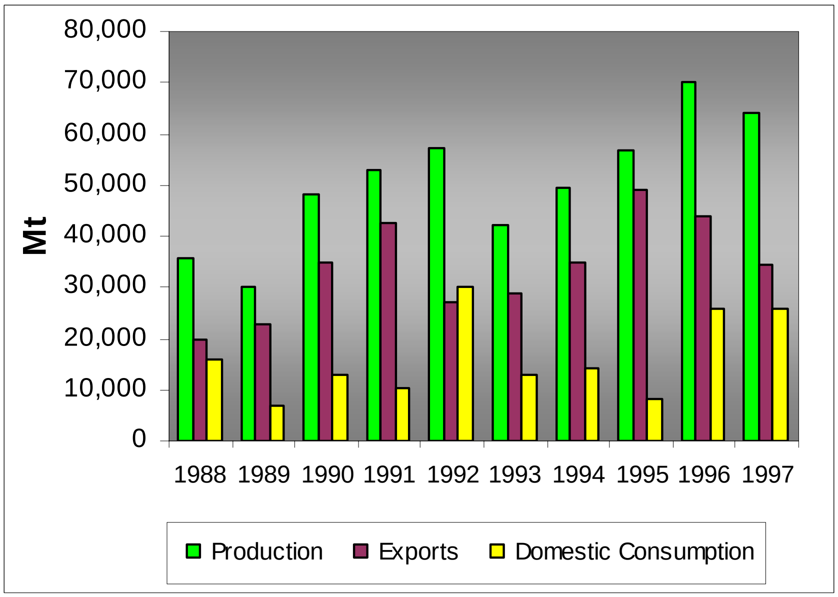
However, in 1995 the legislation changed, and the domestic market was opened in order to increase competition and improve farm gate returns. Now any grower has the opportunity to sell their produce independently. Later, in 1997, the export market also was opened. Under this legislation, new exporters are allowed to compete for export fruit with AGREXCO (the export company from the FPMB) as long as they show control of at least 10% of the harvested crop during the fruit season (GAIN/ Israel, 1998).

4.6.2 .Local and Export Markets

Israel is one of the world's leading exporters of avocado. Although the volume of exports in 1997 decreased 13% relative to those in 1996, Israel exported 54% of its 1997 total production (Figure 4.23). This high percentage indicates that the industry is basically export driven with the local market serving only to absorb surpluses and fruit not suitable for export as fresh.

About 50% of the total production of avocado is consumed in Israel either as fresh or as processed avocados.

Thanks to promotional campaigns, domestic consumption in 1997 was about 20,000 to 25,000 tonnes: much higher in comparison to 1995 volumes (Figure 4.23). Growth in domestic consumption in 1997 was due also to the increase from 1,000 to 5,000 tonnes in the demand for fruit as raw material for the manufacture of avocado products such as soaps and oil (GAIN/ Israel, 1998).



Source: FAO, 1999 Databases, GAIN/Israel, 1998.

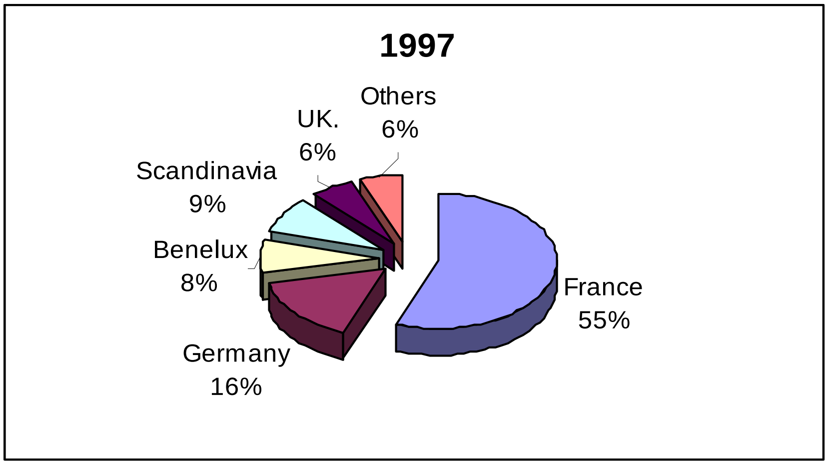
Figure 4. 23. Israel's Production Exports and Domestic Consumption Volumes.

Ettinger is the most popular variety among consumers in Israel, because it reaches maturity before frost strikes in December and is high yielding (Market Asia, 1995). Hass, however, is the cultivar preferred for export by most European countries. Israel's main export market is Europe and, in contrast to South African avocados, there are no tariffs on exports of Israeli avocados to Europe.

France is the main country of destination for about half of Israel's exports, with the rest being absorbed by other European countries such as Germany, Scandinavia, Benelux and the United

Kingdom. Small amounts are also sent to Italy, Switzerland, Austria, (Figure 4.24) (FAS, 1997b).

Israel's export marketing season to Europe is from October to May, thus causing it to compete with South African avocados during March and April, and also at the end of the South African season in October. However, Israel delivers Hass to France during March and April, when no Hass are available from South Africa (van Zyl and Ferreira, 1995). Nevertheless, Spain also supplies Hass in France during the same months as Israel (March, April and May) and therefore constitutes Israel's main competitor.

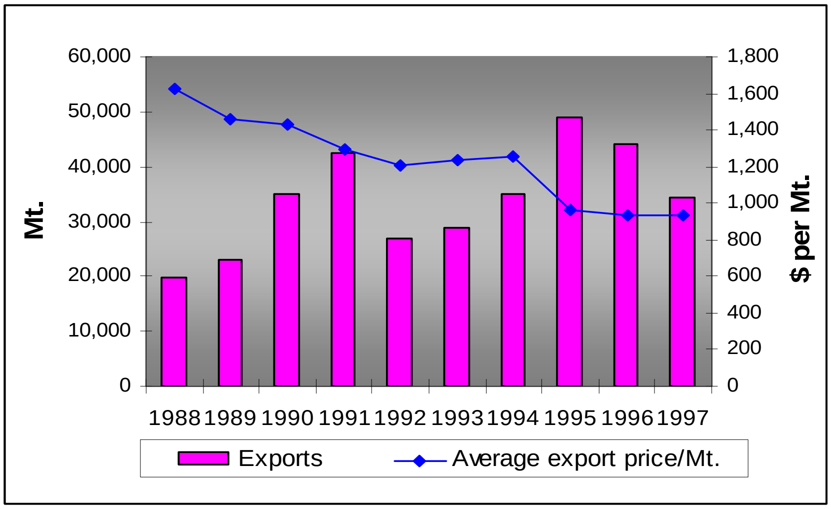


Source: GAIN/ Israel, 1998.

Figure 4. 24. Israeli's Avocado Exports by Destination during 1997

4.6.3 . Market Prices

Although the avocado industry in Israel was originally thought of as an export industry, low export prices and strong competition are causing higher volumes to be sold in the local market for better prices than overseas. For instance Israel's average export price in 1997 was $935 per metric ton (FOB), only a 2% decrease from 1996's average export prices but, low in comparison to prices achieved by the US and Chile in the export markets (Figure 4.25).



Source: FAO, 1999 Databases; GAIN/Israel, 1998.

Figure 4. 25. Volume and Value of Israeli Avocado Exports

Pressure on prices is due mainly to Mexican being avocados being available in large amounts and at cheap prices in the European market. Spain represents Israel's main competitor because Spanish avocados, although limited, have the advantage of proximity to the European market and therefore rapid adaptability to greater or lower demand.

4.6.4 . Future Trends

The area planted in avocados in Israel is forecast to decrease due to low profitability, scarcity of suitable water and the potential for other more profitable land uses. Thus, by the year 2005 it is expected that the area planted will decrease to 4,500 ha.

Nevertheless those remaining in the business wisely tend to grow a wide range of cultivars in order to lengthen the marketing season (Gafni, 1998) and diversify the supply to European countries.

Due to recent heat-waves in the growing regions no increases in avocado production are expected. Production is estimated to remain steady at about 55,000 to 60,000 tonnes for the foreseeable future .

Liberation of the marketing of avocados in Israel will create intense competition in the local and export markets. Export companies are forming and it is expected that Export Marketing companies will be formed to specialise in the management of the marketing activities overseas. However, if local prices remain higher than foreign prices, then it seems that the best strategy would be to further develop the local market, which apparently is now demanding higher-quality fruit.

Due to increased competition in the European market, Israel is studying the possibility of exporting to the US. market. However, the strict US. phytosanitary requirements for imports make this possibility (at the moment) non-profitable for Israel (GAIN/Israel, 1998). In addition, Israeli producers are hoping to export more avocados into the Mid-East countries and to develop markets in the Pacific Rim countries.

Table 4. 1Table 4. 2Table 4. 3Table 4. 4Table 4. 5Table 4. 6Table 4. 7Table 4. 8Table 4. 9Table 4. 10Table 4. 11Table 4. 12Table 4. 13Table 4. 14Table 4. 15

Figure 4. 1Figure 4. 2Figure 4. 3Figure 4. 4

Figure 4. 5Figure 4. 6Figure 4. 7Figure 4. 8Figure 4. 9Figure 4. 10Figure 4. 11Figure 4. 12Figure 4. 13Figure 4. 14Figure 4. 15Figure 4. 16Figure 4. 17Figure 4. 18Figure 4. 19Figure 4. 20Figure 4. 21Figure 4. 22Figure 4. 23Figure 4. 24Figure 4. 25

4.7 The United States Avocado Industry

The United States is the world's second- largest producer of avocados after Mexico. Since 1992 U.S production has represented about 8% of the total world production of avocados. In 1997, U.S production reached 178,000 metric tonnes.

Avocado production in the US. is limited to California, Florida and Hawaii. These states produce different types of avocados due the differences in climate and consumer preferences. Thus, the three races are well adapted and successfully grown in the US. The Mexican cultivar is grown in the San Joaquin Valley of California, the Guatemalan in Southern California, and the West Indian in Florida.
Nevertheless, almost 85-90% of the total U.S. avocado production is grown in California's southern coast region. This region includes the San Diego, Riverside, Ventura and Santa Barbara counties. San Diego county alone produces 60% of all California's avocados. However, the area planted in San Diego has declined since 1990 due to the higher cost of water, but this has been compensated for an increase in area in Ventura County. It should be remembered that avocado trees are sensitive to poorly-drained conditions, thus in California the trees are frequently planted on hillsides to enhance drainage (FAS, 1997b).

As in the case of Mexico, in the US. Hass is the preferred and most commercially produced cultivar. In fact, Hass comprises 90% of the Californian crop (CAC, 1998).

Avocados grown in Florida account for about 15% of the total U.S. avocado production. There are approximately 63 commercial cultivars grown in Florida, but the most important in commerce are Booth-8, Choquete, Hall, Lula, Monroe, Pollock and Simmonds (Fruit and Tree Nuts, 1996). Since 1990 nearly all of Florida's avocados have been grown southwest of Miami, in Dade County. The area planted in Florida has been declining due to adverse weather conditions. For instance, high winds from Hurricane Andrew in 1992 caused tree losses eliminating nearly 1,230 ha planted in avocado. The growers' disappointment was such that many of them left the avocado business. Since then only 144 ha. have been replanted (Fruit and Tree Nuts, 1996).

The main avocado orchards in Hawaii are located in the Kona, Hilo and Big Island areas. The State's main cultivar is Sharwil, however, it is basically restricted to the local market (Hawaii, Department of Agriculture, 1997).

To date an approximate total of 30,000 ha. have been planted in avocados in the US. The major part of this area (25,162 ha) is in California between San Luis de Obispo and the Mexican border. Approximately 4,700 ha. and 209 ha are planted in Florida and Hawaii respectively (Fruit and Tree Nuts, 1996; Hawaii Department of Agriculture, 1997; CAC, 1998). Interestingly, US. avocado groves are relatively small. The average avocado grove size in California is around 4 ha. This grove size represents 64.5% of the total area planted, and only 6.7% of groves are over 17 ha. (Crane, 1996).

The average harvested area has decreased 20% since 1990, remaining at about 27,000 ha. from 1994 to 1997, (Table 4.16). However, the California Avocado Commission is predicting increases as the number of bearing trees is also increasing. The average country productivity represented mainly by California yields, has remained on average 6.4 tonnes per hectare, fairly constant since 1994.

Interestingly, after Hurricane Andrew, Florida is recovering with a relatively small production achieving higher yields per hectare than California.

In Hawaii, the harvested area is still very limited. Hawaii contributes less than 1% to the total US. production, (Table 4.17). Crops are continuously affected by bad weather conditions such as windstorms, droughts and volcanic smoke. Hawaii's production is difficult to transport out of the state.

Table 4. 16. Area Harvested and Yield per Hectare of Avocados by State in the US.

Year/ State	Area Harvested (ha)			Yield per Hectare (Mt/ha)			Total National	
	CA.	Florida	Hawaii	CA.	Florida	Hawaii	Area ha.	Average Mt/ha.
1992	29,889	3,444	90	9.5	2	3.9	33,423	5
1993	27,429	2,378	103	5	1.9	2.4	29,910	3
1994	25,133	2,337	90	6.2	8.6	2.8	27,560	6
1995	25,051	2,378	86	6.8	8	2.9	27,515	6.4
1996	24,559	2,337	82	6.8	10	2.4	26,978	6.4
1997	24,559	2,419	103	6.3	10	2.4	27,081	6.5

Source: National Agriculture Statistical Service (NASS), 1998.

Table 4. 17. US. Production of Avocados by Producing State.

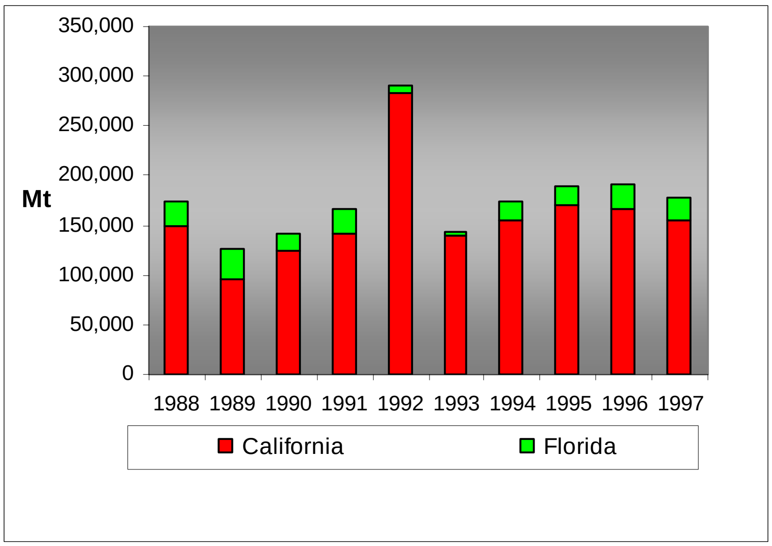
Year	California (Mt)	Florida (Mt)	Hawaii (Mt)	Total (Mt)
1990	123,379	17,781	410	141,161
1991	141,523	25,674	380	167,197
1992	284,000	7,200	350	291,550
1993	139,000	4,400	250	143,650
1994	155,000	20,000	250	175,250
1995	171,000	19,000	250	190,250
1996	167,000	23,500	200	173,000
1997	154,000	24,000	250	178,250

Source: California Avocado Commission (CAC), 1998. FAO Databases. NASS, 1998. Hawaii Department of Agriculture, 1997.

In 1997, California's production declined to 154,000 tonnes, 10% lower than in 1995. This was partly due to strong winds and frosts at the beginning of the year (FAS, 1997a). Florida is recovering its avocado production levels. This State produced 24,000 tonnes in 1997, 13% up from 1995, (Table 4.17, Figure 4.25). Hawaii's production is declining and sales are becoming irregular which makes it difficult to cover production costs.

Nevertheless, the value of the avocado industry in the US. Increased from $214 million in 1987 to $278 million in 1997 (NASS, 1998).

Frost, freezing temperatures and hurricanes appear to represent a high risk especially in California and Florida. Temperatures below -1°C can occur in these regions, and are anticipated to happen every 7-10 years in Florida, but less often in California. When a severe freeze occurs it has repercussions, lowering the production for 2 or 3 seasons following the freeze (FCIC, 1997). For these reasons, California and Florida growers are purchasing insurance, as also do growers in the citrus industry to reduce losses.



* Hawaii's production of avocados is not shown in this graph.
Source: California Avocado Commission (CAS), 1998; FAO, 1999 Databases; NASS, 1998.

Figure 4. 26. U.S. Avocado Production by Areas: California and Florida.

4.7.1 US. Avocado Industry Structure

The US. avocado industry is composed, and basically represented by approximately 6,000 avocado growers organised in five districts in California (CAC, 1998). Approximately 40% of the growers in this area are members of co-operative organisations, that in turn, are in charge of selling the fruit in the market. These members are basically like 'shareholders' who are committed to supply the co-operative with 100% of their fruit. The rest of the growers are independent and have the option to choose one or more marketers for their product (Crane, 1996).

The California avocado industry is represented by the California Avocado Commission (CAC) based in Santa Ana California. The CAC, which was created in 1961 is the official information source about Californian Avocados and the California Avocado Industry.

The CAC is funded by a percentage-of-revenue fee established in California's Marketing Act. Market development programmes in consumer advertising, "RipeMax!" Merchandising, Hispanic marketing, public relations, foodservice, industry affairs and production research are funded out of this fee (CAC, 1998). The "Ripemax" programme emphasises merchandising Californian avocados at three levels of ripeness to satisfy all customer needs (CAS, 1998).

The core objective of the CAC is to increase consumer awareness of, and demand for, the fruit.

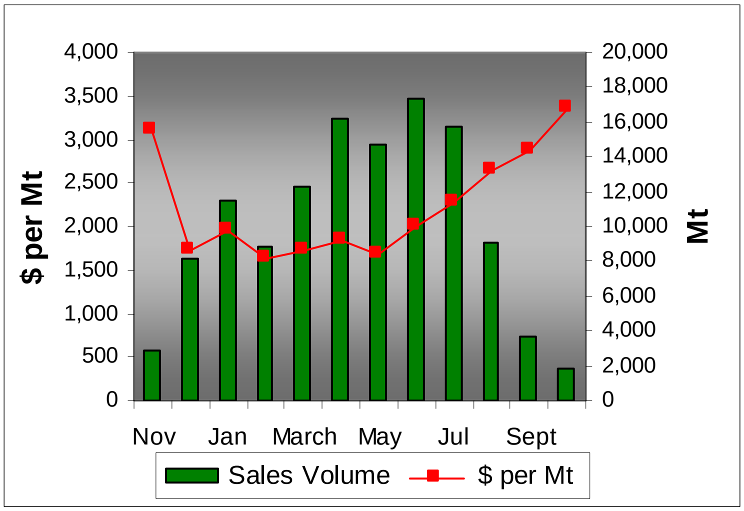
4.7.2 Local Market, Exports and Imports of Avocados

Avocado constitutes one of the top 20 fruits sold in the United States (CAC, 1994). Avocado per capita consumption in the United States grew to its maximum of 1.1 kg in 1987. However freezing weather in the 1990s in California lowered production for various seasons, resulting in high prices. High prices caused a decrease in the consumption to 0.9-1.0 kg (top level reached in 1993), level at which it has basically remained. (FCIC, 1997).

Avocados are sold mainly in the fresh market and consumed as fresh in salads and especially in the preparation of guacamole. The principal consumption market for the fruit is Los Angeles. This is considered the world's largest single market for avocados. San Francisco and San Diego markets are also categorised among the top 10 for consumption (CAC, 1998).

Local market figures indicate that during 1997 more than 42% of U.S. households purchased avocados, up 32% from ten years ago (CAC, 1998). As the most widely grown cultivar, Hass accounts for 80% of consumption in the U.S market, nonetheless, Fuerte is also an established favourite cultivar among consumers. Around 122,000 and 2,000 tonnes of Hass and Fuerte fruit respectively were sold in the local market during 1997 (CAC, 1998).

Prices of US- grown avocados in the local market vary according to the availability of produce. For instance, Hass achieves higher prices during low production months, October and November than during the rest of the year (1997) (Figure 4.27).



Source: California Avocado Commission, 1997/1998 reports.

Figure 4. 27. Sales Volumes and Prices per Mt of California Hass in the Local Market during 1997.

California produces avocados year round but the largest volume is shipped between March and August while Florida's selling season extends from June through March, with the major part between August and December.

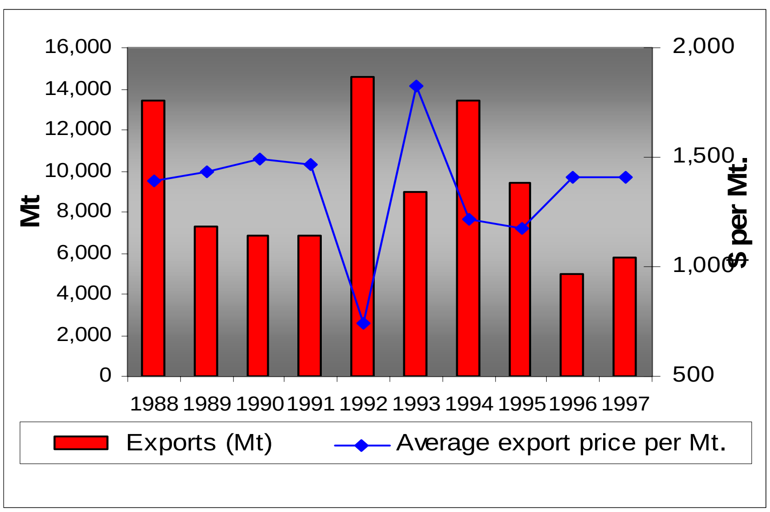
Hawaiian avocados are seldom present in the local market. The government authorises the entrance of Hawaiian avocados into the US. only if the fruit undergoes cold postharvest treatment to eliminate the risk of fruit fly infestation. Hawaii's small production is destined for the local market and other winter markets outside the continental U.S (Hawaii Department of Agriculture, 1997), such as Alaska, where, due to cold weather, there is low risk of pest survival.

On the other hand, U.S exports in 1997 totalled 5,819 tonnes accounting for 3% of the national production. This volume seems very low for such a large producer as the United States. This export volume was almost the same as for the previous year (5,001 tonnes), (Table 4.18). Apparently low prices (on average $1,300 per metric ton) received in foreign markets, a strong American dollar and increasing domestic demand have discouraged exports in recent years, (Figure 4.28).

Table 4. 18. Production, Internal Demand and Export Volumes of US- grown Avocados

Year	Production Mt	Exports Mt	Internal Demand* Mt	% Exported
1988	174,722	13,384	161,338	8
1989	126,147	7,299	118,848	6
1990	141,570	6,849	134,721	5
1991	167,577	6,829	160,748	4
1992	291,550	14,602	276,948	5
1993	143,650	9,015	134,635	6
1994	175,250	13,380	161,870	8
1995	190,250	9,444	180,806	5
1996	173,000	5,001	167,999	3
1997	178,250	5,819	172,431	3

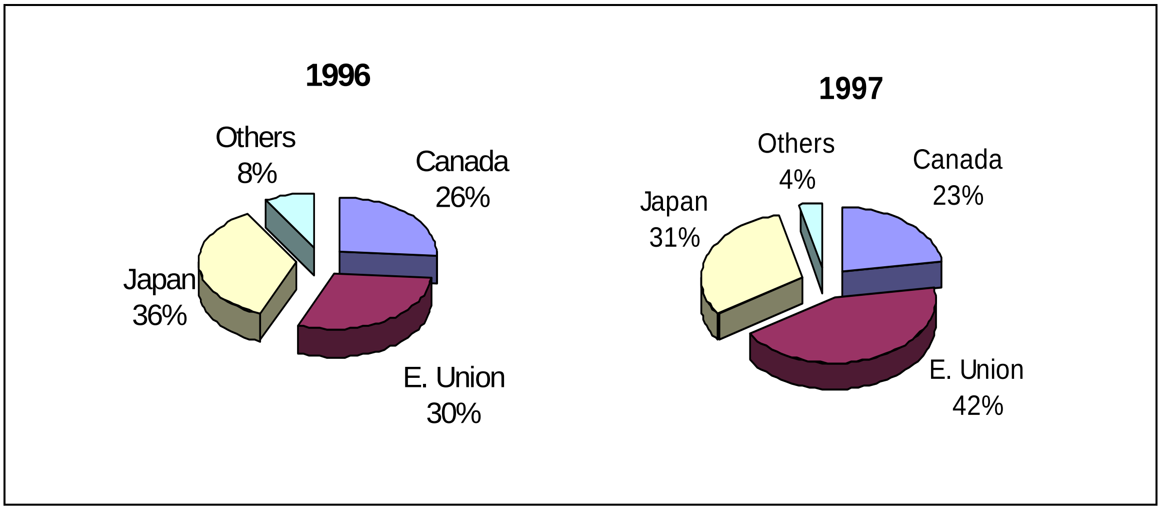
* demand referred to US-grown fruit.
Source: FAO,1999 Databases, NASS, 1998.



Source: FAS, 1998b; FAO, 1999 Databases.

Figure 4. 28. Exports Volume and Value in Dollars per Mt of United States Avocados

The main export markets for US. avocados are the European Union, specifically France and the Netherlands, also Japan and Canada (FAS, 1998b). In 1992 the US. experienced a bumper crop of almost 300,000 tonnes. This high volume allowed the USA to slowly recapture the European market (van Zyl and Ferreira, 1995), (Figure 4.29)



Source: FAS, 1998b, US. Department of Agriculture.

Figure 4. 29. Percentage of U.S Exports by Country of Destination during 1996 and 1997.

While the US. is recovering its share of the European market, traders are predicting a decrease in the US. share in the Japanese market due to the strong entrance of the Mexican produce. In fact U.S presence in the Japanese market has decreased from 36% in 1996 to 31% in 1997.

Of all the selected countries studied, the United States is the only country which, as well as being a large producer, is also an importer of avocados. This shows that the United States has a rather large internal demand for avocados, having to import especially during California's off-season. For instance in 1997, around 26,000 metric tonnes were brought into the country- almost 30% up from 1995- (Table 4.20, Figure 4.31). The main supplier of avocados to the US. market has traditionally been Chile, but more recently New Zealand has increased its imports to this market.

California and Florida used to supply the whole country with avocados, however, prices varied greatly during low production months. This situation has changed since 1997 when the Animal and Plant Health Inspection Service (APHIS) approved importation of avocados from Mexico-Michoacan to the District of Columbia and 19 north-eastern states: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Ohio, Michigan Wisconsin, Illinois, Indiana, and Kentucky (APHIS, 1997).

The measure has brought many arguments and much discussion; especially on the part of those who are against this approval. The US. industry fears that, if the phytosanitary regulations work well, then Mexican avocados will soon be allowed to enter into the rest of the United States competing with local produce (USDA News, 1996). According to US. industry experts, allowing Mexican avocados open entry into the US. market will impact directly upon the United States avocado industry due to great differences in prices and production volumes, (Table 4.19) (1997 Official reports on this impact are not yet available).

Table 4. 19. Avocado Comparison between the U.S and Mexico

Countries/ criteria	Mexico	USA
Average wholesale price	$0.62 per kg.	$1.06 per kg.
Retail price	$8 (in Canada)	$30 (in US.)
Average Yields	8.5 Mt/ha.	6.4 Mt/ha.
Hectare	90,000 ha.	27,000 ha.
Total Production	800,000 Mt.	178,250 Mt.

Source: US Department of Agriculture News, 1996.

As can be seen, there exists an obvious price advantage of Mexican over the US. produce that could create significant competition for US. growers.

Nevertheless, in the meantime Mexican imports to these 19 states will be allowed only from November through February, and under stringent phytosanitary requirements regulating production, packing and transportation. For instance, Mexican producers will have to apply a country-of–origin sticker to each avocado indicating the phytosanitary number of the packinghouse (NASS, 1997). This time period from November to February precedes the peak harvest of Californian Hass avocados.

To the rest of the country, most of the U.S imports arrive between September and December, and mainly from Chile. Almost 95% of Chile's exports are directed to the US. market. A review of the Chilean avocado industry will be given inside the study of the United States avocado industry.

4.7.2.1 The Avocado Industry in Chile

In 1996 avocados constituted 7.3 % of the total Chilean fruit orchard area, in fourth place after table grapes, apples and pears (CIREN, 1996). Chile produced 55,000 metric tonnes of avocados in 1997, which represents an increase of 8% from 1996 volumes. This increase was due to a large number of orchards reaching bearing age. The area of cultivated land in avocados in Chile has grown from 8,000 ha in 1990 to 16,919 ha. in 1999 (Table 4.20) with most of the expansion having been planted with Hass. This makes Chile the third most important avocado growing country in the world (after Mexico and the USA) (Axxes, 1999). Moreover, the planted land is forecast to increase further, as there is good demand for Chilean produce, which gets attractive international prices.

Table 4. 20. Avocado Planted Area and Production in Chile

Years	Planted Area (ha)	Production (Mt)
1990	8,315	38,800
1991	8,450	39,000
1992	9,144	45,000
1993	9,376	45,000
1994	10,049	50,000
1995	11,560	48,000
1996	12,850	51,200
1997	16,919	51,000

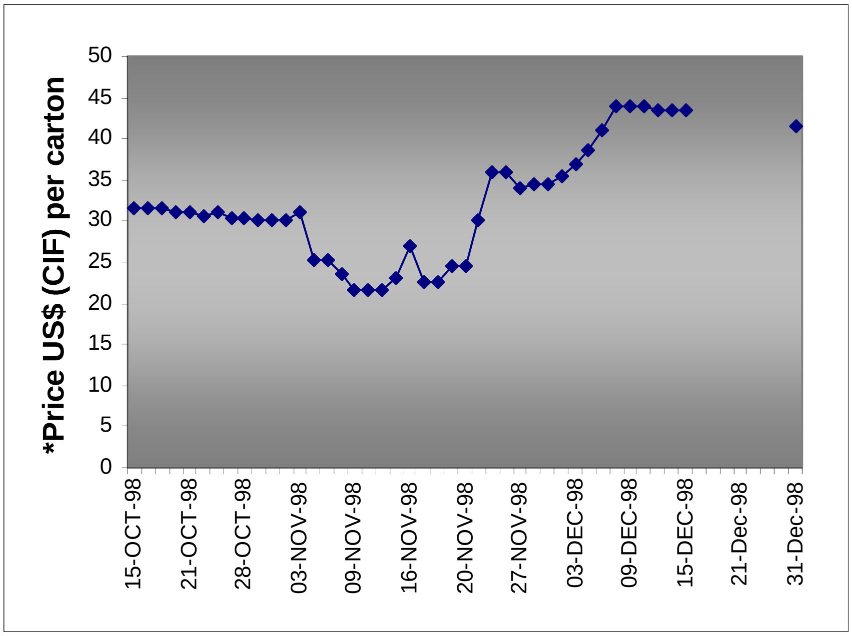
Source: GAIN/ Chile, 1998

More than 80% of production originates in the central part of the country. Chilean production is year- round, and mainly of the Hass cultivar. Hass accounts for over 75% of all avocado production in Chile. Other cultivars (California- type) Negra la Cruz, Fuerte, Edranol, Esther, Bacon and Zutano are also grown, however these cultivars are exclusively for the domestic market (Axxes, 1999).

In comparison to other producer countries, Chilean avocados are naturally free of pests and spraying is not necessary, thanks to the characteristics of the growing regions: arid with little rain (except for winter times). This factor is Chile's main advantage, because it enhances fruit quality and reduces production costs (GAIN/Chile, 1998). Therefore Chile is able to offer good quality produce at competitive prices.

In 1997 Chile exported 30% of its total production, up 3% from 1996. The USA continues to be Chile's largest export market, importing 98% of Chilean export produce in 1997. Since Mexican avocados are permitted access to the U.S. market from November to February, the strategy of Chilean exporters appears to be to export most of their avocados before November (FAS, 1997b). However, Chilean export fruit obtains higher prices after November than during October/ November, months when the bulk of imports from this country arrive. For instance, during the October/ November (1998) period, Chilean produce received prices as low as $21.5/carton for Hass 40s count (ie. 40 avocados per carton), two layer carton, whereas prices are higher prior to October (about $32/carton) and more than doubled to $44.5/ carton after these months (Figure, 4.30). During these months also, New Zealand produce -as well as small volumes from Dominican Republic- arrives.

The Chilean government has no subsidy or special incentives for avocado production.



*Prices for a carton containing 40 avocados
Source: Today's Market Prices, 1999.

Figure 4. 30. Prices of Chilean Fruit count 40 (2 layer carton) in Los Angeles.

4.7.2.1.1 Future Trends

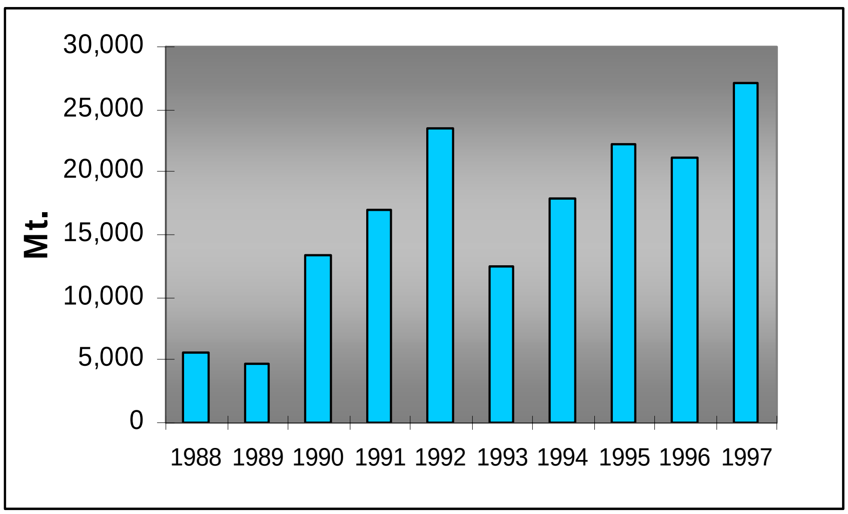
Further increases in Chile's production are expected as Hass orchards planted in recent years come into production. Of total plantings, it is estimated that 50% are still not fully mature. Moreover, Chile's avocado planted area has recently been expanding at the rate of over 500 hectares per year. The total area planted in avocados is expected to expand further in the future, but at a slower rate than in the past (GAIN/Chile, 1998). Thus, due to maturing orchards and excellent weather conditions in all growing areas experts are forecasting over 85,000 tonnes of Hass avocados for 1999.

In order to absorb these large amounts of avocados, Chile is promoting internal consumption through intensive advertising. Domestic avocado consumption in Chile is around 3 kg. per person, which industry sources regard to be low for a producing country (GAIN/Chile, 1998).

Chilean exports are expected to continue to be strong during 1999. Export volumes for 1999 are forecast to increase to 44,000 tonnes, 3 percent above last year's shipments (FAS, 1999).

In addition Chilean producers and exporters looking into the future are also concentrating efforts towards developing new markets in Europe and in Argentine. For this purpose, Chilean producers and exporters are contributing two cents per kilo of fruit exported toward foreign market promotional campaigns. Despite continued efforts to diversify markets, Chile is still dependent on the US. market. For 1998, Chilean exports to the United States reached 27,944 tonnes (FAS, 1999).

The volume of US imports is variable from year to year. There are years of high imports which reflect periods of low domestic production (Figure 4.31). This fluctuation of domestic production volumes may be due to the bearing cycles of the avocado tree: high yields one year followed by low yields the next year (Market Asia, 1995). There is currently intensive research underway to reduce this phenomenon in US. avocado trees.



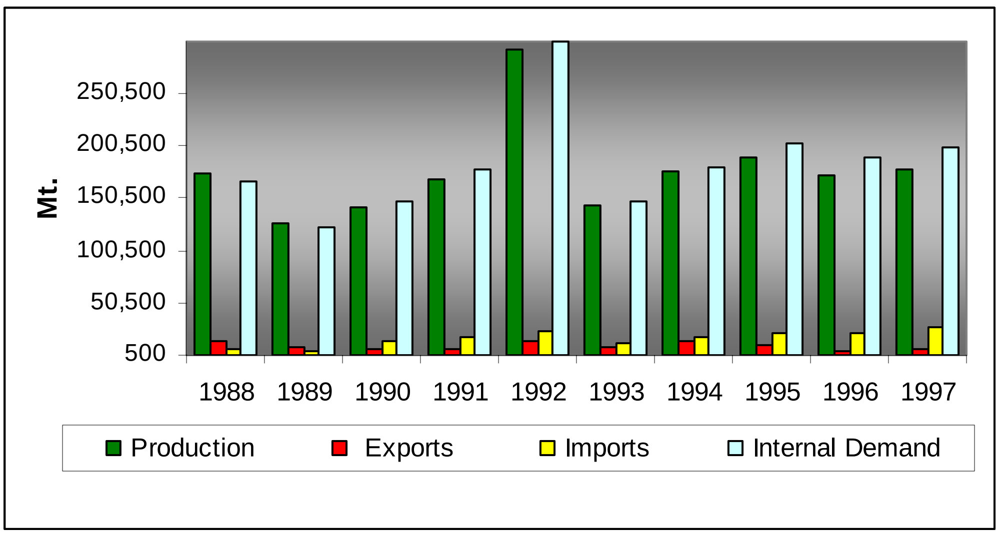
Source: GAIN/Chile, 1998; FAO, 1999 Databases; FAS, 1998.
Figure 4. 31. United States Avocado Imports.

Nevertheless, basically US. consumption has increased at the same pace as the national production. During 1997 US. production was supplemented with avocado imports to cover an internal demand of 199,547 tonnes, 5% higher than during 1996 (Table 4.21, Figure 4.32).

Table 4. 21. Production, Exports, Imports and Total Internal Demand for Avocados in the United States.

Year	Production Mt.	Exports Mt.	Imports Mt	Total Domestic Consumption Mt.
1992	291,550	14,602	23,535	300,483
1993	143,650	9,015	12,466	147,101
1994	175,250	13,380	17,874	179,744
1995	190,250	9,444	22,298	203,104
1996	173,000	5,001	21,175	189,174
1997	178,250	5,819	27,116	199,547

Source: FAO, 1999 Databases; NASS, 1998.



Source: FAO, 1999 Databases; NASS, 1998.

Figure 4. 32. Production, Exports, Imports and Total Internal Demand for Avocados in the United States.

4.7.2.2 Marketing Channels

There are currently 13 marketing organisations and the big fruit seller "Chiquita" in California. These 13 organisations have been in the avocado business for up to 71 years and are all California based. With the exception of two which are co-operatives, the rest are private companies (Crane, 1996). They act as wholesalers, buying the produce from growers and selling it to retailers and processors.

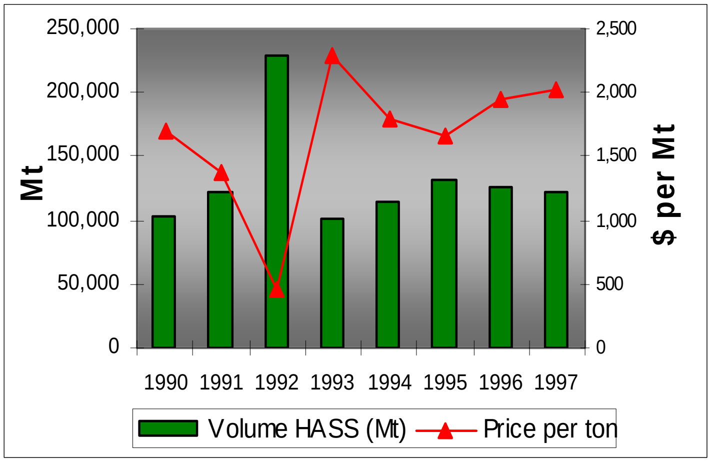
Retail chains are the main channel for fresh avocados through to the consumers. The CAC works very actively in the local market to build brand awareness. Californian avocado promotional campaigns are undertaken through radio, TV and at the point of sale to keep Californian avocados ‘top of mind’. About 60% of U.S. avocado production is consumed in California.

In order to maintain a year-round presence of promotion in the market, the CAC is working on a joint radio advertising campaign with the Chileans who supply fruit during California’s low-season (CAC, 1998). The costs of this campaign total approximately $600,000 of which Chile’s contribution will be 60% (GAIN/Chile, 1998).

4.7.3 Market Prices

Prices in the domestic market are recovering after a boost in production during the 1992 season that caused a drop in prices due to oversupply of the market (Figure 4.26 and Figure 4.33). During 1997 the average price was $2,018 per metric ton, 7% higher than in 1996 but still 12% below the peak of $2,284 per metric ton reached during 1993.

In California avocados are harvested year round, however, the peak season is from February to May when lower market prices are achieved. Low-production months and higher market prices are achieved from June through November. Prices show, therefore, a seasonal pattern. Usually Hass avocado prices at the store are running from about 75 cents to $1 per fruit.



Source: California Avocado Commission Reports, 1998

Figure 4. 33. Total Value and Total Volumes of California 'Hass' Traded in the US.

In order to reduce the pressure on prices during this the October- November period, the United States imports important volumes of avocados (mainly from Chile).

Price is still a cause for concern relating to the entrance of Mexican produce into the United States. Californians fear that cheaper Mexican imports will give rise to a 'black market' and Mexican avocados will be sold outside the permitted area (the north-eastern states). Analysts have estimated that depending on volume, Mexican avocado imports could cause U.S produce prices to drop as much as 17% by 2010 (Groves and Sheridan, 1997). This situation, although negative for the industry, means that American consumers will benefit from increased competition and lower prices.

4.7.4 Future Trends

Crop and tree damage caused by Hurricane Andrew in 1992, and the slow replanting of trees means Florida avocado production is very small in comparison to that of California. Although some increases in production occurred in 1996 and in 1997, no strong resurgence of avocado planting has occurred, nor is expected in Florida. Moreover, last seasons crop (1997) was affected by cold temperatures which were predicted to cause

damage to the 1998 production, for which official data are not available yet. Due to these factors, industry sources anticipate that California will dominate U.S production in the next years (NASS,1997; FAS, 1998b).
In 1999 a 23% lighter than usual avocado crop is to expected from California. The crop may come not only lighter in global volume, but also some days late because of colder than usual temperatures in the main producing areas (data not available yet).

U.S. internal consumption of avocados is anticipated to increase due to the opening of the market to Mexican produce. In addition, the increasing interest of the American consumer in healthy, gourmet foods enhanced with cheap avocado prices-due to increased competition- would raise the per capita consumption to over 200,000 tonnes for the year 2000 (FAS, 1998b). Because of all these factors, the US. still represents an attractive market for avocados.

US. exports of avocados in 1999 are forecast to remain at about 4,000 to 5,000 tonnes. During 1999, total U.S imports are likely to increase significantly to 60,000 tonnes due to the expected smaller U.S production (FAS, 1999).

Observations in this Chapter

This review indicates that avocado producer countries will face major challenges relative to increasing production with low prices over the short and medium term. With the exception of Mexico and the U.S., the rest of the producer countries studied are fairly new in the industry, thus, they possess great potential for growing. With higher supplies expected in all these countries, economic returns will continue to decline.
Information indicates that, in general, producer countries are aware of the importance of becoming more cost-effective e.g. reducing farming costs, and obtaining higher productivity and quality produce.

Worldwide Hass is the major crop cultivated. In the long term, diversification of the industry with alternative cultivars can certainly be another way of coping with oversupply and drops in prices for a single cultivar. Scientific research, therefore, plays an important role in this respect, and is crucial for staying ahead of competitors. Research should also be focussed on the improvement of postharvest techniques to enable avocados to be stored for longer periods, and released only them when better prices are being paid in the market.

The development of new markets is essential to raise avocado consumption, but this could also be an expensive task. However, through joint-market-research projects between countries, same as omnibus-type surveys for market research, costs could be reduced. For instance, a market niche for avocados could be found in China and other highly-populated Asian countries.

It seems fundamental for the success of those involved in the avocado industry to work together in private unions, committees or associations. This industry structure is found commonly practised in all the countries selected for this study. Industry groups allow concentration of especially marketing efforts, and collaboration among the members in order to achieve common goals. In addition, it gives strength to the industry to face competitors in overseas markets.

Among the factors that influence export prices are the volumes traded from competitors, the general economic conditions in importing countries, the cultivar traded, the exchange rate and the quality of the fruit.

In avocado export leader countries usually the local market is supplied with fruit which, without being of bad quality, does not meet export (usually strict) quality requirements. This fruit is rejected (for exporting) due to imperfections in the skin (cosmetic appearance). Forecast increases in production and export volumes would also mean higher volumes of this fruit being sent to the local market as a result of classification and selection operations. Therefore, it is clear that higher investment in local marketing strategies is needed to increase domestic avocado consumption.

Alternatively, the development of industries derived from fresh avocado fruit should also be considered. Processed products such as guacamole, purees and avocado oil constitute industry alternatives for using extra volumes of fresh fruit that could not be marketed either locally or abroad. For the multiplicity of applications and high prices that it achieves, avocado oil represents an interesting industry which should be researched further.

A review of the avocado oil market, and future production estimates will be given in the following chapter.

Table 4. 1. Avocado Production Volumes of the Main World Producers from 1992 to 1997. Mt.

Year	Mexico	USA	Chile	Israel	Spain	Sth. Africa	Dom. Rep.	Indone.	Brazil	Total	WORLD
1992	724,523	291,550	48,000	57,000	53,197	45,710	145,000	93,270	111,742	**1,557,381**	**2,211,825**
1993	709,296	143,650	42,000	42,000	51,745	36,921	160,000	94,000	105,801	**1,378,544**	**2,037,456**
1994	799,929	175,250	58,000	49,400	34,100	37,748	165,000	102,037	102,644	**1,518,278**	**2,166,030**
1995	790,097	190,250	50,000	56,750	27,955	45,428	155,000	162,697	93,767	**1,554,054**	**2,178,033**
1996	802,625	173,000	55,000	70,000	52,085	53,801	155,000	143,151	94,000	**1,604,522**	**2,250,634**
1997	762,336	178,250	53,000	64,000	60,000	44,586	155,000	129,946	94,000	**1,544,791**	**2,213,848**

Source FAO Databases, 1999.

Table 4.12. Mexican Avocado Exports by Destination. Mt.

Year	France	Canada	Japan	U.K.	Nether.	Switzer.	C. Amer.	Others	Total
1992	6,157	2,290	1,640	429	322	2,038	n/a	2,800	**15,676**
1993	8,406	2,087	914	597	123	2,383	n/a	4,319	**18,829**
1994	9,337	3,140	2,270	1,834	429	2,712	n/a	14,028	**33,750**
1995	18,169	4,333	2,847	2,547	886	4,527	n/a	21,286	**54,595**
1996	25,125	7,225	3,316	3,689	1,221	1,883	1,346	34,751	**78,556**
1997	19,050	7,080	4,135	2,770	1,320	579	10,982	3,908	**49,824**

n/a= not available.

Source: United States Department of Agriculture, Attache Reports, 1998.

Chapter 5 Avocado Oil Market Overview and Production Forecast in Selected Countries

5. Introduction

The analysis in Chapter 4 implies that, because avocado plantations in the main producer countries are rather young, world production surpluses are expected. With these increases in production, the volume of undergrade fruit (i.e. fruit that does not meet export quality standards) will consequently increase.

This fact is a concern for avocado industries throughout the world. Usually markets for lower-quality fruit and the local market absorb the volumes of undergrade fruit, however there is a limit for this. Firstly, as consumers tend to opt for sophistication, markets for low quality fruit will no longer exist, and secondly, local markets will become saturated at some point in the future.

Thus, competition to sell fruit will become very tight, and even if producers could sell their avocados, they might not receive prices sufficient to cover production and marketing costs. Therefore, it is forecast that large volumes of low price rated avocados would exist and would force the industry to look for alternative uses for avocados.

One way to utilise these avocados, which at the end cost as much to produce as the export fruit, is by adding value to them through conversion from a primary product to a processed one. With the rapid advancement of technology and increases in the standards of living, new opportunities for traditional primary food industries such as avocados have been created. Technology, enhanced with increasing market competition, has encouraged- and is encouraging- the development of new products. New products such as avocado oil and avocado-derived products such as guacamole and avocado pastes are alternative means of employing surpluses of the fresh industry. Among these products, avocado oil production constitutes a way to extend and add value to the fresh industry because of the high prices this product obtains in the market- although, in general, it is not the producer who receives the benefits of such conversion because they almost always receive less money per kg for processed fruit than for fruit for fresh market. Nevertheless this is an alternative for selling fruit that otherwise would not be sold at all.

Alternatively, avocado growers could get together to process the fruit themselves, and obtain the benefits of such an industry.

Logically, preliminary technical and market research is necessary before entering a new business because the aim of product development research is to create, or to develop, a product which consumers, or the industrial customer, will buy (Schaffner et al., 1998). Limited technical and market research has been published on avocado oil, therefore it is a field where technical and market information constitutes advantage over competitors. Moreover, there appears to be no published information about commercial avocado plantations for oil extraction purposes only, therefore it is thought that the avocado oil industry is a derivative of the fresh industry.

Although Europeans have, for some time, been aware of the special value of avocado oil, this recognition has come much more slowly in the U.S (Swisher, 1988). There is now a strong tendency towards consumption of natural products. Due to controversy about some certain chemicals and their relationship with human diseases, some companies are looking more seriously at the "natural" concept. Natural products are booming in Europe, the U.K and the U.S (Swisher, 1988). This is evident by the large number of sellers of natural products and oils competing in the market.

Avocado oil is widely used in the cosmetics and toiletries industry. The world cosmetic market at retail level has been estimated at US$40 billion annually. This industry is characterised by its fast and constant growth. For instance, the US. cosmetic consumer market was calculated at about US$ 16-18.5 billion in 1990-1993 consuming over US$100 million of natural raw materials (Gilbert, 1995). The US. market for cosmetics and toiletries is expected to reach $29.3 billions in 2003. Manufacturers can expect a volume growth of 3.1% annually over the next five years (Market Studies, 1998). While these figures are for the whole cosmetics and toiletries industry, they give an idea of the width and potential of this market.

In addition, as a food oil, avocado oil could meet the increasing consumer demand around the world for natural oils. Avocado oil has a high smoke point (over 250°C) which make it suitable for cooking. Avocado oil is considered a 'specialty oil' as its production is limited and specialised, therefore it is highly priced.

In general, avocado oil availability is still scarce; this is reflected in the existence of limited production and market information.

Actual prices vary depending on the quality, level of refinement, and country of origin of the oil. In developed countries such as the United States, avocado oil production is expensive because the main expense in this manufacturing industry is the price of the fruit itself. That is why avocado oil in this country is usually a by- product of the fresh fruit industry.

Yields of oil depend on the cultivar, maturity of the fruit and ultimately on the extraction techniques employed (see Chapter 2), however in the industry it is generally considered that the yield of oil will be about 10% of the initial fruit weight (Smith and Lunt, 1981). Unless otherwise stated in this study this value will be taken as a standard.

Around the world there are four main centres of production of avocado oil and other avocado processed products; Mexico, concentrating on the production of processed paste such as guacamole and avocado oil; United States, focussing mainly on the elaboration of guacamole, some edible oil and canned soups; South Africa, devoted solely to oil production using avocado waste; and Israel, producing mash pulps, oil and by-products, shampoos, creams and soaps- which is the most diversified of all four (Bioplus, 1998). Due to their commercial importance and size these producers have dictated world avocado oil prices.

Thus, not surprisingly, the avocado oil industry is dominated by only a few countries that are the main country producers and important exporters of fresh fruit.
The following section is a review, and estimation of the future production of avocado oil in three selected countries: Mexico, United States and South Africa. Israel is not considered in this review due to the general lack of information about the avocado manufacturing industry in that country. In addition, based on the results shown in Chapter 3, an estimation of oil production in New Zealand is given.

Future production levels of avocados are estimated in these countries and a set percentage of production is considered to be the volume of fruit available for oil production. It is recognised that production levels may be negatively affected by many unexpected factors -especially adverse weather conditions such as droughts, floods, frosts or heat waves- and by the natural bearing cycles of the trees from year to year. However, if favourable conditions prevail, avocado production will increase as more trees mature and the industry achieves higher yields of fruit per tree. The interaction of these positive and adverse factors, among others such as government policies, do not allow forecasting for long periods. Thus, a conservative estimate for the next five years seems reasonable.

For oil production estimates, production data of fresh avocados for the past ten years (since 1988 until 1997) have been obtained through the Food and Agriculture Organisation (FAO) databases and from Industry Sources (see Chapter 4). Production data for fresh avocados will be projected for the next five years (until 2005) by means of regression analysis. In some cases two models would fit the trend of the figures, but the best fit in terms of higher R (closer to -1 or +1) value has been chosen. The equation that describes the model according to the pattern shown will be given and used for projecting. This methodology will be used for forecasting and showing avocado production trends for New Zealand and the other countries selected in this study.

5.1. Estimation of the Avocado Oil Production in New Zealand

The New Zealand avocado industry is mainly export-driven. Aside from being the traditional supplier of the Australian market, since 1996 New Zealand has expanded its sales to the United States. As described previously, the United States represents the market with most potential for increasing consumption of New Zealand avocados.

Thus, New Zealand grows avocados mainly to export fresh, and surpluses or second grade fruit is, in the best of cases, sold in the local market. The concern is that avocado production in New Zealand is growing very rapidly and obviously volumes of local market-grade fruit are also expected to increase.

Therefore, increasing actual domestic consumption has become a marketing challenge for the industry. However, developing consumer habits to eat larger volumes of avocados is a difficult task, and the speed of the response might not keep pace with production increases. Although the local consumers will be benefited by perhaps, lower prices due to abundance of produce, this situation is detrimental to growers whose returns would be reduced due to an oversupply.

Thus, soon there will be a necessity for widening the scope of the industry and looking for diversification i.e. finding new ways of employing the production surpluses profitably. It is believed that processing these avocados adds value to the industry and offers innovative products to the consumers.

New Zealanders perceive avocados as a ‘difficult and messy fruit’ thus, there is a possibility that offering processed avocado products will increase consumers ‘ease’ with eating avocados. Those avocado consumers who once experienced frustration when choosing fresh avocados and stopped buying them, could be recovered through indirect consumption of avocado oil and other processed products.

Internationally, avocado consumers are becoming better informed as to the beneficial properties of the fruit oil consumed as food. Therefore, there is also the possibility of them including avocado oil as part of their regular diets. Provided excellent quality oil is produced, the international ‘good quality perception’ for New Zealand fresh avocados can also be expanded to

New Zealand avocado oil. This might mean lower marketing costs and an advantage over competitors.

At the moment there is no avocado oil production or any other avocado processing in New Zealand. Thus, an estimation of the possibility of oil production in New Zealand in the future is provided in the following section.

5.1.1. Analysis and Discussion of the Potential for Oil Production in New Zealand

The estimation of the potential for avocado oil production in New Zealand depends on production of fresh fruit and on the amount of fruit left in the country after exports for local trade. Thus, based on past production numbers from 1988 and different production estimates given by ndustry sources for the years 1999 and 2000, production numbers until the year 2005 have been projected. Growth in production shows a positive relationship with time ($R^2 = 0.91$). The relationship between these two variables is described by the exponential model $Y = 5.5024E\text{-}127e^{(0.1498X)}$ where 'Y' is production and 'X' is years. This indicates a rapid increase in production, and that New Zealand may be producing over 16,000 tonnes of avocados by the year 2005 (Table, 5.1).

In the past three years, New Zealand has exported over 60% of its production. Considering the increasing competition for export markets (especially the US. market) and the marketing difficulties for developing new markets, it is assumed that New Zealand exports would remain at 60% of its national produce over the next few years. Projected export volumes until the year 2005 are shown in Table 5.1.

Usually, the local market absorbs the produce left after exports. Although this produce is sent to the domestic market not all of it is sold, there is a great percentage of avocados that are, at the end, wasted (Industry source, personal communication, 1999). The main reason for this is the current low per capita consumption of avocados in New Zealand. Therefore, it is assumed that, in the event that oil were to be produced, this industry would capture the excesses of fruit and would not affect the local consumption of fresh avocados. Thus it is considered that every year 3% of fruit destined for the local market would be fruit suitable for oil extraction.

Results from the research described in Chapter 3 seem to indicate that there is a time difference in maturation between fruit from the two main avocado growing regions in New Zealand (Te Puke and the Far North). In the case of fruit from Te Puke, the oil content is over 29% from about mid January and remains high until the end of April -while oil content in fruit from the Far North is 25% and over only from February. Thus, fruit from Te Puke always has higher oil content than fruit from the Far North. Results indicate that, at the height of the season oil yields up to 31% can be obtained from Te Puke fruit.

The results imply that fruit from Te Puke could be preferred from the point of view of oil extraction because higher yields can be obtained than from fruit from the Far North.

However, as it is more likely that an oil production plant would source avocados from both regions, in order to keep a continuous supply, an average fruit oil content is considered for this study. The averaged results for fruit from both regions show that high oil yields (over 26%) could be obtained in the last 3 months (February to April) of the season.

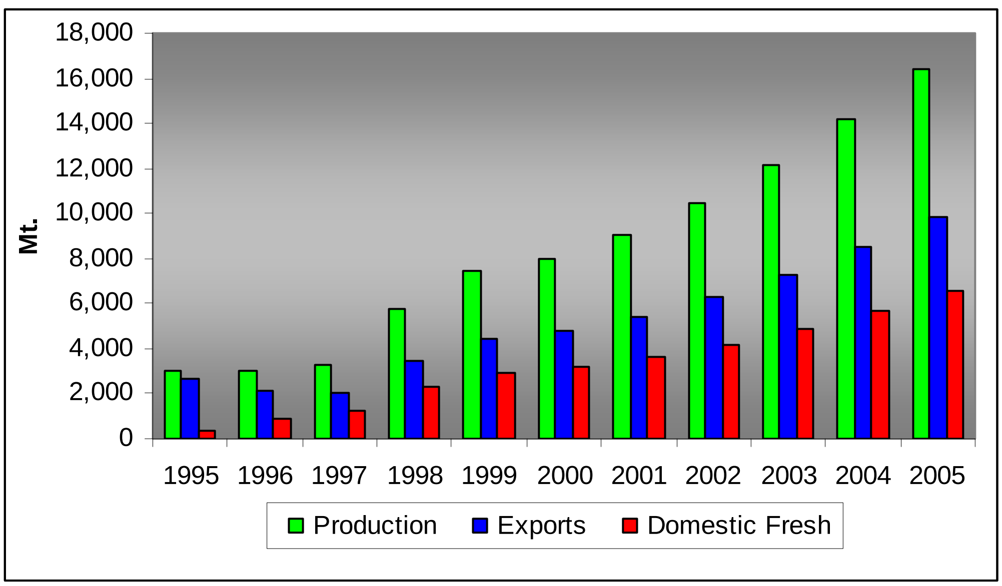
Nevertheless these oil yields would not be totally feasible in commercial practice (i.e. employing a non-solvent extraction method) (see Chapter 2). Thus, it is clear that the percentage of oil extracted varies with the extraction method and with the point of time in the season.

In the estimation of avocado oil production it will be considered that in general, an oil yield equal to 15% of the initial fruit weight can be obtained from New Zealand fruit.

Table 5. 1. Estimate of Avocado Production, Exports and Availability of Fruit for Domestic Consumption (as fresh) and for Avocado Oil Production in New Zealand.

Year	Production Volume (Mt)	Exports Volume (Mt)	Fruit for Domestic Consumption as Fresh (Mt)	Fruit For Avocado Oil (Mt)
1999	7,425	4455	2,970	149
2000	8,000	4800	3,200	160
2001	9,030	5418	3,612	181
2002	10,490	6294	4,196	210
2003	12,186	7312	4,874	244
2004	14,156	8494	5,662	283
2005	16,444	9866	6,578	329

Source: own elaboration



Source: own elaboration

Figure 5. 1. Projected Trend of Avocado Production, Exports and Availability of Fruit for Domestic Consumption (as fresh) in New Zealand.

Great increases in production and export volumes are expected. Out of approximately 16,000 tonnes almost 10,000 of them would be exported. Although New Zealand would continue exporting a major part of its avocados, a stronger domestic market is required to cope with the increases. Currently only 7% of the total population are regular consumers (eat avocados once a week) of avocados, and it is assumed that this figure would remain stable in the middle term (3-5 years). Therefore it is projected that approximately 160 tonnes of fresh produce could be destined for oil in the year 2000, and that this figure would double by the year 2005 (Table 5.1). Of course, the amount of produce supplied to this manufacturing industry depends on the sales of the final oil, thus larger volumes of fruit than those shown in Table 5.1 might be available to be used for oil extraction.

For a relatively young industry such as the New Zealand avocado industry, the prospects for an increasing growth in production and exports are good. In addition, with the marketing efforts that are currently underway it is expected that there will be an increase in domestic consumption of avocados over the next 6 years (Figure 5.1). On current production trends in New Zealand, the likelihood of an oil-extraction plant is not remote. An oil industry in New Zealand would benefit the growers because it would absorb the oversupply of avocados in the local market that otherwise would compete with their premium fruit. As a result, producers would obtain better prices and better returns.

5.2. Estimation of Avocado Oil Production in Mexico

The main destination of Mexican processed avocados is the United States market. The U.S. market absorbs almost 90% of Mexican processed avocados, which are manufactured mainly by U.S. companies operating in Mexico. During 1997, processed avocado exports into the U.S. totalled 11,825 tonnes (valued at $21 million). These processed products included guacamole, paste and avocado oil. These products are demanded primarily by institutions, restaurants and supermarket chains (Market Asia, 1995).

Generally, Mexican processors source their avocados by going directly into the orchards to choose the product they prefer. They may choose to buy either the total production of the orchard or fruit from individual trees. They send trucks with plastic boxes to collect the fruit, and may contract a picking company to ensure they get the quality fruit they want (FAS, 1998b).

“Avoleo” is known as the first avocado oil factory installed in Mexico. It commenced operation in 1989 processing about 150 tonnes, which placed it among the largest avocado oil producers in the world.

There is scarce and limited statistical information about avocado oil in Mexico, however industry sources report that around 10% of the total production represent undergrade fruit suitable for avocado oil production, and that this percentage is likely to remain at the same level for the following years (Bioplus, 1998).

Thus, considering that 10% of Mexican national production will be regarded as fruit not suitable to meet market requirements but suitable for avocado oil production, and that this proportion will remain stable, the availability of fruit for oil processing for the next five years can be estimated.

5.2.1. Analysis and Discussion of the Estimation of Oil Production in Mexico

Data for avocado production in Mexico from the past ten years (from 1988 to 1997) fit a logarithmic regression model: *Y = -606,480,494.6 X + 79,920,280.6 LnX* (where 'Y' is production and 'X' is time) showing a high positive relationship with time in years (R^2 = 0.82). Using this equation, the values of avocado production for the next five years were predicted, (Table 5.2).

Projected values show that national production would increase from 762,000 tonnes in 1997 to 1,185,000 tonnes towards the year 2005.

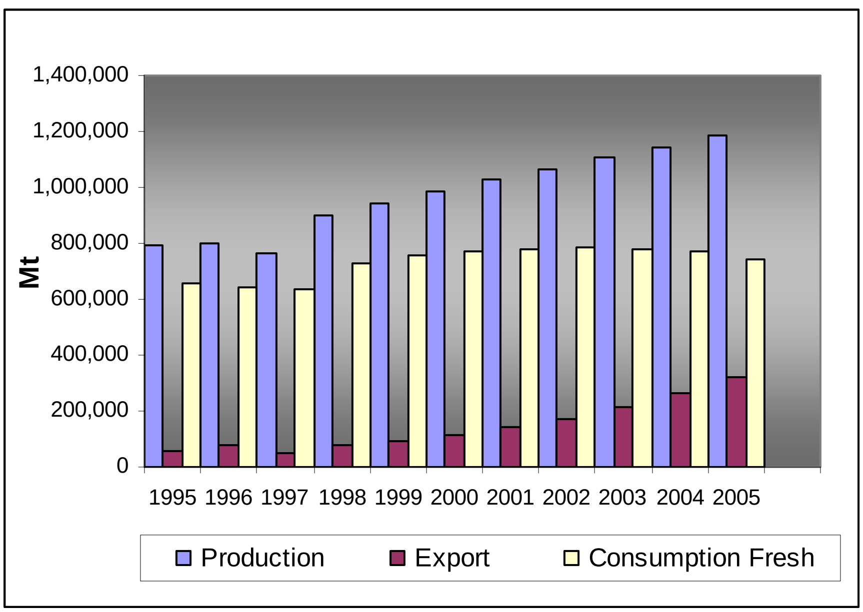
Table 5.2. Estimate of Avocado Production, Exports, and Availability of Fruit for Domestic Consumption and Avocado Oil Production in Mexico

Year	Production Volume (Mt)	Export Volume (Mt)	Fruit for Domestic Consumption as Fresh (Mt)	Fruit For Avocado Oil (Mt)
1999	945,793	93,763	757,451	94,579
2000	985,764	115,166	772,022	98,576
2001	1,025,714	141,454	781,689	102,571
2002	1,065,644	173,742	785,337	106,564
2003	1,105,555	213,401	781,598	110,556
2004	1,145,445	262,113	768,788	114,545
2005	1,185,315	321,943	744,840	118,532

Source: own elaboration

Similarly, export volumes also showed a positive relationship with time. The relationship between exports and time fits an exponential curve best described by the equation $Y = 3.009E\text{-}174e^{0.2056X}$ (R^2 = 0.91). With this equation export volumes for future years have been obtained. Projections showed that export volumes would increase markedly from 49,000 tonnes in 1997 to 321,900 tonnes in 2005. The main reason for these events seems to be the opening of the U.S. market which means that Mexican produce will be attempting to enter more markets around the world.

Thus, both production and exports show positive growth in future years. However, volume of exports showed an exponential growth while production showed only a linear one. These differential growth patterns may cause an imbalance of supply to the domestic market (it should be remembered that Mexico's domestic consumption is of one the highest in the world). As a result of this, a drop in domestic consumption may occur due to a low availability of fruit in the local market. In fact, projected values (Table 5.2) show that every time more fruit would be destined to be exported and less would be available for the internal market. This situation would put pressure on domestic prices, which could be an issue in a domestic market such as Mexico, where demand seems to be price-driven. Projections show that internal consumption of fresh will increase slightly at the beginning, then start to decrease towards the year 2005, (Figure 5.2).



Source: own elaboration

Figure 5.2. Projected Trend of Avocado Production, Export and Availability of Fruit for Domestic Consumption (as fresh) in Mexico.

These trends mean that volumes of avocados which had not been exported would not be able to be sold. Manufactured avocado products will be the alternative for using these volumes of avocados and presenting them to the public with a higher –perhaps justified- price than fresh fruit.

As a result of the increase in the dynamics of the Mexican avocado industry, the availability of fruit suitable for avocado oil would increase (Table 5.2) by about 55% for the year 2005 with respect to 1997 figures. In addition, considering 10% oil yield in the extraction process would mean that avocado oil production in Mexico would be about 11,850 tonnes in the year 2005.
Mexico fruit is increasing both in quantity and quality, thus, it has the advantage of cheap good quality raw material for oil extraction. For these reasons, Mexico is one of the countries with more potential for oil production.

5.3. Estimation of Avocado Oil Production in South Africa

Avocado production in South Africa has shown great variability in past years. Nevertheless, usually about 50% of the crop is exported, and internal consumption either as fresh or as processed avocados represents 35% of the national production.
Average figures for the last five years indicate that approximately 2% of the total production is generally fruit destined for processing. The avocado-based manufacturing industry in South Africa specialises in the production of avocado oil more than other avocado processed products.

5.3.1. Analysis and Discussion of Avocado Oil Production in South Africa

South African avocado production for the past ten years (from 1988 to 1997) shows high variability with time and no definitive trend. With such figures a strong relationship in time could not be found. The avocado industry however, is forecasting large increases in production taking in account that 47.5% of the trees had not reached full bearing age (more than 6 years of age). In fact, industry sources expect that avocado production in South Africa will double within the next five years from 1998 (given favourable climatic conditions).
Market demand, both export and local, will be forecast by means of regression analysis with time (in years). There is a proportion of avocados that are sold through other outlets to the informal sector, which will be ignored, as no reliable data are available.

Considering these factors, linear regression analysis will be applied for estimating production of avocados in the next five years. Production and time were found to be positively related using the regression model $Y = 283.39X + 43120$. ($R^2 = 0.2$). This equation was used to calculate future values. Values in Table 5.3 show that South African production would increase from 44,586 tonnes in 1997 to 48,221 tonnes towards the year 2005. In contrast to Mexico, South African exports showed a negative but linear relationship with time. The export function curve is described by the equation $Y = 839015.5 + -407.56\ X$ ($R^2 = -0.32$). With this equation export volumes for future years have been obtained. Projections showed that export volumes would tend to decrease slowly from 24,296 tonnes in 1999 to 21,850 tonnes in 2005. In addition, the availability of fruit for domestic consumption as fresh shows a tendency to increase (Figure 5.2).

Similar analysis of the industry, future reduced exports with increasing production, might have led the South African avocado industry to reinforce the marketing strategy in the domestic market with aggressive integrated campaigns to recover consumer confidence in avocados. Strengthening the domestic market is currently part of the industry strategy in the view of the increasing competition in the European market, i.e. the recent strong presence of Mexican and Chilean produce in Europe, not to mention the increasing trend in the production of avocados in Israel.

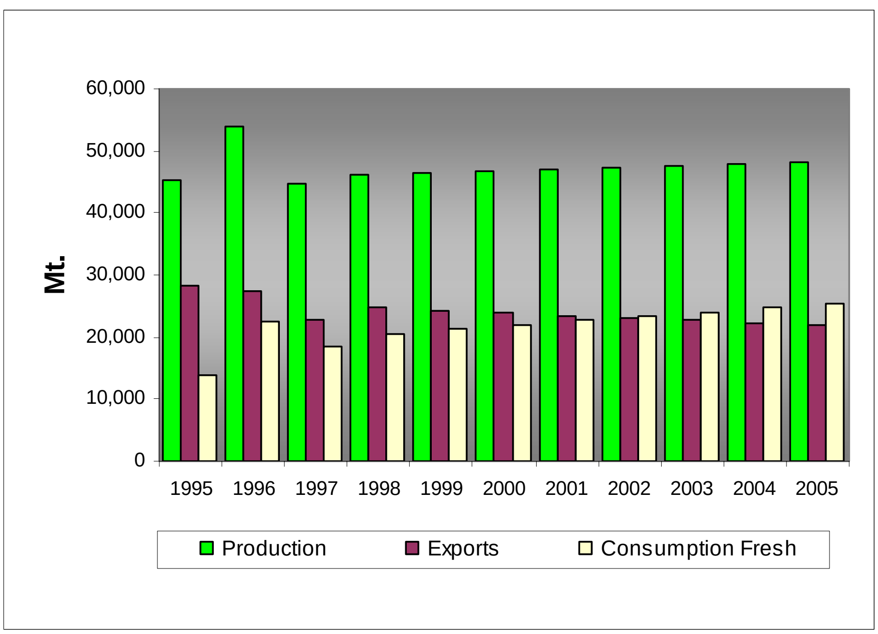
Therefore, it is expected that more produce will be seen in the domestic market, which could also be produce suitable for further processing. According to the forecast, by the year 2005 about 960 tonnes would be destined for oil extraction which is 4% more than 1999 volumes. With the standard of 10% oil yield, it is estimated that South Africa will produce nearly 100 tonnes of avocado oil in 2005.

It seems that, although South Africa has already an avocado oil industry, it is fairly small. However in the long term, it is expected that this processing industry will grow as local market quality demands become more and more stringent- due to current local marketing strategies, all surplus and undergrade fruit is kept off the markets.

Table 5.3. Estimate of Avocado Production, Exports and Availability of fruit for Domestic Consumption as fresh and Avocado Oil Production in South Africa.

Year	Production Volume (Mt)	Export Volume (Mt)	Fruit for Domestic Consumption as Fresh (Mt)	Fruit For Avocado Oil (Mt)
1999	46,521	24,296	21,294	930
2000	46,804	23,888	21,980	936
2001	47,088	23,481	22,665	942
2002	47,371	23,073	23,351	947
2003	47,654	22,666	24,035	953
2004	47,938	22,258	24,721	959
2005	48,221	21,850	25,407	964

Source own elaboration



Source: own elaboration

Figure 5.3. Projected Trend of Avocado Production, Export Volumes and Availability of Fruit for Domestic Consumption (as fresh) in South Africa.

5.4. Estimation of Avocado Oil Production in the United States

The United States is considered the second largest consumer of avocados after Mexico. For the past ten years internal consumption of fresh avocados has being rising at almost the same pace as national production with irregular amounts of avocados imported and only reduced volumes of export since 1995. This market behaviour reflects good prediction tools by the US. avocado industry, which seems to have closely anticipated production volumes, and which had prepared the local market to absorb the majority of the produce.

Thus, it can be seen that the United States possess a strong avocado fresh market industry which in turn might imply only a small processing industry. In fact, total domestic consumption indicates that almost all the crop is sold to be consumed as fresh and only small volumes are destined for processing –meaning, in general terms, a good quality crop. This situation makes it difficult obtaining avocados to be used as raw material for oil extraction.

Since 1991, California started to use avocados for processing-however, this production later ceased due to the high cost of the avocados (used as raw material). Currently it is estimated that less than 5% of US-grown avocados go for the manufacture of avocado-derived products. However, recently there has been a noticeable and substantial increase in the demand for pulp or retail-ready processed avocado especially from Mexico (FAS, 1997a). For instance, guacamole sales in supermarkets grew over 12% in 1998 and is projected to double by the year 2000 (CAC, 1999).

Avocado oil is also among these processed products, although guacamole and frozen pulp are the main products demanded in the local market. Thus, about 10,000 tonnes of prepared avocado products are imported from Mexico each year (FAS, 1998a).

Executives from ‘Calavo’, one of oldest and most important avocado companies in the US, referred to the avocado oil industry as a business with big potential because of the every time stronger consumer trends towards ‘natural foods’. However, the limiting factor for expanding this business is the high cost of the fruit itself. That is why ‘Calavo’ produces avocado oil not from whole fruit but from the pulp left in the skins after the guacamole operation.

Other US. firms may in fact process avocados in Mexico as they are cheaper there than in the US, and transport the extracted oil to the US. However, it is thought that these operations will be performed only for a previously placed avocado oil order. The rest of the time only small stocks of this product are stored. Apparently this would be the only way of selling the product at competitive prices in the local and international markets

5.4.1. Analysis and Discussion of Avocado Oil Production in the United States.

For the following estimates it is considered that 2% of the national production is destined specifically for the manufacturing of avocado oil. This percentage would allow estimating the future availability of fruit for this industry in the medium term (next five years).

Production of avocados showed a linear growth with time, and by the year 2005 it was estimated that production would be around 209,270 tonnes. The equation describing the positive relationship between these two variables is: $Y = -7{,}184{,}454.5 + 3687.6\ X$ ($R^2 = 0.6$) where 'Y' is production in metric tonnes and 'X' is the time in years. From these projected figures the quantities of fruit which would be destined for future oil processing were calculated.
In order to obtain a complete scenario of the avocado US. industry in the future, the volume of exports, domestic consumption and imports were also projected. United States exports and time variables were found negatively related ($R^2 = -0.4$) through an exponential function $Y = 4.526E37.e^{(-0.0390\ X)}$. As domestic consumption has increased at the same pace as the national production, these two variables have been projected together for the next five years. Using linear regression analysis, U.S domestic consumption and production were found to be positively related ($R^2 = 0.98$) by the equation $Y = -1415.2 + 1.05\ X$ where 'X' represents production and Y represents domestic consumption. Similarly, as the levels of imports (Y) depend mainly on the demands of the internal market (X) these two variables were analysed together and a logarithmic relationship found between them $Y = -271929 + 23852.5\ Ln\ X$ with R= 0.76.
All these equations have been used to estimate future industry trends as shown in Table.5.4.

Table 5.4. Estimate of Avocado Production, Exports, Imports and Availability of Fruit for Domestic Consumption as fresh and Avocado Oil Production in the United States

Year	Production Volume (Mt)	Exports Volume (Mt)	Imports Volume (Mt)	Fruit for Domestic Consumption as Fresh (Mt)	Fruit For Avocado Oil (Mt)
1999	187,144	6,306	18,619	195,049	3,743
2000	190,832	6,065	19,088	198,921	3,817
2001	194,520	5,833	19,532	202,792	3,890
2002	198,207	5,610	19,998	206,663	3,964
2003	201,895	5,396	20,441	210,535	4,038
2004	205,583	5,189	20,876	214,406	4,112
2005	209,270	4,991	21,303	218,277	4,185

Source: own elaboration

Results of the regression analyses show a decreasing trend towards the year 2005 for exports from the US., while the domestic consumption increases (Figure 5.4). Domestic consumption of avocados has been forecast to increase as Mexican produce (in the long term) gains access to other parts of the territory at competitive prices. However, it is estimated that national production would be large enough to cover for most of this demand keeping import volumes increasing but at a slow rate (Table 5.4).

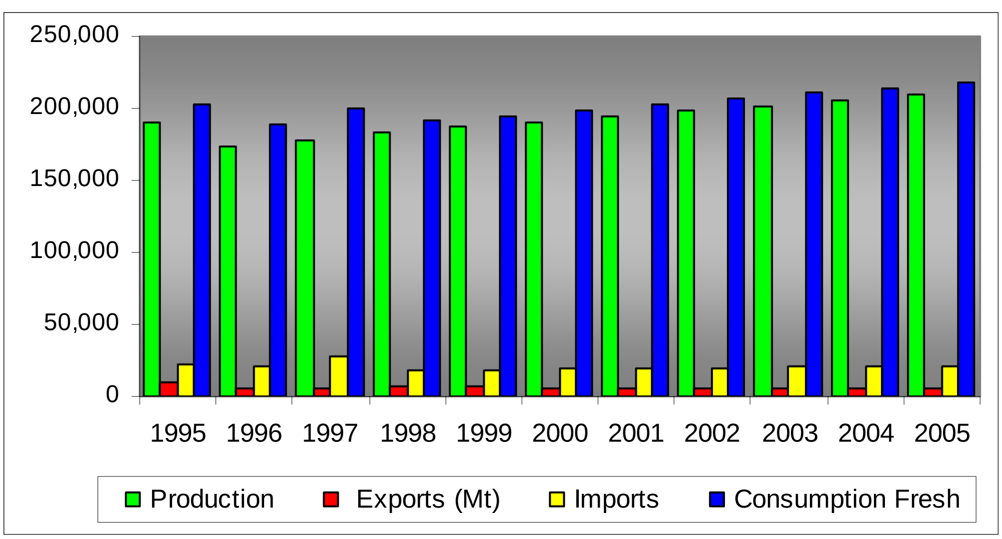


Figure 5.4. Projected Trend of Avocado Production, Export and Imports and Availability of Fruit for Domestic Consumption (as fresh) in the United States.

The availability of fruit for avocado oil extraction would increase to over 4,000 tonnes by the year 2005 (Table 5.4). This volume of fruit would yield approximately 400 tonnes of oil (considering 10% standard yield) which can be used for different applications. Avocado oil is already widely used in the cosmetic industry, but thanks to recent extraction technologies, avocado oil suitable for human consumption is more commonly found on the supermarket shelves. Moreover industry sources estimate that, as more and more people become aware of the healthy nutritional properties of avocados and avocado oil, (which are similar to if not better than olive oil) the demand for such products would increase and therefore a stronger oil industry would emerge in the United States. In the United States the value of the market for avocado oil has been estimated at 2 million dollars (Hough, 1991).

Observations in this Chapter

Analysis of the avocado industry in the selected countries shows that in general export volumes would tend to increase at a slower rate than production rates. These factors would eventually bring an oversupply of the fresh market. Consequently, export prices would tend to decrease, making competition even more difficult. Low prices would favour internal consumption but discourage growers and exporters.
These factors would negatively affect the avocado fresh industry around the world.

The increasing world production trend of avocados would encourage the search for developing products that can employ the future oversupply while remaining profitable. Avocado oil production might represent a profitable alternative, as it seems generally to use avocados that otherwise might not generate any revenue.

The New Zealand avocado industry is rather young and large increases in production are estimated. In the medium term (5 years) exports to the Australian market would decrease, although, it seems they will be compensated for with exports to the United States, a promising market. However, competition in the US. market is expected to increase, therefore exports from New Zealand might not maintain the so far increasing rate in the long term. Thus increasing volumes of fruit would be sent to the local market but the New Zealand consumer might not be ready to buy such volumes of avocados. The New Zealand avocado industry needs product diversification. Avocado oil production might represent a profitable alternative because it constitutes an outlet for fruit surpluses and undergrade fruit which, after all, cost as much to produce as the export fruit. Moreover, as a value- added product, avocado oil obtains higher prices than fresh fruit in the market.
Fruit from Te Puke might be preferred over that from the Far North for oil extraction due to higher oil content.
In addition, oil production could be a means of controlling and stabilising the peak season's production of fruit, meaning better prices for growers.

In general, there are only a few producers of avocado oil around the world. This product is still regarded as a 'specialty' product and, as such, obtains high prices in the market. This is reflected in the limited commercial and production information about avocado oil. Thus, it is possible that more producer countries would consider the production of avocado oil as an attractive business.

Although the market for the product already exists i.e. there is a demand created because of changes in consumption patterns around the world. In the future, a larger proportion of avocados will be sent for processing which will force the strengthening of strategies for the development of avocado oil export markets.

Chapter 6 Conclusions

This work confirmed the high and positive relationship which exists between total lipids and dry matter content in avocados. During the study period (from September 1998 to April 1999) fruit from Te Puke showed consistently higher lipid content (and dry matter content) than fruit from the Far North.

At both sites, the beneficial monounsaturated oleic acid was the major fatty acid synthesised, with fruit from Te Puke showing higher levels of oleic acid than fruit from the Far North. This suggests that there may be a regional effect influencing the synthesis and composition of lipids in the fruit, which is likely to be due to temperature. Further research is necessary to determine the extent of this effect.

The ratio of monounsaturated (oleic and palmitoleic acids) to saturated fatty acids (palmitic acid) and the ratio of polyunsaturated (linoleic and linolenic acids) to saturated fatty acids is higher for Te Puke fruit than for Far North fruit. These fatty acids ratios for both regions are similar to those of olive oil.

According to the results, at both sites 24 percent dry matter is reached around September and is equivalent to 17 percent lipid content, more than double the traditional level of lipid required for the commencement of harvesting California fruit (8 %).

Further research is needed to see if New Zealand fruit from Te Puke, or perhaps from another growing region, could be harvested earlier than its competitors in the Southern Hemisphere (ie. Chile) in order to obtain higher prices, without affecting fruit quality.

New Zealand avocado production has increased at an average annual rate of 15% since 1995. The industry is rather young, with almost 40% of the total area (472 ha) planted with trees less than 10 years of age, which means that they have not reached full maturity, leaving potential for further increases in production. In general, the reasons for this situation are; the increasing interest in the industry (apparently profitable) by new growers, more avocado trees planted recently and the young age of the trees.

The New Zealand avocado industry is export driven, with over 50% of the crop being exported. The main export markets are Australia and (more recently) the United States, with only small and inconsistent amounts of produce yet being exported to other countries.

So far, New Zealand avocados have enjoyed premium prices in the export markets. However, with increasing competition, especially in the U.S market, prices are expected to decrease. Although New Zealand would continue exporting a major part of its avocados, a stronger domestic market is required to cope with the anticipated increases in production. The industry has realised the need to further develop the domestic market and increase the local consumption. Ready to eat avocados, a result of ethylene treatment, have made a difference to both local consumers and handlers. Marketing efforts have slowly achieved improved acceptability of avocados by the New Zealand consumer.

There is a need for the industry to develop a minimum harvest maturity index for avocados in New Zealand's specific growing conditions. If consumer acceptability is the final aim of the industry, then refinement of maturity parameters is needed. This is especially crucial in a quite new and inexperienced avocado-consuming market such as New Zealand, where consumption habits could be created and moulded. To grow the internal avocado market, education is critical to help the consumer overcome purchase barriers.

The main international avocado producers are Mexico, USA, South Africa, Israel and Chile. The main exporters of avocados are South Africa, Israel and Chile. With the exception of Mexico and the USA, the other three countries have relatively young avocado industries. In South Africa for instance, 48% of the planted area has yet to reach full production. In Chile, it is estimated that 50% of the trees have not reached maturity.

Moreover Chile's avocado planted area has recently been expanding at a rate of over 500 hectares per year. The area planted in avocados in Israel is forecast to decrease due to low profitability and low yields per tree.

Mexico and the United States are large producers and consumers of avocados. Especially, Mexican avocados are rapidly gaining popularity and an increased share in the export markets such as Japan and Europe, because of their larger volume and lower prices than those of their competitors. Production of avocados in the United States is irregular with strong bearing cycles. The United States' consumption of avocados is expected to increase, therefore this market represents a good opportunity for all exporters. In this respect, Chile represents New Zealand's main competitor (in the US. and other future markets) because both countries have similar growing conditions, in addition Chilean fruit is cheaper than that from New Zealand.

Analysis of the avocado industry in the selected countries shows that in general export volumes would tend to increase at a slower rate than production. These factors would eventually bring an oversupply of the fresh market. In fact, average export prices have decreased during the years as higher volumes of fruit are traded and new exporters enter into the business.

Usually fruit that is not exported is expected to be sold in the domestic market. In the view of these factors, these countries are devoting more attention to their domestic markets. Marketing strategies are underway in South Africa, Israel, Chile and New Zealand in order to raise internal consumption of avocados.

Domestic consumption of avocados in these exporting countries, however, would not grow as fast as production. New industry alternatives are necessary. One way to utilise surplus of avocados is by adding value to them through conversion from a primary product to a processed one such as avocado oil.

Avocado oil has a high smoke point (over 250°C) which make it suitable for cooking. At present there is a strong tendency towards consumption of natural products. Nevertheless, because avocado oil is still considered a ‘specialty oil’, its production is limited and specialised, therefore highly priced. In addition, avocado oil is widely used in the cosmetics and toiletries industry. This industry is characterised by its fast, constant growth and high prices.

Avocado oil is produced mainly in Mexico, the United States, South Africa and Israel. The quality of fruit from Mexico is increasing providing an advantage of cheap good quality raw material for oil extraction. Therefore Mexico is one country with considerable potential for oil production. Although it seems that South Africa has a small avocado oil industry. However in the long term, it is expected that this processing industry will grow as the quality demands of fresh fruit in the local market improve, and all surplus and undergrade fruit is diverted from the markets to processing. Projected domestic consumption of avocados in the US. indicates that almost all the crop is sold to be consumed as fresh, and only small volumes are destined for processing. U.S industry sources estimated that, as more and more people become aware of the healthy nutritional properties of avocado oil, (which are similar to, if not better than, those olive oil) the demand for such a product would increase, and therefore a stronger oil industry would emerge in the United States. Industry experts in the United States have estimated the market for avocado oil at 2 million dollars.

Oil extraction laboratory techniques used in this study allowed higher yields due to the use of organic solvents. However, organic solvents are not permitted for commercial extraction of avocado oil. The oil percentages obtained in this work are much higher than those that would expected in the industrial extraction. Commercial avocado oil extraction in producer countries such as USA, South Africa and Mexico is by means of pressing and centrifugal force. More Research and Development work is required to improve the efficiency of oil extraction.

In New Zealand, the main cultivar planted is Hass. Hass is being recommended as the most suitable for oil extraction because of its advantages such as a high percentage of pulp relative to the stone, a minimum of skin content, high oil content and availability (fruit that is not suitable for export could be used for oil extraction).

The use of undergrade fruit for processing could represent a means of keeping high prices in the local market during the peak season with economic benefits to the growers.

In every food processing industry the quality of the raw material entering the production line is crucial for the quality of the final produce. This is also true for the production of avocado oil. The quality of the avocados for oil extraction should be such that the only reasons why the fruit is not suitable for export are size and, external and superficial quality problems. In other words, only cosmetic appearance would be the reason limiting its export. The use of rotten fruit would add quality problems to the final oil.

Results for New Zealand grown-fruit showed that oil content in avocados varies from around 15% to 30% depending on the time of harvest. As oil content increases during the season, the best time for processing avocados would be during the last three months of harvest in February, March and April.

At the moment there is no avocado oil extraction in New Zealand. However, projections showed that, if an oil industry is developed, by the year 2005 approximately 330 tons of fresh produce could be destined for oil extraction.

In addition, oil processors might want to use only fruit from Te Puke, as its nutritional quality could be used as a marketing advantage over oil produced from other regions. Te Puke fruit contained higher levels of oil than Far North fruit, therefore higher yields could be obtained during commercial oil extraction. However, if oil processors obtain their avocados from both regions, then the nutritional advantage of fruit from Te Puke would disappear.

Values for fruit from Te Puke (in New Zealand) are very similar to those from the USA, (with the exception of linolenic acid). Therefore New Zealand fruit from Te Puke could be marketed as being of the same nutritional quality, in terms of fatty acids, as fruit from California in the USA.

Limited technical and market research has been published on avocado oil, therefore a company or a country that possesses such information will gain an advantage over competitors. Moreover, no information is available about commercial avocado plantations planted solely for oil extraction purposes.

The data obtained in this report should be regarded as preliminary information and a basis for further research both in the fresh industry and in the future avocado processing industry. Future studies should include seasonal changes in avocado lipids related to organoleptic characteristics. These findings must be validated over more than one harvest season before recommendations may be made to growers and processors.

Chapter 7 References

- Aguilera- Montañez, J. L. and Salazar-García, S. 1991. The Avocado Industry in Michoacán, Mexico. South African Avocado Growers' Association. Yearbook. 14, 94-97.

- American Heart Association (AHA), 1998. Cholesterol. Internet site. http://americanheart.org/Heart_and_Stroke_A_Z_Guide/tfa.html

- Andrikopolous, N. K. 1989. The Tocopherol Content of Greek Olive Oils. Journal of The Science of Food and Agriculture. 46, 503-509.

- ANON, Gourmet Oils in the 1990s. International News on Fats, Oils, and Related Materials (INFORM). 2, 2. 98-112.

- APHIS (Animal & Plant Health Inspection Service), 1997. US. Department of Agriculture. Importing Mexican Avocados. Fact Sheet. http://aphisweb.aphis.usda.gov/oa/avofact.html

- Appleman, D. 1969. Personal Communication with Biale and Young 1969. In: The Biochemistry of fruits and their products. Hulme, A.C (Ed) Academic Press, London, pp 16-19.

- Asociación Agrícola Local de Productores de Aguacate de Urupan Michoacán (APROAM). Web site. http://www.aproam.com

- Avo News, March and June 1999. New Zealand Avocado Industry Council and the New Zealand Avocado Growers Association.

- Avo Flyer, November 1998. New Zealand Avocado Industry Council.

- Avo Flyer, January. 1999. New Zealand Avocado Industry Council.

- Avocado Industry Council, New Zealand (AIC), 1999.

- Axxes, Chile, 1999. Financial Consultants http://www.axxes.cl/

- Bailey, R. 1994. An Overview of the New Zealand Avocado Industry. South African Avocado Growers Association. 17, 121-122.

- Barber, R. F. and Lyford P. B. 1999. Horticultural Business Associates. Avocado Crop Estimates.

- Barron, E. J. and Sumpf, P.K. 1962. Fat Metabolism in Higher Plants, XIX. The Biosynthesis of Triglycerides by Avocado Mesocarp Enzymes. Biochemica and Biophysica Acta 60. 329-337.

- Barry, G.A; Brown, B. I and Baker, L.R. 1983. The Use of Low-resolution Nuclear Magnetic Resonance for Determining Avocado Maturity by Oil Content. Journal of Food Technology. 18, 401-410.

- Ben-Et, G; Dolev, A and Tatarsky, D. 1973. Compounds Contributing to Heat-induced Bitter Off-flavour in Avocado. Journal of Food Science, 38, 546.

- Berger, K.G. and Hamilton,R. J.1990. Lipids and Oxygen: Is Rancidity Avoidable in Practice? In: Developments in Oils and Fats. Edited by Hamilton, R. J. First ed. Blackie Academic & Professional.

- Bergh, B. O. 1975. Advances in Fruit Breeding, ed. J Janick and J. N Moore. Purdue University. Press, West Lafayette.

- Bergh, B. O. 1985. Avocado Varieties for California. Yearbook of the California Avocado Society. 68, 75-93.

- Bergh, B. O. 1991. The Avocado in Human Nutrition. World Avocado Congress II. The shape of things to come. California. USA.

- Bergh, B. and Ellstrand, N. 1989. Taxonomy of the Avocado. California Avocado Society Yearbook. 135-145.

- Bergh, B; Kumamoto, J and Chen, P. 1989. Determining Maturity in Whole avocados. California Avocado Society. Yearbook. 173-176.

- Biale, J.B and Young, R. E. 1969. The Avocado Pear In " Biochemistry of fruits and their products" Ed. Hulme.

- Bioplus, 1998. Aguacate. http://www.bioplus.com.mx/aguacate.htm

- Bligh, E.G and Dyer, W.J. 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology, 37. 911-917.

- Bower, J. P. 1978. Ecophyisological Studies of Three cvs. of Persea Americana (Mill.) Emphasising Photosynthesis and Internal Water Relations. M.Sc. Agric. Thesis, University Natal, Pietermaritzburg.

- Bower, J.P; Wolstenholme, B. N; and De Jager J. M. 1978. Incoming Solar Radiation and Internal Water Status as Stress Factors in Avocado Persea Americana (Mill). Cv. Edranol. Crop Production. 7. 129-134.

- Bower, J. P and Cutting, J.G. 1988. Avocado Fruit Development and Ripening Physiology. Horticultural Review, 10, 229-271.

- Carrol, J. 1998. Interviewed in "New Zealand Avocados Experience Success in the U.S. Market". Australia- New Zealand Direct Line (ANZDL). http://www.anzdl.com/about/Press/Avocados.asp

- CAC, California Avocado Commission. 1999. http://www.avocado.org/commission/comm44.shtml

- CAG, California Avocado Growers, 1999 and California Avocado Information site. University of California Co-operative extension http://www.avocado.org/growers/grow128.shtml.

- California Rare Fruit Growers (CRFG) Inc. 1998 Internet site. http://marketreport.com/avocados.htm

- Christie, A.W. 1939. California Avocado Association Yearbook. 24, 73.

- Christakis, G; Fordyce, M.K and Krtz, C. S. 1980. The Biological Aspects of Olive Oil. Proceedings of the International Congress Biological Value of Olive oil, 3rd, Chanea Greece.

- Church, C.G and Chace, E. M. 1922. Some Changes in the Composition of California Avocados During Growth. Washington D.C. US. Department of Agriculture. Bulletin No 1073.

- CIREN, Centro de Informacion de Recursos Naturales de Chile, 1996. http://www.fruitonline.com/statist3.htm 30/05/1999

- Coffland, R. 1991. Interviewed In: Gourmet Oils in the 1990s. International News on Fats, Oils, and Related Materials (INFORM). 2, 2. 98-112.

- Colguhoun, D. M; Moores, D; Sommerset, M and Humphries, J. 1992. Comparison of the Effects on Lipoproteins and Apolipoproteins of a Diet High in Monounsatuarted fatty acids, Enriched with Avocado, and a High-carbohydrate Diet American Journal of Clinical Nutrition, 56, 671-677.

- Committee on Medical Aspects of Food Policy (COMA). 1984. Report on Health and Social Subjects No 28, HMSO, London.

- Cork, L. 1999. New Zealand Avocado Local Market Promotion Officer. The Marketing Department.

- Crane, A. 1996. Technical and Economic Aspects of the Harvesting, Packing and Transporting of Avocados in the United States of America. California Avocado Society. Yearbook. 45-55.

- Cutting, J. 1999. Industry Technical Manager of the Avocado Industry in New Zealand.

- Cutting, J.G.M. and Wolstenholme, B.N. 1992. Maturity and Water Loss Effects on Avocado (Persea americana Mill.) Postharvest Physiology in Cool Environments. Journal of Horticultural Science, 67 (4), 569-575.

- Da Gama Avocado Oil, 1998. PO Box 51, Hazyview 1242. South Africa.

- Davenport, J.B and Ellis, S.C. 1959.Chemical Changes during Growth and Storage of the Avocado fruit. Australian Journal of Biological Sciences. 12, 445-454.

- Dolendo, A. L; Luh, B. S. and Pratt, H. K. 1966. Relation of Fatty Acids Changes to Respiration Rate during Ripening of Avocado Fruit. Journal of Food Science 31,(3), 332-336.

- Eaks, I. 1990. Change in the Fatty Acid Composition of Avocado Fruit During Ontogeny, Cold Storage and Ripening. Tropical Fruit in International Trade. Acta Horticulturae 269: 141-151.

- East, R. 1990. Changing Consumer Behaviour. Print Cassell Educational Limited. London.

- Eckey, E. W.1954. Vegetable Fats and Oils, p.836. Reinhold Publishing Corp., New York.

- Embajada de Sudáfrica en España. 1998. Sección Económica Madrid: Sudáfrica Exporta. http://www.sudafrica.com/junio/noticia14.htm 4/5/99.

- Encyclopedia of Chemical Technology. 1979. Vol. 7.p.153.Edited by Kirk Othmer, John Wiley & Sons, New York.

- Enser, M. 1995. Meat Lipids. In: Developments in Oils and Fats. Edited by Hamilton, R. J. First ed. Blackie Academic & Professional.

- FAS, Foreign Agricultural Service, US. Department of Agriculture 1997a. Avocado Situation in Selected Countries. http://www.fas.usda.gov/htp/circular/1997/97/02/feb97htp2.html#AvocadoFeature. 11/7/99.

- FAS, Foreign Agricultural Service, US. Department of Agriculture 1997b. On line Avocado Situation in Selected Countries Reviewed. http://www.fas.usda.gov/htp/circular/1998/98-02/avo98fea.html. 10/4/99.

- FAS, Foreign Agricultural Service, US. Department of Agriculture, 1998a. On line The Mexican Avocado Industry Prepares to Export to the U.S. Northeast...http://www.fas.usda.gov/htp/circular/1997/97-10/mexavo97.htm. 4/4/99.

- FAS, Foreign Agricultural Service, US. Department of Agriculture, 1998b. Online. Avocado Situation. April. http://www.fas.usda.gov/htp/circular/1998/98-02/avo98fea.html

- FAS, Foreign Agricultural Service, US. Department of Agriculture, 1999. Online. Avocado Situation. http://www.fas.usda.gov/htp/circular/1999/99%2D02/avocado.htm

- FCIC. Federal Crop Insurance Corporation, US. Department of Agriculture. 1997. An Economic Assessment of Avocados. http://www.act.fcic.usda.gov/research/txt/avocado.txt

- Food and Agriculture Organisation (FAO) Databases. 1999. http://apps.fao.org/cgi-bin/nph-db.pl?subset=agriculture. 06/07/99.

- Folch, J; Lees, M. and Stanley, G.H.S. 1957. A Simple Method for the Isolation and Purification of Total Lipids from Animal Tissues. Journal of Biological Chemistry, 226. 497-509.

- Francis, L. 1997. The New Zealand/Australian Avocado Conference. California Avocado Society Yearbook. 33- 34.

- Fruit and Tree Nuts, 1996. Situation and Outlook Report. Traditional Tropical Fruits in South Florida. April. Economic Research Service, U.S. Department of Agriculture. Washington.

- Gafni, U. 1998. Avocado in Israel. South African Avocado Grower's Association Yearbook. 21, 69-70.

- Gaillard, J. P. Brevets en Rapport Avec la Technologie de L'Avocat in L'Avocatier, sa culture et ses produits, edied by G. P Maison neuve et Larose, Techniques Agricoles et Productions Tropicales, Paris.

- Galinsky, B. 1995. Market Survey: Avocado. Global Agribusiness Information Network (GAIN). http://www.fintrac.com/gain/mkinfo/tpm/spr95/avocado.html.

- Global Agribusiness Information Network. (GAIN), 1998. USDA. Japan Report #JA8119.http://www.fas.usda.gov/scriptsg/gain_display_report.exe? 29/05/99.

- Global Agriculture Information Network (GAIN), 1998. USDA. Chile Report # CI8036. 26/7/99. http://www.fas.usda.gov/scripts/gain_display_report.exe?Rep_ID=25403648.

- Global Agriculture Information Network (GAIN), 1998. USDA. Israel Report # IS804. 26/7/99. http://www.fas.usda.gov/scripts/gain_display_report.exe?Rep_ID=25372841.

- Global Agriculture Information Network (GAIN), 1998. USDA. South Africa Report # SF8036. 26/7/99. http://www.fas.usda.gov/scripts/gain_display_report.exe?Rep_ID=25372866.

- Gilbert, B. 1995. Economic Plants of the Amazon. Their Industrial Development in Defense of the Forest. In: Chemistry of the Amazon: Biodiversity, Natural Products, and Environmental Issues. American Chemical Society. Symposium Series 588, Chapter 3.

- Groves, M and Sheridan, M. 1997.U.S. Lifts Ban on Avocados from Mexico. Business Section Los Angeles Times. http://www.sunny-avocado.com/news1.htm. 02/1/97

- Grundy, S, M. 1986. Comparison of Monounsaturated Fatty Acids and Carbohydrates for Lowering Plasma Cholesterol. New England Journal of Medicine. 314, 745-748.

- Grundy, S.M. 1988. Comparison of Monounsaturated Fatty Acids and Carbohydrates for Reducing Raised Levels of Plasma Cholesterol in Man. American Journal of Clinical Nutrition, 47, 965-969.

- Gush, S. 1998. Product Group Manager. New Zealand Avocado Industry Council Ltd.

- Hall, A. P.; Moore, J. G. and Morgan, A. F. 1955. Journal of Agriculture and Food Chemistry 3, 250.

- Hatton, T.T.; Soule, M. Jr. and Popenoe, J. 1957. Effect of Fruit Position and Weight on Percentage of Oil in Lula Avocados in Florida. American Society for Horticultural Science. 69, 217-220.

- Hatton, T.T and Reeder, W. F. 1969. Mantaining Market Quality of Florida Avocados. Proceedings of Conference in Tropical and Subtropical Fruits, pp 227-280. London.

- Hawaii Department of Agriculture, 1997. National Agricultural Statistics Service. US. Department of Agriculture. http://www.usda.gov/hi/avocad97.htm

- Hilditch, T.P. and Williams, P.N. 1956. The Chemical Constitution of Natural Fats. Third edition. Chapman and Hall Ltd.

- Hilton-Barber, D. 1995. Integrated Local Marketing Strategy for the South African Avocado Industry. Proceedings of the World Avocado Congress III. Israel.

- Hodgkin, G. B. 1928. Oil Testing of Avocados and its Significance California Avocado Association Yearbook. 13, 68-72.

- Hodgkin, G. B. 1939. California Avocado Association Yearbook. 24, 141.

- Hofski, R. 1996. Accepted and Perceived Limiting Factors to Avocado Production in Israel. Solutions and Setbacks. California Avocado Society Yearbook. 27-35.

- Hopkirk, G. 1989. Avocado Maturity Assessment. Division of Horticulture and Processing. DSIR.

- Hope, T. 1963. Quality Tests Identify Best Avocados. Queensland Agricultural Journal. 89, 657-660.

- Hough, A. 1991. Interview In: Gourmet Oils in the 1990s. International News on Fats, Oils, and Related Materials (INFORM). 2, 2. 98-112.

- Howard, T and Savage, G. 1994. The Advantages of Increasing Olive Oil in the Diet. Nutritional Trends for the Future. Proceedings of a Continuing Education Seminar. Edited by Savage, G.P and Webster, G and Plows, E.

- Hudson , B. J. F. 1975. Chemistry Industry. 763.

- Hughes, J. P. 1971. Farmers Weekly, South Africa, p.61.

- Human, T. P. 1987. Oil as a by-product of Avocado. South African Avocado Growers Association Yearbook, 10. 159-164.

- Inoue, H and Tateishi, A. 1995. Ripening and Fatty Acid Composition of Avocado Fruit in Japan. Proceedings of the III World Avocado Congress.

- International Olive Oil Council (IOOC), 1984. International Trade Standards Applying to Olive Oils and Olive- Residue Oils. COI/T.15 NC No 1.Madrid Spain.

- Jaffe, M. E. and Gross, H. 1923.University of California. Agriculture Experiment Station. Bulletin. 365,630.

- James, W.P.T; Duthie, G.G and Wahle, K.W.J 1989. The Mediaterranean Diet: Protection or Simple non-toxic? European Journal of Clinical Nutrition, 43 (supplement 2), 49-55.

- Kader, A. A. and Arpaia, Mary Lu. 1992. Postharvest systems: Subtropical Fruits. In: Postharvest Technology of Horticultural Crops. Second edition. University of California. Division of Agriculture and Natural Resources. Publication 3311.

- Kaiser, C.; Smith, M. T and Wolstenholme, B.N. 1992. Overview of Lipids in the Avocado Fruit with Particular Reference to the Natal Midlands. South African Avocado Growers' Association Yearbook. 15, 78-82.

- Kaiser, C. and Wolstenholme, B.N. 1994. Aspects of Delayed Harvest of Hass Avocado (Persea americana Mill.) Fruit in Cool Subtropical Climate. I. Fruit lipid and fatty acid accumulation. Journal of Horticultural Science. 69, 3, 437-445.

- Kaiser, C.; Keevil, S.D.; Levin, J. and Wolstenholme, B.N. 1996. Towards Maturity Standards for Fuerte Avocado Fruit in the Cool Subtropical Kwazulu- Natal Midlands. South African Avocado Growers' Association Yearbook. 19, 101- 108.

- Keys, A. 1970. Coronary Heart Disease in Seven Countries, the diet. Circulation, 41 (supplement 1), 162-183.

- Kikuta. Y and Erickson, L.C 1968. Seasonal Changes of Avocado Lipids During Fruit Development and Storage. California Avocado Society Yearbook, 52, 102-108.

- Kiritsakis, A and Markakis, P. 1987. Olive Oil: A Review. Advances in Food Research. 31. 453-482.

- Kinsella, J.E.; Lokesh, B. and Stone, R. A. 1990. Dietary n-3 Polyunsaturated Fatty Acids and Amelioration of Cardiovascular Disease: Possible Mechanisms. American Journal of Clinical Nutrition. 52, 1-28.

- Kiritsakis, A. K. 1990. Olive Oil. American Oil Chemists' Society. Champaign Illinois.

- Kruger, F.J.; Stassen, P.J.C.and Snijders, B. 1995. A Preliminary Study on Variation in the Maturity Parameters of Avocados from the Kiepersol- Hazyview area. South African Avocado Growers' Association Yearbook. 5, 74-77.

- Kruger, F.J. and Classens, V.E. 1996a. The Influence of Rainfall and Irrigation on the Maturity Parameters of South African Export Avocados. South African Avocado Growers' Association Yearbook. 19, 93-95.

- Kruger, F.J. and Classens, V.E. 1996b. Comparison of Export Avocado Maturation at Burgersahll during the '94 and 95' seasons. South African Avocado Growers' Association Yearbook. 19, 105-108.

- Labay, E. and Trochoulias T. 1982. The effect of Temperature on Growth and Dry Matter Production of Avocado Plants. Australian Journal of Agricultural Resources. 33, 549-548.

- Lahav, E. 1997. The Israeli Avocado Industry. A Status Report. California Avocado Society Yearbook. 45-46.

- Lahav, E and Kalmar, D. 1977. Water Requirements of Avocado in Israel II. Influence on Yield, Fruit Growth and Oil Content. Australian Journal of Agricultural Research, 28. 869-877.

- Lawes, G. S. 1980. Maturity and Quality in Avocados. The Orchadist of N. Z. March, 63-64.

- Lee, S. K. 1981. Methods of Percent Oil Analysis of Avocado Fruit. California Avocado Society Yearbook. 65, 133-141.

- Lee, S.K, Young, R. E, Schiffman, P.M and Coggins, C.W, Jr. 1983. Maturity Studies of Avocado Fruit Based on Picking Dates and Dry Weight. Journal of the American Society for Horticultural Science, 108, (3) 390-394.

- Lesley B.E. and Christie, A. W. 1929. Use of the Refractometric Method in Determination of Oil in Avocados. Industrial and Engineering Chemistry (Analytical Edition) 1:24.

- Lercker, G. Capella, P. and Deserti, P. 1973. Volatile and Aromatic Compounds of Extra Virgin Olive Oils. Sci. Tecnh. Alim. 3, 299.

- Leung, A. Y.1980. Avocado. Encyclopedia of Common Natural Ingredients Used in Food, Drugs and Cosmetics. Wiley-Interscience.

- Lewis, C, Morris, R. and O'Brien, K. 1978. The Oil Content of Avocado Mesocarp. Journal of Science, Food and Agriculture. 29, 243-249.

- Lewis, C. 1978. The Maturity of Avocados- A General Review. Journal of Science, Food and Agriculture 29. 857-866..

- Lichtenstein, A.; Kennedy, E.; Barrier, P.; Danford, D.; Ernst, D.; Grundy, S.; Leveille, G.; Van Horn, L.; Willimians, C. and Booth, S. 1998. Dietary Fat Consumption and Health. Nutrition Reviews. 56. 5, S3-S19.

- Lough, A.K.; Navia, J.M. and Harris, R.S. 1966. Journal of the American Oil Chemists' Society. 43. 627.

- Lozano, Y. F.; Dhuique- Maer, C.; Bannon, C.; Gaydou, E. M. 1993. Unsaponifiable Matter, Total Sterol and Tocopherol Contents of Avocado Oil Varieties. Journal of the American Oil Chemists' Society. 70, 6. 561-565.

- Luza, J.G. ; Lizana, L.A; Masson, L., 1990. Comparative Lipids Evolution during cold storage of three avocado cultivars. Acta Horticulturae 269, Tropical Fruit in International Trade.

- Lyman, R. L; Cook, C. R and Williams, M.A. 1964. Liver Lipids Accumulation in Isoleucina- Deficient rats. Journal of Nutrition. 82, 432-438.

- Lyon, J.M. 1973. Chilling Injury in Plants. Annual Review of Plant Phyisiology. 24. 445-466.

- Market Asia, 1995. Agribusiness Information. World Market for Avocado. RAP Market Information Bulletin, No. 10. http://fintrac.com/rap/bulletins/market/avocado.html. 29/3/99.

- Market Studies, Inc. 1998. U.S. Cosmetics and Toiletries Market: 1998/99 Edition. http://www.marketstudies.com/cos989/hihglts.htm

- Mayfield, E. 1994. A consumer's guide to fats. US. Food and Drug administration. nternet site.

- Mazliak, P. 1965a. Les lipides de l' avocat. I. Composition en Acides Gras des Diverses Parties du Fruit. Fruits 20: 49-57.

- Mazliak, P. 1965 b. Les lipides de l' avocat. II. Variation de la Composition en Acides Gras des Lipides du Pericarpe Selon la Composition de l'atmosphere autor des Frutis en Maturation. Fruits, 20, 117-120.

- McOnie, A. J and Wolstenholme B. N. 1982. Avocado Fruit Growth and Maturity in Two Natal Localities. South African Avocado Growers' Association Yearbook. 5, 74-77.

- Messrs McLachlan and Lazar (Pty) Ltd. Consulting Industrial Chemists Johannesburg, South Africa. PO Box 3344.

- Milne, L. 1996. The South African Avocado Industry in 1996. California Avocado Society, Yearbook, 1996. 41-43.

- MOF. Ministry of Finance, Japan. 1998. http://www.mof.go.jp/english/trade-st/199828ce.htm#EXPORT

- Montedoro, G. ; Bertuccioli, M.; and Anichini, F. 1978. Aroma Analysis of Virgin Olive Oil by Head Space Volatiles and Extraction Techniques. In: Flavor of Foods and Beverages. Chemistry and Technology. Charalampous, G and G. Inglett Editors. Academic Press, NY.

- Moreton, R. S. 1988. Physiology of Lipid Accumulation of Yeasts. In: Single Cell Oil. (Moreton, R. S Ed.) Longman Scientific and Technical, Essex, England, 1-32.

- NASS. National Agricultural Statistics Service. 1997. USDA. Statistical Highlights of US. Agriculture. http://www.usda.gov/nass/pubs/stathigh/1997/sthi96-c.htm

- NASS. National Agricultural Statistics Service. 1998. USDA. Agricultural Statistics. Non-citrus Fruits and Nuts Final Estimates 1992-1997. http://usda.mannlib.cornell.edu/usda/reports/general/sb/b9501298.pdf

- Natural Oils, 1998. http://www.naturaloils.com/terms.html

- New Zealand Fruit Growers Federation.1998. New Zealand Fruit Industry- An Investment in the Future.

- Oil Flavour web http://www.flavorweb.com/oilstats.htm

- Omundsen, H. 1999. Product Group Manager. New Zealand Avocado Industry Council Ltd.

- Patridge, C. 1995. Manager, SAAGA. Personal Interview with van Zyl, J. L and Ferreira, S.G, 1995.In: An Overview of the Avocado Industry in South Africa. South African Avocado Grower's Assocaition Yearbook, 18.

- Paz-Vega, R. 1989. Mexican Avocados: Threat or opportunity for California. California Avocado Society. Yearbook, 73, 97-106.

- Pearce, H. P. 1959. The Nutritional Value of the Avocado. California Avocado Society Yearbook, 83.

- Pearson, D. 1975. Seasonal English Market Variation in the Composition of South African and Israeli Avocados. Journal of the Science of Food and Agriculture, 26, 207-213.

- Pike, O. A. 1998. Fat Characterisation. In: Food Analysis. Second edition. Chapman and Hall Food Science. USA.

- Platt-Aloia, K. A and Thomson, W.W. 1981. Ultrastructure of the Mesocarp of Mature Avocado Fruit and Changes Associated with Ripening, Annals of Botany. 48, 451-465.

- Platt- Aloia, K. A.; Oross, J.W. and Thompson W.W. 1983. Ultrastructural Study of the Development of Oil Cells in the Mesocarp of Avocado Fruit. Bot. Gaz 144. 49-55.

- Poucher, W.A. 1974. Perfumes, Cosmetics and Soups. The Raw Materials of Perfumery. London. Chapman and Hall. 381 pp.

- QZONE, 1998. Research into Avocados in New Zealand. New Zealand Growers Association.

- Ranney, C.A.; Gillette, G.; Brydon, A; McIntyre, S.; Rivers, O.; Vasquez, C.A.and Wilson E. 1992. Physiological Maturity and Percent Dry Matter of California Avocado. Proceedings of the Second World Avocado Congress. 379-385.

- Ramirez R. 1995. (spokesperson for the Mexican Consulate of San Diego). Interviewed in Lifting of Avocado Ban viewed as Benefiting Trade Relations. http://www.sddt.com/95headlines/DN95_09_04/story95_09_04_01.html

- Ratovohery, J.V.; Lozano, Y.F. and Gaydou, E. M. 1988. Fruit Development Effect on Fatty Acid Compoistion of Persea americana Fruit Mesocarp. Journal of Agricultural Food Chemistry. 36, 287-293.

- Reid, M. S. 1992. Maturation and Maturity indices. Postharvest Technology of Horticultural Crops. Second Edition. Publication 3311. 21.

- Ricks, D, J. 19XX. Functional Natural Oils. Coronado Natural Oils, Ltd. Biologicals and Botanicals.

- Ross, J.H.E.; Sanchez, J; Millan, F; Murphy, D .J. 1993. Differential Presence of Oleosins in Oleaogenic Seed and Mesocarp in Olive (olea europea) and Avocado (Persea americana). Plant Science, 93, 203-210.

- Rosenthal, I; Merin, U.; Popel, G. and Bernstein, S. 1985. An Analytical Assay for the Determination of Oil Content in Avocado. California Avocado Society. Yearbook, 133-136.

- San Agustin, S. 1995. Lifting of Avocado Ban Viewed as Benefiting Trade Relations. http://www.sddt.com/95headlines/DN95_09_04/story95_09_04_01.html

- Schaffer, B; Andersen, P.C. 1994: Handbook of Environmental Physiology of Fruit Crops. Vol. II. Sub-tropical and Tropical Crops. CRC Press Inc. Florida.

- Schaffner D.J; Schroder, W. and Earle, M. 1998. Food Marketing. An International Perspective. WCB McGraw-Hill.

- Schroeder, C. A.1952. Floral Development, Sporogenensis and Embryology in the avocado Persea americana. Bot. Gaz. 113, 270-278.

- Schroeder, C. A.1953. Growth and Development of the Fuerte Avocado Fruit. Journal of the American Society for Horticultural Science. Los Angeles. 61, 103-109.

- Schroeder, C.A. 1985. Physiological Gradient in Avocado Fruit. California Avocado Society. Yearbook. 137-143.

- Schroeder, C.A. 1987. Physiological Gradients in Fleshy Pericarp of Avocado. South African Avocado Growers’ Association. Yearbook. 10. 32-34

- Shepherd, J. 1988. The Ever- Whirling Wheel of Change…..or, Time Turned Topsy-Turvy. Yearbook of the California Avocado Society, 72. 159-163.

- Simoni, R. D; Criddle, R. G., and Stumpf, P. K. 1967. Journal of Biol. Chem.242.573.

- Slater, G. G.; Shankman, S.; Shepherd, J. S.; and Alphin-Slater, R. B. 1975. Seasonal Variation in the Composition of California Avocados. Journal Agricultural Food Chemistry, 23. (3), 468-474.

- Smith, N. J. H; Williams, J.T; Plucknett, D, L. and Talbot, J. P. 1992. Tropical Forests and Their Crops. Comstock Publishing Associates.

- Smith, H. and Lunt, RE. 1981. Avocado Oil, the Cinderella of the Avocado Industry? South African Avocado Growers' Association. Yearbook. 4.21.

- Soule, M. J and Harding, P. L. 1955. Relation of Maturity of Florida Avocados to Physical Characters. Proceedings of Florida State Horticultural Society, 68. 303-308.

- South African Department of Agriculture, 1995. Directorate of Economic Trends.

- Southwell, K.H; Harris, R.V. and Swetman, A. A. 1990. Extraction and Refining of Oil Obtained from Dried Avocado Fruit using a Small Expeller. Tropical Science. 30, 121-131.

- Stahl, A. L. 1933. Changes in Composition of Florida Avocados in Relation to Maturity. Agricultural Experiment Station, Gainesville, Florida, May, Bulletin 259.

- Statistics New Zealand. Yearbook. 1997.

- Stryer, L. 1988. Introduction to Biological Membranes. In: Biochemistry, 3rd Edition. W. H. Freeman and Company, New York, USA, 283-312.

- Stumpf, P. K and Conn. E. E. 1987. The Biochemistry of Plants. Lipids: Structure and Function. Academic Press.

- Superior National Oils Inetrnational (SNOI). 1998. Product Information: Avocado Oil. http://www.snoi.com/

- Swartz, D.H. 1976. N'Praktiese avokado-oliebepalingsmetode vir produsente. Citrus and Subtropical Fruit Journal. 511. 8-11.14.

- Swisher, H. E. 1988. Avocado Oil. From Food Use to Skin Care. Journal of the American Oil Chemists' Society. Vol. 65. 11.

- Thiers, H. 1971. Fruits, 26: 133.

- Today's Market Prices, 1999. Site: http://www.todaymarket.com/tmp_info.htm

- Ulbricht, T. L. V and Southgate, D.A.T. 1991. Coronary Heart Disease: Seven Dietary Factors. The Lancet, 338. 985-992.

- Undurraga, P; Olaeta, J. and Gardizabal, F. 1987. Seasonal Changes on Chemical Parameters in Six Avocado (Persea americana Mill) Cultivars Grown in Chile. South African Avocado Growers' Association, Yearbook. 10, 138-140.

- USDA, 1994. New Zealand Food Market Report. Office of Agricultural Affairs of the United States Department of Agriculture/Foreign Agricultural Service in Wellington, New Zealand.

- U.S. Agricultural Attache Reports, 1998. U.S. Bureau of Census. http://www.fas.usda.gov/scriptsw/AttacheRep/attache_frm.idc

- US. Department of Agriculture. News, 1996. Direct and Indirect Impact upon Avocado Trade in the United States and Mexico. http//gurukul.ucc.american.edu/ted/avocado.htm. 29/05/1999.

- U.S Food and Drug Administration (FDA). 1976. Avocado Oil. Product Formulation Data.

- Vakis, N.J.; Gregoriou, C. and Papademetriou, M. 1985. Maturity and Picking dates of Avocados Under Cyprus Conditions. California Avoado Society, Yearbook. 81-88.

- Van Den Dool, B. and Wolstenholme B.N. 1983. Further Studies on Avocado Fruit Growth and Maturity in Inland Natal. South African Avocado Growers' Association. Yearbook 6. 34-40.

- van Zyl, J. L and Ferreira, S.G. 1995. An Overview of the Avocado Industry in South Africa. South African Avocado Growers' Association. Yearbook 18. 23-30.

- van Heerden, I. 1997. Avocado oil, Food of the Month. Diet Doc. http://www.mweb.co.za/health/diet/food/food17.html.

- Vorster, L. 1997. The South African Avocado Industry. California Avocado Society Yerabook, 49-50.

- Watada, A. E; Herner, R.C; Kader, A. A; Romani, R. J. and Staby, G.L. 1984. Terminology for the Description of Developmental Stages of Horticultural Crops. HortScience, (19), 1. 20-21.

- Werman, M. J. and Neeman, I. 1986. Oxidatice Stability of Avocado Oil. Journal of the American Oil Chemists Society. 63. No 3. 355-360.

- Werman, M. J. and Neeman, I. 1987. Avocado Oil Production and Chemical Characteristics. Journal of American Oil Chemists' Society. 64, 2. 229- 232.

- Werman, M. J.; Neeman, I and Mokady , S. 1991. Avocado Oils and Hepatic Lipid Metabolism in Growing Rats. Food Chemistry and Toxicology. 29. No 2. 93-99.

- Whiley, A.W; Saranah, J.B; Cull, B.W. and Pegg, k.G. 1987. Effective Management of Avocado Tree Growth Cycles Can Assist with Productivity Gain. Proceedings Avocado Seminar held at Tauranga.

- Whitmore, J. S. 1986. The Climatic Suitability of South Africa for Production of Avocados. NPWCAR Project. CSIR Pretoria.

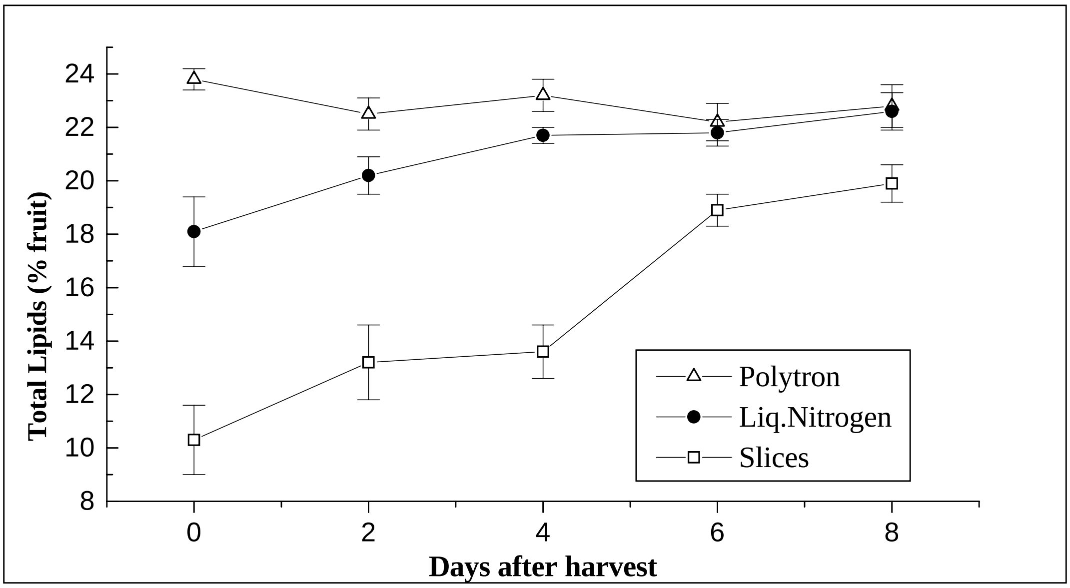
- World Health Organization (WHO). 1982. Technical Report Series No 678, Geneva.

- Wolfe, H, S; Toy, L. R. and Stahl, A. L. 1934. Agriculture Experiment Station. Bulletin. 272, 46.

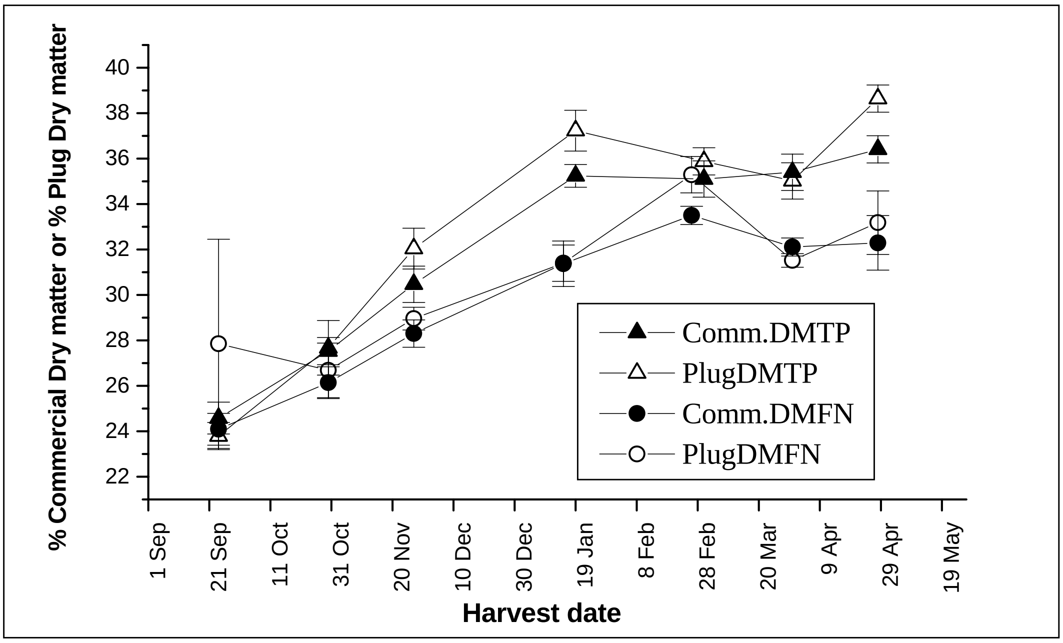
- Wolstenholme, N.B. 1988. An Overview of Avocado Technology Towards 2000. Australian Avocado Bicentennial Conference: Avocados Towards 2000.

- Woolf, A.B. 1999. Research Scientist. The Horticulture and Food Research Institute of New Zealand Ltd. MT. Albert Research Centre.

- Woolf, A.B., McLeod, D.L., Burdon, J.N and White, A. 1997. Using the Anderson Firmometer. HortResearch Client Report No 97/119.



Appendix 1. Mean percentage of lipids extracted from 'Hass' avocado fruit immediately after harvest, and after 2, 4, 6 and 8 days (8 = ripe soft) after harvest . Fruit were ethylene treated at 17 °C for 48 hours. Each point is the average of six replicates of three fruit. Samples were extracted using three different methods. Vertical bars = SEM. Initial average dry matter = 35%, n= 18.



Appendix 2. Mean commercial dry matter and plug dry matter of 'Hass' avocado fruit harvested from Te Puke and the Far North from September to April. Each point is the average of four replicates of five fruit. Vertical bars = SEM. Comm.DMTP=Commercial dry matter Te Puke; Comm.DMFN= Commercial dry matter Far North; PlugDMTP= Plug dry matter Te Puke; PlugDMFN= Plug dry matter Far North.

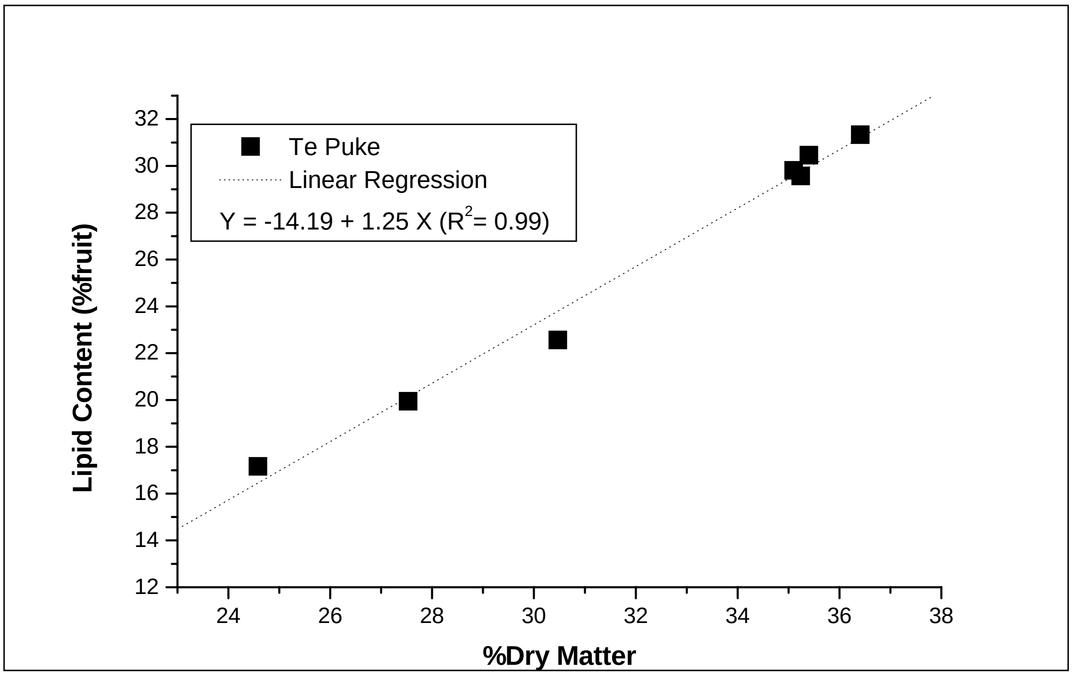


Figure 3.2.a.Relationship between lipid content and dry matter of 'Hass' avocado fruit harvested from Te Puke, September1998 to April 1999. Each point is the average of four replicates of five fruit. Dotted line = linear regression described by the equation found.

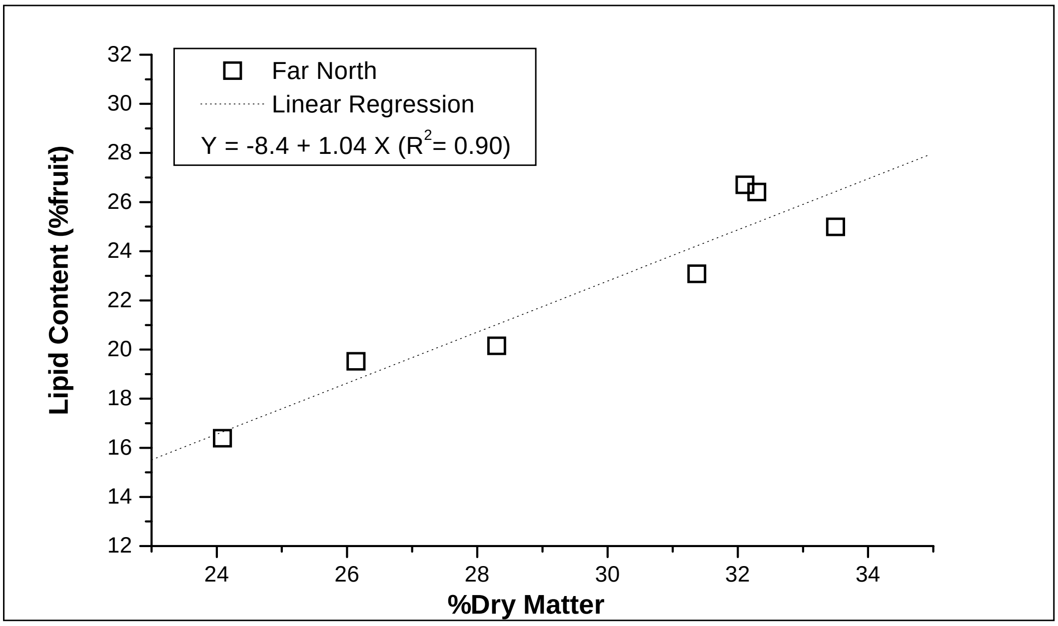


Figure 3.2.b.Relationship between lipid content and dry matter of 'Hass' avocado fruit harvested from Far North, September 1998 to April 1999. Each point is the average of four replicates of five fruit. Dotted line = linear regression described by the equation found.

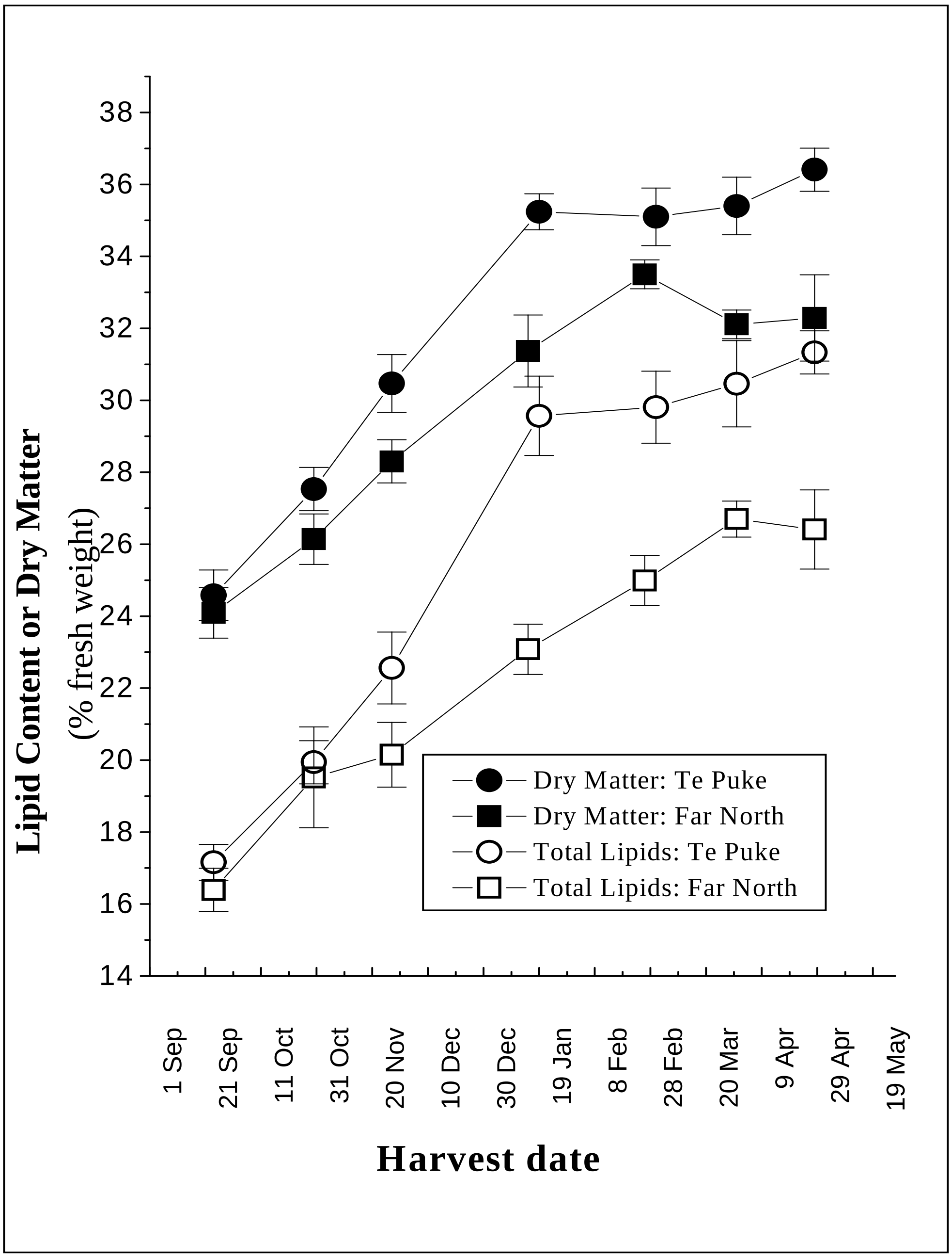


Figure 3.1. Lipid content and dry matter of 'Hass' avocado fruit harvested from Te Puke and the Far North from September 1998 to April 1999. Each point is the average of four replicates of five fruit. Vertical bars = SEM.

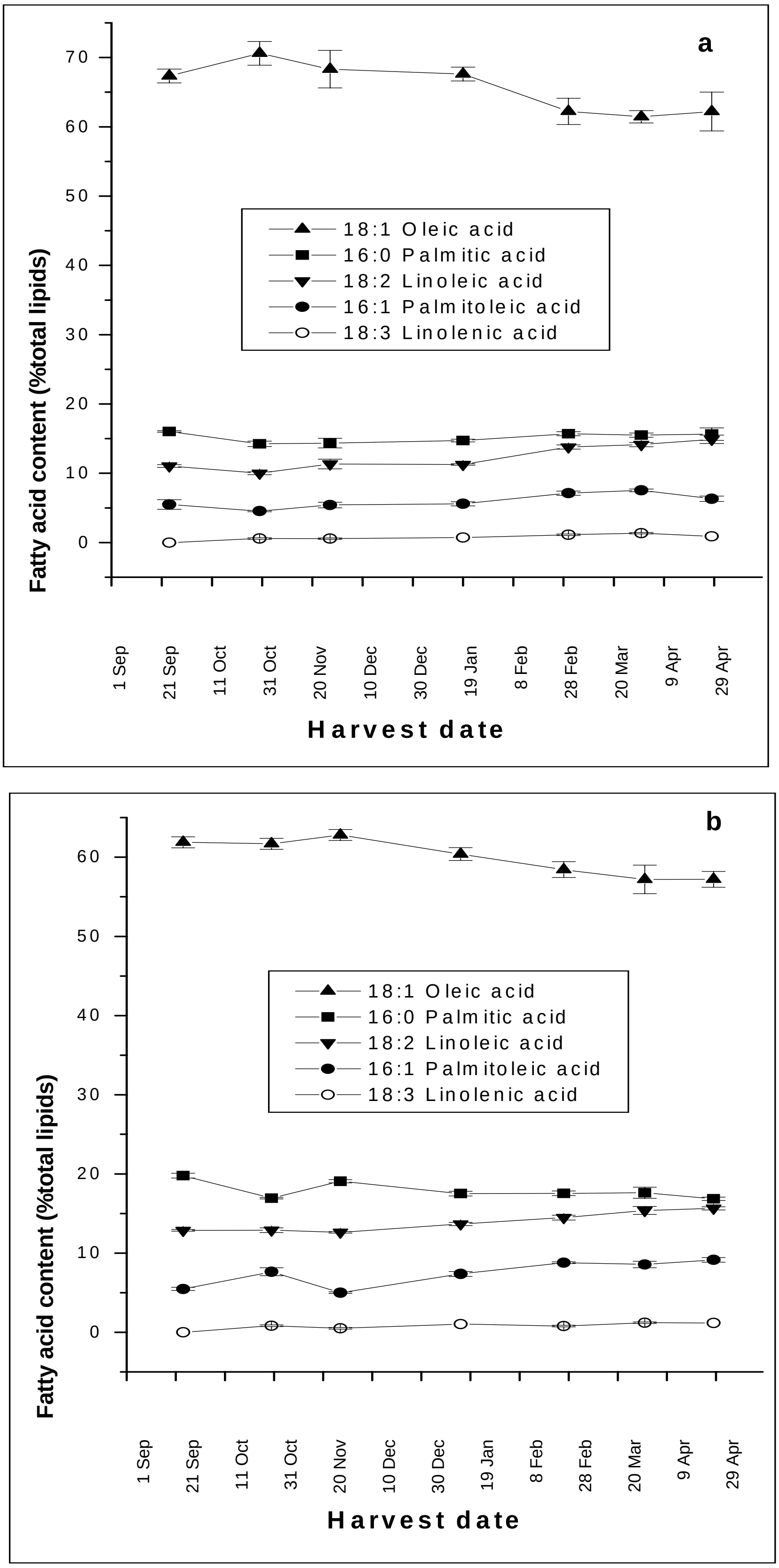


Figure 3.5. (a) Te Puke and (b) Far North. Fatty acid content as a percentage of total lipids for 'Hass' avocado fruit harvested from September 1998 to April 1999. Each point is the average of four replicates of five fruit. Vertical bars = SEM.

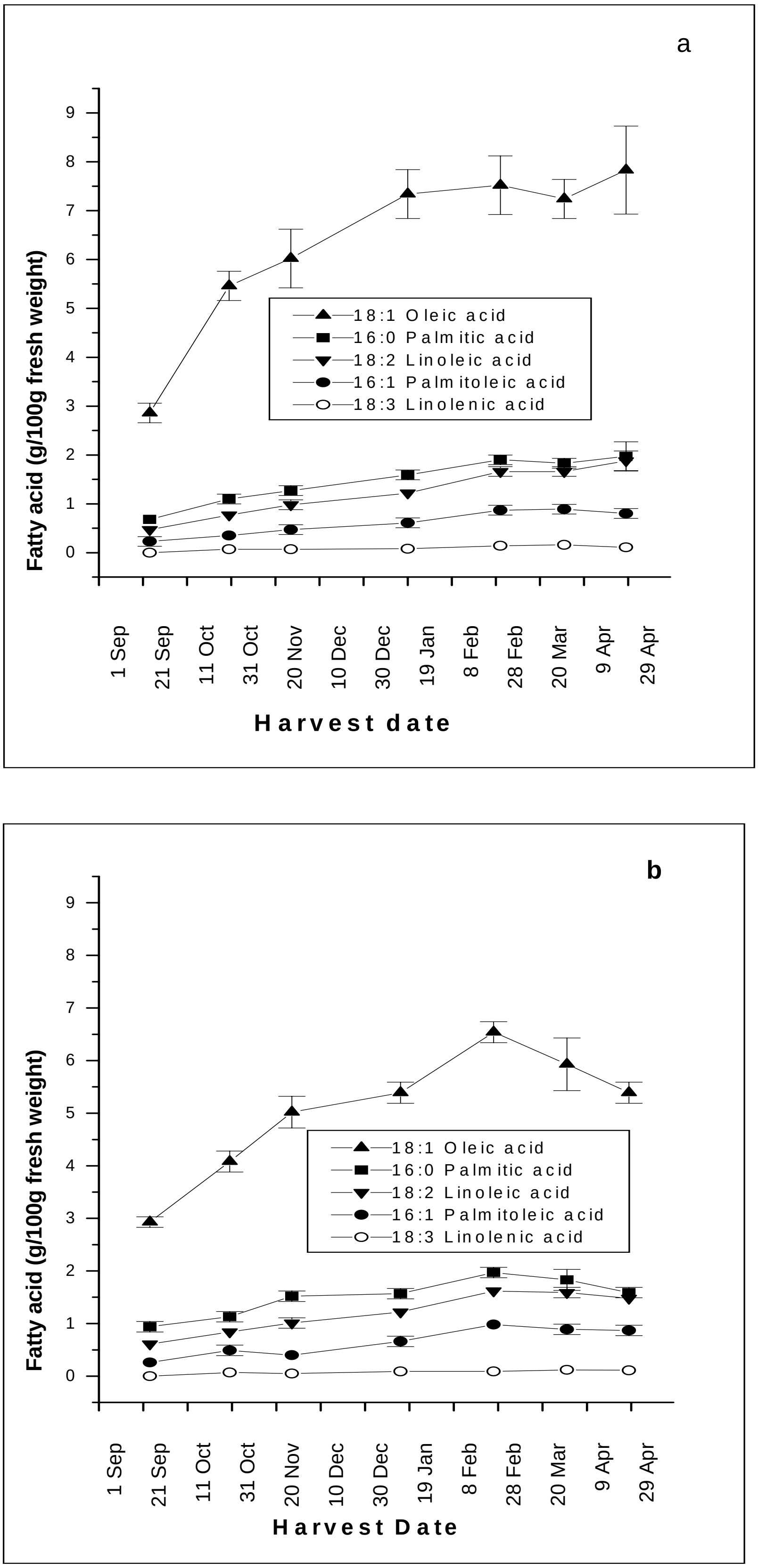
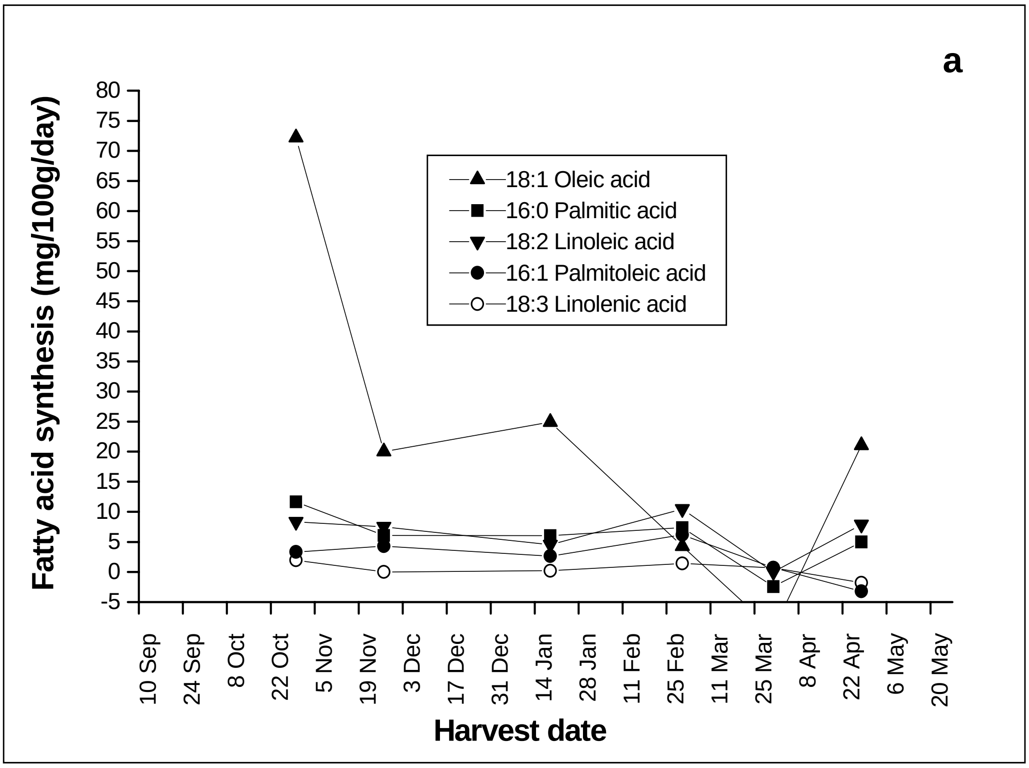


Figure 3.4. (a) Te Puke and (b) Far North. Fatty acid concentration in 'Hass' avocado fruit harvested from September1998 to April 1999. Each point is the average of four replicates of five fruit. Vertical bars = SEM.



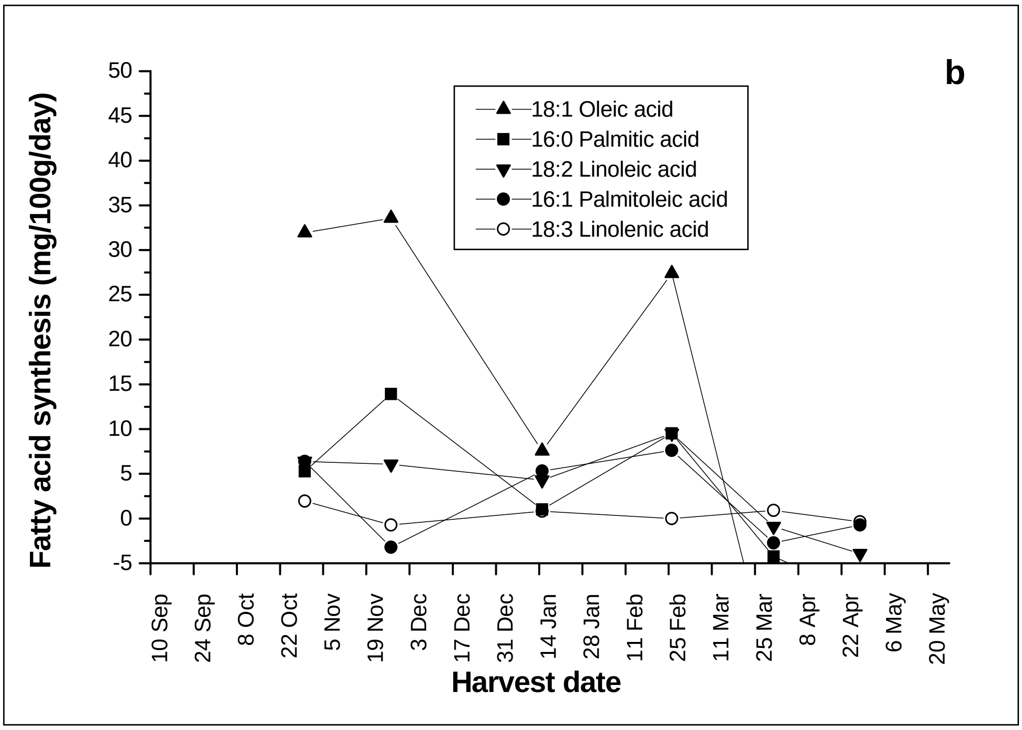


Figure 3.3 (a) Te Puke and (b) Far North. Rate of fatty acid synthesis in 'Hass' avocado fruit harvested from September to April. Each point is the average of four replicates of five fruit. Vertical bars = SEM.