IFEAT SOCIO–ECONOMIC REPORT ORANGE

By Dr Peter Greenhalgh

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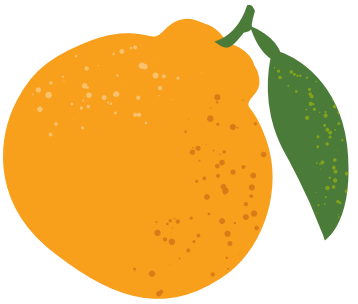
Citrus sinensis

Family: Rutaceae



INTRODUCTION

Citrus species are grown throughout the world and citrus is the most important tree fruit crop. Citrus oils are the largest group of essential oils with orange oil and its derivatives being by far the largest citrus oil, followed by lemon. The orange fruit is obtained from the orange tree (*Citrus*) the origins of which are cited as southern Asia around 4,000 years ago. Trade and wars led to the expansion of cultivation and during the Middle Ages oranges were taken to Europe by the Arabs. One of Columbus's expeditions brought seedlings to the Americas in 1500.

Oranges are produced worldwide, predominantly in tropical and sub-tropical regions. Fresh fruit and juice are the dominant revenue streams from orange production but the fruit provides other products including various essential oils and essences. Some very large orange growers, particularly China, Egypt, and India, produce negligible amounts of orange oil. The production of orange oils and other derivatives account for only a relatively small but increasing proportion of the revenues generated from the orange sector. Nevertheless, income from essential oils and limonene is an important contributor to profitability for orange growers and processors, as well as helping minimise risk since different markets with different dynamics are supplied. This is driven by the amount of fruit which goes to processing. In some major orange growing countries, most of the fruit is consumed as fresh fruit rather than juice, so the processing industry is small.

Brazil is the world's leading orange grower and processes most of its production into a range of orange products driven by orange juice concentrate. This contrasts with most other orange producing countries where growers aim to sell their fruit into the fresh fruit market. Fruit that does not meet specifications is processed into juice, and the essential oil is a by-product of producing juice. Brazil dominates global orange oil production with smaller quantities from Mexico, USA, South Africa, Spain, and Italy.

Since oranges are grown in both the northern and southern hemispheres and on all continents, they are available throughout the year. Brazil and South Africa are the major southern hemisphere producers and harvesting and processing is usually undertaken from June to December. The major northern hemisphere producers are, in scale of production, Mexico, USA, Spain, and Italy, with harvesting and processing taking place from November to June.

This report deals with sweet oranges from *Citrus sinensis* and not bitter orange (*Citrus aurantium*), which is the source of various aromatic materials including bitter orange, neroli, and petitgrain oils. Interestingly, the prices of these oils are much higher than orange oil in part because no juice and very few other by-products are produced. The following sections discuss the growth characteristics, varieties, and range of orange products; the processing, uses and varieties; global trends in production and in major producing countries; major challenges, price trends, economic, social, and environmental aspects.

GROWTH CHARACTERISTICS AND VARIETIES

Sweet orange trees have a long gestation period, taking three to four years before the first fruit harvest. Fruit yields decline after approximately 12 years and invariably trees are replaced after approximately 18 years. Thus, decisions made 20 years ago affect the industry today and decisions being made today will continue to affect the industry for 20 years.

Many hundreds of different varieties of orange trees are grown. These can be separated into several sub-groups including:

- Navel orange (e.g., Washington, Bahia, Cara Cara, Lane Late)
- Common blond orange (e.g., Valencia, Pera Pera)
- Blood/pigmented orange (e.g., Tarocco, Moro, Sanguinello)
- Sugar/acidless orange (e.g., Succari, Lima)

Considerable R&D is being undertaken by the larger orange producers and governments to increase output and yields as well as overcome pests and diseases, which are an increasing problem.

Brazil has three main orange varieties:

- Early varieties (Hamlin, Westin, and Rubi) with less yield and lower aldehyde content, and fruit nine months after blooming.
- Middle variety (Pera), better yield and higher aldehyde, stronger fruit, 12 months after blooming.
- Late varieties (Natal and Valencia), blooming comes later and fruit comes 12 months after blooming.

Climatic and soil conditions mean there are orange harvests practically the whole year round in Brazil. As regards varieties, 55% of the oranges

grown in São Paulo State are Natal, Valencia, and other late-harvest varieties, 23% are Hamlin and early-harvest varieties, and 22% Pera, as well as other mid-season varieties. Late varieties are more productive and preferred by growers. Different varieties are planted to try to ensure more regular production as well as manage disease and reduce the impact of climatic factors. Several research institutes are devoted to orange in São Paulo and Minas Gerais. They are trying to overcome citrus canker and HLB disease (Huanglongbing also known as "greening"), as well as increase productivity. The different varieties help to keep factories running for a longer time than simply relying on one variety. All varieties are blended to standardise production and nature. Single variety oils like Valencia are usually only available from small processors in the south of Brazil.

To start blooming the tree can be stressed in two ways, either by water or temperature. A tree may have up to four different bloomings at four different times. Pickers will do their best to pick the best fruits for the fresh market and/or processing. Because of the multiple blooming there is no mechanical harvesting, only hand harvesting. If the tree is shaken it could be damaged and all the fruit could fall. In Brazil the dates of the blooms are the first usually in June/July, second in August/September, third in October/November, and fourth in December/January. The dates can vary between trees and orchards. Regarding the 2022/23 crop's production, 27.5% of production was in the first bloom, 58.3% in the second bloom, 12.4% in the third bloom, and 1.8% in the fourth bloom.

ORANGE PRODUCTS

Citrus processing and the recovery of citrus by-products (e.g., juice, peel oil, aroma and essence oils, frozen pulp cells, and cattle feed pellets) are vital economic components of citrus production, especially when large volumes of citrus are processed. Oranges have practically no waste, with most parts being used. An average orange is made up of pellets/peel (49.25%), juice (43%), frozen cells (2.70%), essential oil (0.2% to 0.4%), pulp wash (1.75%), d'limonene (0.092%), water phase (0.46%) and oil phase (0.011%). Both oil phase and water phase are dependent on juice being produced - none is produced if the juice is sold as NFC (not from concentrate), which is an increasing amount. The components and product yields vary between species, countries, volumes processed, equipment used, and their efficiencies. One guesstimate suggests that one metric tonne (MT) of oranges not only provides revenue from citrus pellets, pectin, and cattle feed, but also, more importantly, approximately 100 kg of frozen concentrated orange juice 65 brix (FCOJ), 3-4 kg of orange oil, 1-1.5 kg of limonene, 0.1 kg of oil phase essence, and 1 kg of water phase essence. Interestingly it is sometimes green oranges that are processed - suggesting the term "orange" is a misnomer! The green colour is chlorophyll which decreases after exposure to colder temperatures allowing the carotenoids to dominate leading to orange skins. Sometimes the oranges may be affected by HLB ("greening") which is not desirable.

Figure 1 shows the cross section of an orange in which four different types of orange essential oils are located, two from the peel and two from the fruit. The waxy cuticle is the fruit's outside protective barrier. The flavedo region immediately below is made up of oil glands from which two types of essential oil can be extracted. Below this is the albedo, the sponge-like white portion of the peel, which consists of large cells rich in pectic substances and hemicelluloses. The edible portion is the endocarp, made up of segments containing juice vesicles. Within the juice's composition there are two other flavouring components, namely the oil and water phase essences.

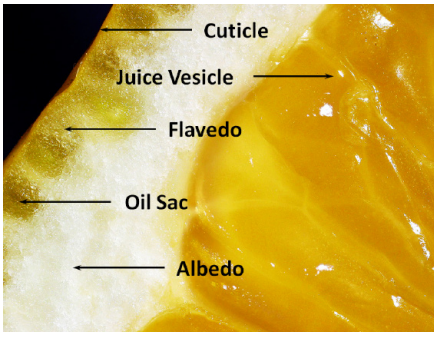


Figure 1: Structure of Orange Fruit
Source: Walsh (2008)

PROCESSING

Usually, the main aim of citrus farmers is to sell fruit into the fresh fruit market while any fruit that does not meet specification is often sent for juice processing, and the oil is a by-product from juice production. Brazil and Florida are the major exceptions in focusing on growing oranges for processing - Brazil (and Mexico) producing FCOJ while Florida produces NFC. Processing of orange is invariably undertaken close to where oranges are produced – they are not shipped and then processed, although there have been very rare exceptions such as when Cuba shipped fresh oranges to East Germany for processing. The recovery of citrus by-products is an increasingly important economic feature of citrus processing operations and the long-term upward trend in orange oil prices can have a significant impact on profits. It is particularly appropriate when large volumes of fruit are processed. Therefore, many juice processors have installed state-of-the-art centrifuges to maximise yields and de-winterising machinery to remove waxes.

While most essential oils are extracted by steam distillation, citrus oils, including orange, are extracted as a by-product of juice extraction by centrifugation, which produces a cold pressed orange oil (CPOO). The oil is extracted, without heat, from orange peel, predominantly using JBT (FMC) and, to a lesser extent Brown extractors, to express the oil from the fruit, although there are other extractors. The oil is captured in water and this oil and water emulsion can be separated using centrifuges. Essence oil and water phase essence are by-products of the juice concentration processes which Dr James Redd developed the processes for in the early 1960s - and as a result is considered the father of Florida's flavour industry. The CPOO is isolated from the surface of the peel by scraping the surface and washing off with water. This is centrifuged to yield CPOO.

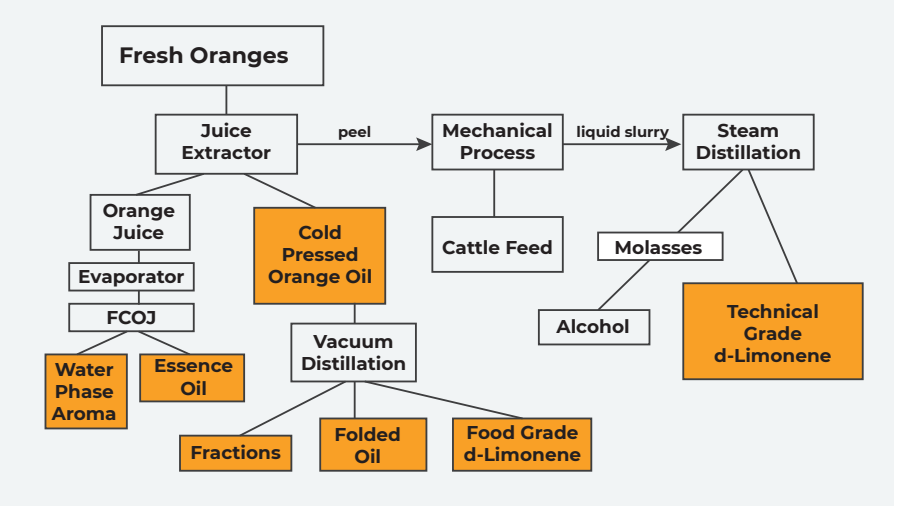


Figure 2: Orange Processing Flow Chart
Source: Florida Chemical Company

Figure 2 illustrates the complex industrial scale process by which oranges are processed into a range of orange products. The processing operations are usually very large scale, handling many thousands of tonnes of oranges each day. Following harvesting, the fruit arrives on large trucks and is washed, graded, sorted, and delivered to the extraction plant to produce three different streams: juice, peel oil, and peel solids. Cold pressed orange oil (CPOO) is liberated from the peel by pressing or rasping. The juice is then squeezed from the orange using modern commercial orange juice extractors designed to efficiently remove oil without changing its intrinsic properties. The two alternative approaches are (a) rasping the peel to force the oil out of the cell or (b) pricking the skin and rupturing the oil cell:

- JBT (FMC) equipment is the most used. It was developed around 1950 and extracts the oil and juice together but gives a lower oil yield. It punctures the outside of the skin releasing the oil, and simultaneously perforates the centre of the fruit to remove the juice and pulp. Many hundreds of fruit per minute can be processed. For greatest efficiency the fruit should be the same size and shape as the cup. FMC/JBT lease rather than sell their machines and when the patent expired, a Spanish copy called Exzel came on to the market, which can be bought.

- The Brown oil extractor from the USA uses a two-step system, like the Italian raspers (known as pelatrices or sfumatrice machines) but instead the peel is cut with small knives, and then in a second step the juice is extracted. It gives a higher yield of oil, which may be as much as 0.05%, but some believe the juice is of a poorer quality. Brown machines are also only leased. FMC has developed a similar oil extractor called the MORE.

When the extraction process is completed, the juice has the pulp and seed fragments removed. The juice is either pasteurised to produce not-from-concentrate (NFC) or evaporated into concentrated orange juice. Evaporators are used to concentrate the juice to approximately 65° Brix with most of the water removed. During the concentration of this juice, orange oil phase essence ex juice and orange water phase aroma (also called orange aroma) are removed and captured. In addition, the spent peel solids may be further processed at the feedmill to obtain several additional by-products. The main objective is to remove moisture from the peel and recover the remaining peel oil (approximately 40%) not collected by the FMC or Brown extractors. After lime (calcium hydroxide) addition and pressing of the peels, the press cake is dried to produce animal feed. The press liquor is distilled in the waste heat evaporator to concentrate the molasses and obtain feedmill d-limonene, normally at a minimum of 93% pure.

The main component of orange oil is limonene (up to 95%) but it can also be recovered from waste peel in the feedmill during the juice making process. Whereas orange oil is extracted using a mechanical process, d-limonene is produced by distilling orange peel. D-limonene can be obtained in several ways:

Food grade

- After cold press extraction, the water and oil can be separated and the waste water fractionated to obtain d-limonene food grade.
- Obtained from folding orange oil to produce orange terpenes food grade.
- Obtained from folding orange oil phase oil.
- The peels can be further pressed using charcoal and solvent to extract d-limonene technical grade. After lime (calcium hydroxide) addition and pressing of the peels, the press liquor is distilled in the waste heat evaporator to obtain technical d-limonene.

The volume of d'limonene produced is difficult to quantify but one industry source suggests that current annual production is approximately 35,000 MT (20,000 MT of technical grade + 15,000 MT of food grade d-limonene) as well as 40,000 MT of orange oil. Orange oil and d-limonene production vary according to the volume of oranges processed, the equipment used, the maturity and variety of the fruit.

Until recently, Brazil traded approximately 60%-65% of all orange oil and d-limonene produced in the world, followed by the USA with 25%-30%. However, the recent collapse of Florida's orange fruit production has led to a sizeable increase in Brazil and Mexico's global share.

The oil phase and water phase are referred to as "essences" and obtained by concentration of the juice. There is a shortage of these two products because of decreased demand for concentrated orange juice, and rising consumer preference for NFC orange juice, which does not lead to the production of orange essence oil. NFC dominates USA production and Brazil and Mexico produce approximately 80% and 20% of orange essences available globally. Over the past decade production of orange essences has fallen considerably with the growth of NFC production.

The crude orange oil and essence oils can be further processed into other products often used as ingredients for the F&F sector. The range of aroma chemicals that can be extracted from CPOO include aldehyde C8 octanal (0.4%), myrcene (1.5-2.0%), d-limonene/ orange terpenes (95%), 8-3-carene (0.1-0.15%), linalool (0.5%), decanal (0.5%), sinensal (0.05%). In addition, ethyl butyrate can be extracted from the orange oil phase essence ex juice while valencene (used to produce nootkatone) can be extracted from d-limonene. For octanal and decanal, orange oil has been one of the cheapest natural FEMA/GRAS sources. Indeed, one of the benefits of orange oil as a production source was that its by-products or terpenes could be priced at approximately the same level as the starting or raw material oil. For many years it was considered that the terpenes should be approximately 20% cheaper than CPOO. This is not the case today, since the price of terpenes is limited by other competing substances derived from the pine industry.

One process is fractionation using complex distillation columns – known as

folding oils – whereby the terpenes are removed to leave a more water soluble folded oil widely used in the beverage industry. D'limonene is used as a natural cleaning agent or degreaser and can be used in emulsions. Natural isolates are also fractionated from the oil, these will be used by flavour houses to enhance flavour profiles. Single fold citrus oils are also made into various forms of flavours and fragrances depending on the application.

To summarise, the following orange by-products are recovered from the processing operations:

From the peel:

1. *Cold pressed oils (orange oil, peel oil, CPOO)*
- 96-99% volatiles (97% monoterpenes, 4% oxygenates)
- 1-4% non-volatile wax residue
- Used for flavour and fragrances; imparts peely, citrus nuances

2. *Feedmill d-limonene*
- Evaporated product (97% monoterpenes, 4% oxygenates)
- Considered technical grade (non-food grade) material

From the juice:

3. *Essence oil phase (essence oil, OEO)*
- Evaporated product (96% monoterpenes, 5% oxygenates)
- Used for flavour and fragrances; imparts fresh, juicy, citrus nuances

4. *Essence water phase (aroma/aqueous essence)*
- Evaporated product (85% water, 13% ethanol, (^1% oxygenates)
- Used as flavour material; imparts fresh, juicy, citrus nuances

Source: Walsh (2008)

USES

Orange has excellent health properties and has multiple uses, mainly as fresh fruit, then as juice followed by as an essential oil. It is more widely used than any other essential oil and with its derivative d-limonene is used in a wide range of products and industries. The main sector buyers are the F&F industry followed by the resin manufacturers and increasingly in aromatherapy.

Large supplies of orange by-products over the past few decades have enabled them to penetrate many markets but higher prices are leading to significant changes. D-limonene has diverse and growing applications as a solvent, cleaning agent, fragrance additive, and is used by the resins industry in the manufacture of adhesives, tyres, and chewing gum. Limonene is also used to synthesise aroma chemicals such as l'carvone, an important flavour ingredient used in mint flavour compounding in confectionery and oral care. It is also used in the electronics industry as a degreaser and is a starting monomer for block copolymers, butyl rubber and polyisoprene rubber, and in paint solids to impart an orange fragrance.

However, some sizeable industrial uses a decade ago – including 20,000 MT of limonene - have been considerably reduced when the price of limonene jumped from the US$ 1.00/kg level to US$ 6.0/kg leading to long-term reformulations and a sharp drop of demand to less than 10,000 MT a year, even despite a limonene price decrease to levels below US$ 3.00/kg. It is interesting to note that 100% pure d-limonene has no odour, but lower purity has aldehyde c8 (octanal) which gives it odour.

Applications of orange oil include:
- Folded oils for use in flavour compounds (mainly 5x and 10x, with orange terpenes food grade as by-product) with beverage applications being the main one.
- Extraction of flavour natural molecules like decanal, octanal, linalool, and valencene.
- Use in fragrance compounds.

Thus, the sectors using orange products are remarkably diverse - flavours, fragrances, aromatherapy, pharmaceuticals, cosmetics, beverages, bakery, agriculture, oral care, detergents, animal feeds, cleaners, construction materials, confectionery, solvents, pest control, liqueurs, electronics, polishers, plastics, adhesives, paints, resins, disinfectants, and tyres.

However, demand for orange derivatives has become increasingly unbalanced. The market for the dominant products, FCOJ and NFC, has been decreasing for several reasons. Meanwhile, the demand for orange oil and terpenes/d-limonene had been increasing. In part, this was because of new applications and they were being used as substitutes for other products, such as kerosene, acetone, and turpentine as well as starting materials for chemical processes, because until recently they were seen as relatively cheap.

In addition, they are viewed by consumers as a natural product, non-toxic, eco-friendly, and have a lower carbon footprint with net global warming potential. Terpenes are marketed as both nature friendly and human friendly. There are synthetic substitutes but they are too expensive and not readily available, and are not acceptable for use in F&F.

As a result, revenues from oil and derivatives have become significantly more important over the past decade in the economics of orange processing. To keep orange oil and derivatives at acceptable prices for intensive industrial use, it helps that the main processors in Brazil have been running international campaigns to encourage consumers to drink more orange juice.

QUALITY

Quality has become increasingly important as consumer demands have become more stringent. Almost every year new parameters are set which must be complied with along with the old specifications. Moreover, quality specs can vary between different markets and end uses. An increasingly key issue relates to the level of agricultural residues both on the fruit and in the oil. This is discussed in greater detail below.

The quality of orange oil is influenced by several factors. Like most oils, a key factor is the percentages of various aromatic components - orange oil is composed mostly of d-limonene (>90%). Along with d-limonene the constituents in the oil are considered as terpenes, alcohols, and aldehydes. The compounds in the oil can vary depending on the variety, the extraction process, the location, and the weather. Some oil is juicier or fruitier than others, mostly due to the aldehydes and top notes and these notes are often sought after by buyers. Aldehydes can be quite unstable and volatile. One recent undesirable trend has been lower levels of aldehydes, making it increasingly difficult to find premium grade, considered to be a minimum 1.2%. Levels of aldehydes vary between orange products. Thus, single orange oil can range from 0.6% - 1.7%, folded oils, 5-fold 3.6%, 10-fold 7.1%, 20-fold 14.5%, orange terpeneless 41% and orange terpenes 95% - 0.2% aldehyde.

PRODUCTION CHARACTERISTICS

Over 100 countries predominantly within 40 degrees N and S of the Equator produce oranges. Approximately 50 million metric tonnes (MMT) of oranges are produced annually, of which approximately 40% are processed i.e., 20 MMT. Tables 1 and 2 provide estimates of world orange production and processing by major countries.

Table 1: Orange Production for Selected Countries 2018/19 - 2022/23 ('000 MT)

Marketing Years	2018/19	2019/20	2020/21	2021/22	Forecast from July 23 2022/23
Brazil	19,298	14,870	14,676	16,932	16,753
China	7,200	7,400	7,500	7,550	7,600
European Union	6,800	6,268	6,531	6,720	5,856
Mexico	4,716	2,530	4,649	4,595	4,200
Egypt	3,600	3,200	3,570	3,000	3,600
USA	4,923	4,766	3,981	3,108	2,288
South Africa	1,590	1,414	1,511	1,609	1,630
Turkey	1,900	1,700	1,300	1,750	1,320
Vietnam	855	1,017	1,150	1,150	1,583
Argentina	800	700	750	830	800
Morocco	1,183	806	1,039	1,150	783
Australia	515	485	505	535	505
Costa Rica	295	285	290	300	305
Chile	140	135	200	164	174
Guatemala	178	180	180	180	168
Other	309	356	356	397	377
Total	**54,302**	**46,102**	**48,186**	**50,410**	**47,765**

Source: USDA

Table 2: Orange Processing for Selected Countries 2018/19 - 2022/23 ('000 MT)

	2018/19	2019/20	2020/21	2021/22	Forecast from July 23 2022/23
Brazil	14,362	9,915	10,118	12,291	12,090
Mexico	2,200	900	2,200	2,150	1,760
USA	3,378	3,050	2,498	1,826	975
European Union	1,309	848	996	1,110	831
Egypt	360	335	350	300	300
China	520	400	350	249	220
Costa Rica	216	213	215	218	218
Australia	210	195	226	215	210
Argentina	307	190	186	200	200
South Africa	333	76	123	174	155
Other	197	182	196	219	192
Total	**23,392**	**16,304**	**17,488**	**18,952**	**17,151**

Source: USDA

Global orange production for 2022/23 is expected to be 5% lower at 47.8 MMT compared to the last crop owing to lower production in the European Union (EU), the USA, and Turkey, offset partly by a larger crop in Egypt. Fruits allocated to processing will be reduced, resulting in less orange oil production. The actual amount of processing will be dependent on the value the processor can derive from the juice and orange oil produced. Brazil dominates orange processing but the dramatic fall in recent US orange production which means that for the first time in history, Mexico is the second largest orange processor, followed by the USA and the European Union (EU).

The volume of orange oil, terpenes, and d-limonene produced is directly related to the quantity of oranges processed for orange juice. In 2022/23 orange juice production was estimated to be 9% lower at 1.5 MMT (65 degrees Brix) - equivalent to almost 2 MMT of oranges. Juice production fell because of the reduced fruit available for processing in the four major producing regions, namely Brazil, Mexico, the EU, and USA as illustrated in Figure 3. This in turn reduced the amount of orange by-products produced. Figure 3 illustrates trends in the production of orange juice - which in turn can be used as a proxy for the trends in production of other orange by-products. Orange juice - and therefore by-product production - has been substantially lower in the last four years than in previous years, leading to the sizeable rise in by-product prices.

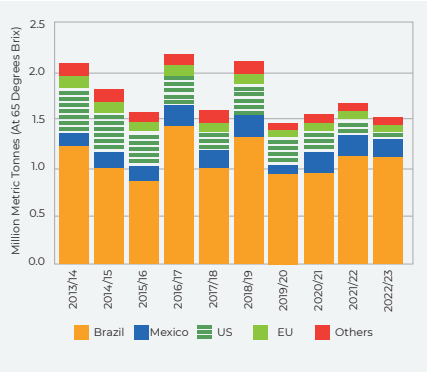
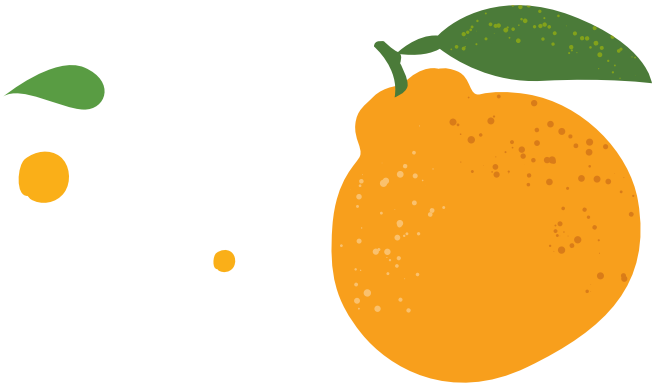


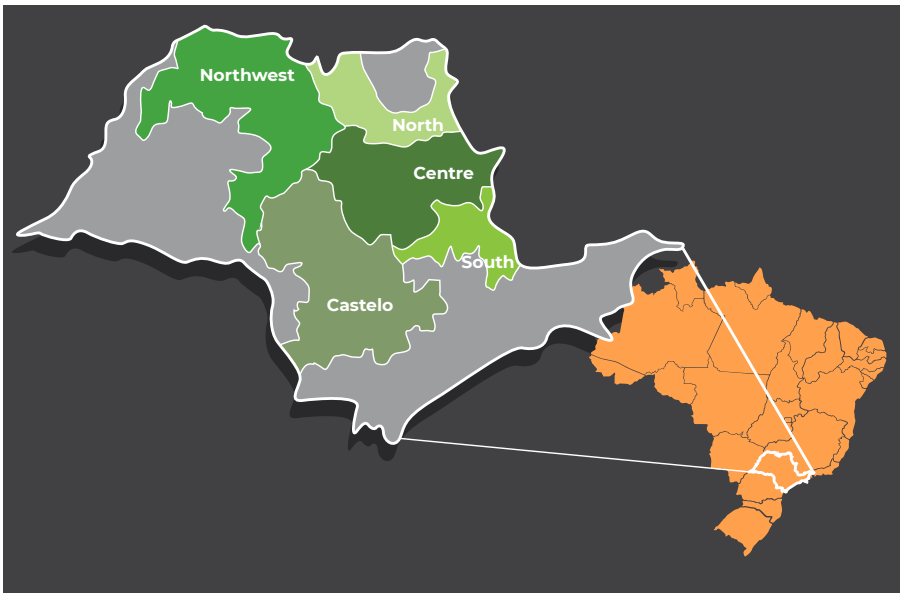
Figure 3: Global Orange Juice Production 2013/14 - 2022/23 (MMT)



Future Production Trends

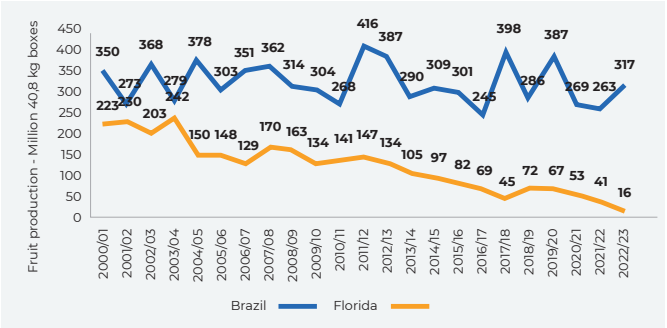
It is important to recognise that over the past century there have been sizeable shifts in orange oil production arising from economic, climatic, and other environmental factors which will continue to lead to shifts in the location of production. All growers face major issues with changing climatic conditions and natural variability while some major growers and processors, particularly in the USA and EU, face substantial pressure on land availability, combined with high labour and other costs. In contrast in China, Egypt, and Turkey, the industry is reported to be growing and thriving but their dominant focus is growing fresh fruit. The supply of orange by-products depends, to a large extent, on the size of the orange harvest and the volume of fruit available for processing in countries where a processing industry is established.

Brazil Citrus Belt Regions (São Paulo and Triângulo Mineiro)



BRAZIL

Brazil's annual orange oil production varies from 30.0 to 40.0 MMT from some 344,389 hectares (ha) of orchards in the Citrus Belt concentrated in the states of São Paulo, which dominates production, and Minas Gerais (see map). Figure 4 illustrates the trend in Brazilian orange crop output in comparison with Florida in the USA. Production fluctuates between seasons but over the past two decades there has not been a significant variation in supply particularly in comparison with US trends. Over the past two decades the trend has been relatively stable despite wide annual fluctuations. The 2023/2024 crop shows a slight decrease compared to the last crop, partly because of the alternate bearing phenomenon. Prices have not fallen as much as expected because of the high demand from the processing industry, who are still filling contract requirements from the last two years because of no carryover inventory. Supply remains lower than demand because of lower-than-expected global output. Demand and prices are still firm. Moreover, input costs are rising, particularly fertilisers, energy, transport, and labour. Greening HLB remains a major issue, while quality is lower and failing to meet specifications for aldehyde content.



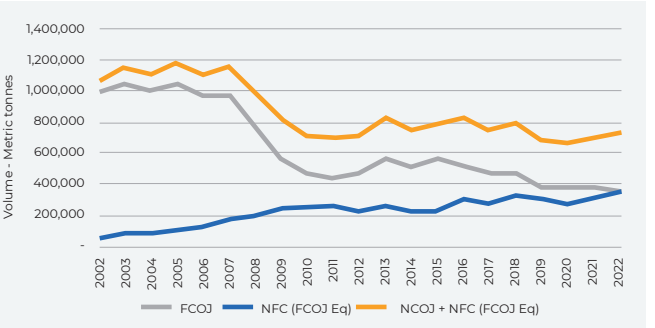
Source: Brazil Ministry of Development, Industry, Commerce and Services (MDIC) and USDA

Figure 4: Brazil and USA Orange Production 2000 - 2023 (Million 40,8 kg boxes)

Minas Gerais has a better juice because of the sweetness but the oil has generally less aldehyde and is lighter in colour. São Paulo is not as good for juice because the oranges are less sweet but the aldehyde is higher and the colour darker. There is no geographical area with high aldehyde material and light colour.

The fresh fruit market makes up approximately 30% of Brazilian production with only very small quantities exported. The remaining 70% is processed, of which 55% is used to produce juice (FCOJ Brix 66° and NFC Brix ≤ 20° - of which more than 90% is exported); 45% is pulp, rind, and seeds, predominantly for animal feeds. Essential oils is 0.3% of which over 90% is exported. Thus, orange is cultivated in Brazil predominantly for the juice and orange oil and other derivative production and prices are very much influenced by the juice market.

Despite global economic growth, there has been a sizeable decline in demand for orange juice over the past two decades and Brazilian exports of FCOJ have fallen by approximately one-fifth, although revenue has doubled because of unit price increases. Figure 5 shows the diverging trends in Brazilian exports of FCOJ and NFC over the past two decades. As yet, it is hard to say whether demand may have stabilised following the COVID pandemic and rise in citrus product consumption. Much will depend on the marketing the industry does to promote the product. In the past, demand was driven by the huge amounts of marketing undertaken by large juice companies, but these brands have now diversified their offers a lot and consumers have a much wider range of options.



Source: Brazil Ministry of Development, Industry, Commerce and Services (MDIC)

Figure 5: Brazil FCOJ and NFC Exports (FCOJ equivalent) 2002 - 2022 (MT)

Meanwhile the supply and exports of CPOO have been relatively stable while the price trend has been dramatically upward. Over the past six years annual average orange oil production has been 30,500 MT with a peak of almost 40,000 MT in 2017/18 and a low of 22,700 MT the previous year. Figure 6 illustrates Brazil's annual orange oil exports have remained relatively stable over the past two decades ranging between 25,000 and 31,000 MT with a peak of 34,765 MT in 2020. However, the unit value has increased substantially with exports in 2020 valued

at US$ 159 m. and lower volume exports in 2022 of 27,141 MT valued at US$ 231 m. While orange CP oil exports have shown a relatively stable trend, orange terpenes, illustrated in Figure 7, have shown a slightly downward trend while prices have shown greater upward volatility. Orange terpene pricing is stuck at around $5/kg, when higher the demand goes elsewhere.

Source: Brazil Ministry of Development, Industry, Commerce and Services (MDIC)

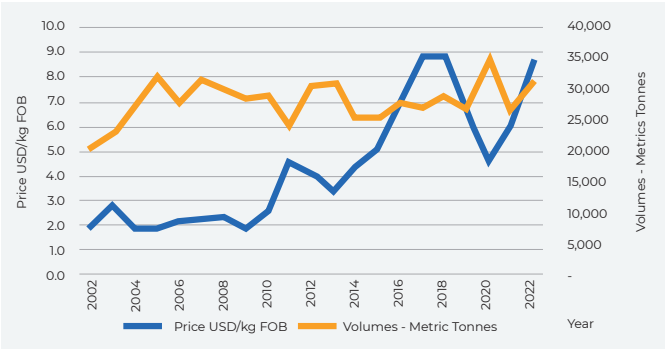


Figure 6: Brazil Orange Oil Exports 2002 - 2022 Volume (MT) and Price (USD/kg fob)

Source: Brazil Ministry of Development, Industry, Commerce and Services

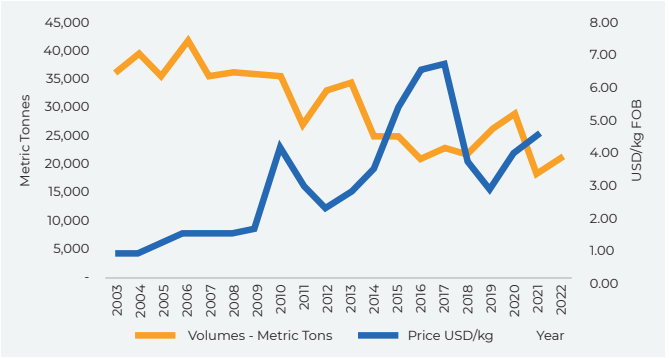


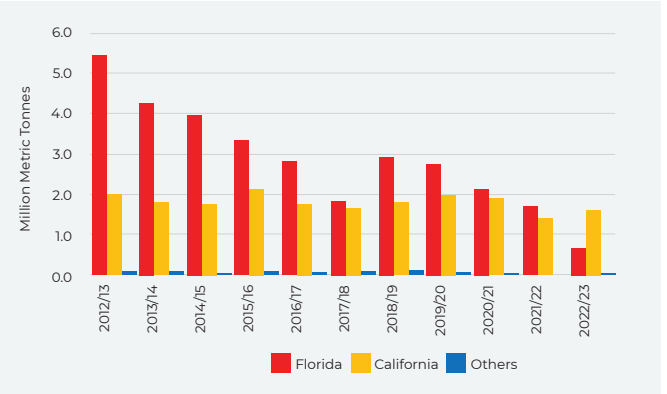
Figure 7: Brazil Orange Terpene Exports 2003 - 2022 Volume (MT) and Price (USD/kg fob)

Orange in Brazil faces competition from alternative crops particularly sugar cane, used for making biofuel. Moreover, sugar cane can provide a return within a year, whereas oranges not only have a gestation period of 3-4 years but also have added risks of greening and greater price volatility. Even though prices are at an all-time high, smaller and medium-sized Brazilian farmers have been reluctant to invest and orange production is increasingly concentrated in three companies: Citrosuco, Cutrale, and Louis Dreyfus, accounting for over 75% of orange processing/ production. Moreover, in the past year this market concentration has led to lawsuits alleging a cartel and price-fixing scheme.

Estimates of orange oil and d-limonene production are difficult to obtain. In 2011 one source estimated that global orange oil and d-limonene production was close to 95,600 MT of which 65,000 MT was produced in Brazil. 95% was undertaken by four major players namely Cutrale, Citrosuco, Citrovita, and Dreyfus. Some 25,000 MT were produced in Florida by four major players, most with plants in Brazil. Some 5,600 MT were produced in the rest of the world, mainly the EU. In total, this would be equivalent to more than 6,000 full container loads (FCL) of CPOO and d'limonene. However, much has changed during the past decade. Citrosuco and Citrovita, who also operated in Florida, have merged and are now under the Citrosuco brand. Mexico is producing more than the USA.

USA

Until the 1980s Florida used to dominate USA and global orange production but in recent decades and particularly in the last few years there has been a dramatic fall in output. As Figure 8 illustrates, this contrasts with California which has recently



Source: USDA

Figure 8: U.S Orange Production

replaced Florida as the largest US orange producing state. Several factors account for the collapse of Florida production including climatic conditions, real estate development, and the losses from citrus canker and HLB greening disease introduced in 2005. Since Florida processes about 90% of its orange crop, the substantially lower production volumes have affected global juice, oil, and other by-product supplies.

Between 2001 and 2021 Florida's citrus growing area declined by just over 50% from approximately 300,000 ha to 150,000 ha, while production volume for utilisation declined by 79%. Oranges accounted for 92% of Florida's citrus production in 2021. Orange essence water phase and essence oils are two by-products of the evaporation process used to produce FCOJ, but production of this form of orange juice has almost disappeared in Florida due to the popularity of freshly squeezed pasteurised orange juice (NFC). It is believed that Brazil now produces over 80% of these two oils available globally, with 20% from Mexico. Prior to the recent collapse of production, Florida annually produced 10,000 - 15,000 MT of orange oil and 5,000 - 10,000 MT of d-limonene. Recent production is almost certainly well below 10,000 MT.

Orange production in 2022/23 is estimated to drop by over a quarter to 2.3 MMT, the lowest level in over 50 years. Yields continue to decline in Florida due to fruit drop caused by citrus greening, reduced area harvested, and high winds from hurricanes. California is estimated to have produced over twice as many oranges as Florida in 2022/23. Consumption and exports are flat while oranges for processing have fallen by more than 50% in the last three years due to the drop in availability, leading to a substantial fall in FCOJ and by-product output (Table 2 and Figure 3). California predominantly produces oranges for the fresh market. US imports of orange products have risen substantially in recent years.

MEXICO

Mexico is a major citrus producer and over the past four decades orange production has shown an upward trend. It is now the third largest orange producer and processor in the world but very far from the volumes available in Brazil. Production is undertaken in 12 states and some 80% is Valencia and 20% early and midseason varieties. Production faces several challenges, the main ones being climatic conditions, the arrival of greening and the operation of criminal gangs. High temperatures and severe drought have impacted production in recent years. Also, aldehyde levels in CPOO have struggled to get close to 1.1%.

Total forecast production in 2022/23 is estimated at 4.2 MMT (103 M boxes), 9% lower than the previous crop. The fall is attributed to the prolonged drought and high temperatures in northeastern Mexico, particularly affecting the states of Tamaulipas and Nuevo Léon, as well as Veracruz and San

Luis Potosi. Fruit available for processing will be lower, while consumption is stable and exports unchanged. Orange processing is undertaken throughout most of the year except for September and October. In 2012/13 there were 15 plants processing an estimated 900,000 MT out of a crop of 4 MMT, with two companies accounting for almost two-thirds of production. Frutech estimated an oil yield at 0.34% producing 3,000 MT of oil. USDA data show wide annual variations in the level of oranges processed, sometimes accounting for almost half of Mexican production. Lower production in 2022/23 will lead to processing volumes falling by almost 20%, with a resultant fall in by-product output (see Table 2 and Figure 3). Orange oil and d-limonene/terpenes are being exported into the neighbouring USA in part to substitute for falling US output.

EUROPEAN UNION

Spain and Italy are at the forefront of European Union orange producing countries. Recent declines in production are due to adverse weather conditions, particularly record-breaking temperatures in Spain and drought conditions in Italy. Another problem for processors is that fresh fruit prices have remained strong in the EU, making it difficult for processors to compete, along with raising input costs. USDA forecasts that total orange for processing in 2022/23 will total only 659,000 MT - some 40% below the previous year.

ITALY

Italy has a thriving citrus industry with over 62,000 citrus farms and 144,000 ha under cultivation, of which 47,000 ha are organic (ISMEA). The average citrus farm is very small at 2.09 ha, reflecting the maintaining of family traditions and a smaller operating scale. The total area of orange groves in Italy in 2022 was estimated at 85,472 ha, with a total orange production of 1.8 MMT. The Tarocco blood orange (December-February) is the most abundant variety, followed by Navel (December-May) and Sanguinella blood orange (Feb-April) and the Washington Navel (December-May). In recent years the trend has been relatively stable in both cultivated area and output. Sicily accounts for just over 60% of the surface area in Italy devoted to oranges, followed by Calabria (23%), Apulia and Basilicata each 6%, and Sardinia (3%).

An estimated 40% of the citrus crop is further processed, which suggests that in the 2022/23 season an estimated 783,730 MT of oranges were processed. The estimated 10% fall in production in 2022/23, due mainly to climatic factors, suggests only 705,350 MT of oranges will be processed. However, this is substantially higher than the USDA forecast.

	Season 2019-2020	Season 2020-2021	Season 2021-2022	Season 2022-2023 (Forecast)
Oranges	1,772,769	1,793,468	1,959,303	1,763,372

Table 3 - Italy: Orange Fruit Production 2019/20 - 2022/23 (MT)

Source: ISTAT

When orange peel is processed to produce candied fruit there is no extraction of essential oil. It is estimated that approximately 55% of the total volume of Italian orange processed is to produce candied fruit, used in cakes and other baked goods. The remaining 45% is used in essential oil production. Based on an average essential oil yield of 0.4% then this would suggest essential oil production of 1,270 MT. Bredenberg (2004) shows Italian annual orange oil production in the decade 1994 to 2003 ranging between 700 MT and 1,520 MT.

SPAIN

Spain accounts for approximately two-thirds of the EU's citrus production and is by far Europe's largest orange producer of both sweet and bitter orange varieties. Spain has a range of both early and late sweet varieties, including Navel, Navelate, Salustiana, Valencia, and Sanguinello enabling it to supply the market throughout most of the year. Sweet orange is heavily concentrated in Valencia and Andalucía, and to a lesser extent the Murcia region. Recent output has fallen mainly because of adverse and extreme weather conditions including excess rainfall, high temperatures, and drought which have impacted the flowering, setting, and fattening phrases.

Production in 2022/23 is forecast to decline to 2.895 MMT of oranges, nearly 20% lower than the last five-year average, with production having peaked in 2018/19 at 3.908 MMT. After several consecutive years of economic slowdown, citrus farmers are increasingly leaving orange production for more profitable products. However, the Spanish orange planted area has been steadily rebounding since 2018, reaching approximately 143,000 ha in 2022, of which an estimated 108,080 ha was planted with sweet orange trees. Sustainable practices, the productivity of Spanish orange farms, and the use of efficient and high-performing varieties have kept Spain as the top orange producer and exporter in the EU.

Estimates vary regarding oranges processed, with one source stating that sweet oranges processed totalled 138,417 MT in 2020 rising to 199,984 MT in 2021, and 207,485 MT in 2022. The yields from 1,000 kg of sweet Spanish orange range between 1.6 and 2.3 kg of orange oil and between 1.5 and 2.2 kg of limonene. If all the by-products were extracted from the 207,485 MT of sweet orange processed in 2022 then using the lower yield estimates this would suggest the approximate production of 3,300 MT of orange oil and 3,000 MT of limonene. However, not all the essential oil by-products are recovered during processing and at best less than half of these amounts are probably achieved. The higher CPOO prices over the last decade have led more processors to install oil recovery units.

Miralles (2004) stated that on average sweet orange oil is only recovered from 80% of the total quantity processed by the industry and in 2002/03 essential oil production was 813 MT. Bredenberg (2004) shows annual orange oil production from 1994 to 2003 ranging between 500 MT and 820 MT.

SOUTH AFRICA

South Africa is one of the largest citrus producing countries in the world and most fruit is orange, accounting for almost two-thirds of citrus production, followed by grapefruit, lemon, and tangerine. Orange production in 2022/23 is estimated up slightly to a record 1.6 MMT because of favourable weather and a slightly larger area being harvested. Three quarters of production is exported and exports are at a record high for the third year in a row. The fresh fruit market dominates the industry and most of the fruit is treated with pesticides pre-harvest and then also post-harvest at the pack houses once the fruit is sorted. This leads to a problem in the oil because the pesticides remain on and in the oil pores on the skin of the fruit.

Approximately 16% is processed and the remainder sold domestically. Approximately 3 kg of orange oil is obtained from 1 MT of fruit. A range of further processing is undertaken to add value to the orange oil and d-limonene produced. This includes fractionation into flavour components and d-limonene, using a complex distillation column. The phase separation process known as folding oils involves the removal of some of the monoterpenes. The folded oil (concentrated) is used in the beverage and confectionery industries. The d-limonene/orange terpenes are used as a natural cleaning agent or degreaser and can be used in emulsions. Natural isolates are also fractionated from the oil, and these are used by flavour houses to enhance flavour profiles.

The past decade has seen a growth in orange production driven by expanding exports of fresh fruit, leading to a decline in processing levels. However, problems with residue levels have negatively impacted exports and could facilitate an expansion of processing.

CHINA

China is the world's second largest orange producer with annual production averaging approximately 7.5 MMT, almost all of which is consumed as fresh fruit. Approximately 250,000 MT are processed each year producing FCOJ and a small production of other by-products all of which are consumed locally. China is most unlikely to enter the international market and if it did then agricultural residues would be an issue.

EGYPT

Egypt is a major producer and exporter of fresh oranges with annual production in 2022/23 estimated at a record 3.6 MMT. Processing has been relatively stable in recent years, around 300,000 MT but is more known for its bitter orange essential oil production. However, the rise in product prices could facilitate increased processing and greater attention being paid to orange by-product production.

MOROCCO

The cultivation of citrus fruits, including oranges, dates back several centuries in Morocco and it is best known for its bitter orange oils, especially neroli. However, it has a rich history of producing orange oil, derived from the peels of oranges. Moroccan oranges are known for their exceptional flavour and aroma, making them highly sought after in both domestic and international markets. Morocco has developed a reputation for producing small quantities of high-quality orange oil. The main variety is Navel, and other varieties include Salustiana and Maroc Late (also called Valencia Late season type). In 2022/23 estimated production fell by almost a third to 783,000 MT because of unfavourable weather and water shortages. Annual orange oil production is approximately 60 MT.

TÜRKIYE

In recent years Türkiye's annual orange production has invariably exceeded 1.5 MMT but negligible quantities are processed so essential oil output is minimal. Moreover, Türkiye faces problems with the level of agricultural residues which have impacted orange exports.

OTHER PRODUCERS

As Tables 1 and 2 show there are other sizeable orange producers who also process orange, including Argentina, Australia, and Costa Rica, but it is not thought that these produce many orange by-products. Bredenberg (2004) estimated that Greece and Israel annually produced around 200-300 MT and 100 MT of orange oil in the early 21st century. Many of these smaller sources of oil are blended with larger production sources, so the oils lose their source identity.

MAJOR CHALLENGES

There are several major challenges facing orange production and the industry:

- ***Climatic variations*** including frosts, droughts, heavy rains, and hurricanes have all seriously impacted production. La Niña, followed in mid 2023 by El Niño, continue to have major impacts on orange and citrus production and many key producing regions are experiencing droughts or intense, unseasonal rainfall that affect key blooming periods. These climatic factors reduce the fruit size and yields and hence the availability of fruit for processing and essential oil production.

- ***Disease and pesticides*** - oranges are susceptible to a range of diseases usually borne by insects that can substantially lower output. These include CTV (citrus tristeza virus), CVC (citrus chlorosis variegated), sudden death virus (SDV), and citrus canker. The dominant threat is greening (HLB), a bacterium spread by the psyllid insect, which reduces yields, kills trees, and impacts quality. Greening is having a major impact on the three major producers Brazil, Mexico, and the USA. In 2022 greening affected 20% of the Brazilian crop and is rising. Substantial research is being undertaken to control the disease which includes removing infected trees, planting resistant rootstock, and using pesticides. Older orchards have a higher proportion of greening, and the bigger the property, the lower the greening occurrence. In Brazil, Fundecitrus (The Citrus Foundation) promotes regular inspections at several farms to identify and quantify the effects of the disease.

- ***Agricultural residue*** issues arising from pesticide use. The industry faces unclear regulation on pesticides residues and there is a need to coordinate accepted reference values to avoid market distortion. Some smaller to medium Brazilian farmers still use pesticides banned by the EU and USA but not by Brazil, in part because they have multiple crops and the pesticides are only restricted to specific crops. Agricultural residue (AR) issues are an on-going challenge and new EU regulations are impacting global trade. Two markets are developing, good AR and poor AR oils.

Pre-harvest most citrus fruit is treated with pesticides and post-harvest at the pack houses once the fruit is sorted. This leads to a problem in the oil because the pesticides remain on and in the oil pores on the skin of the fruit. Often batches are tested to establish the pesticide levels which can influence the use of the oil. If there are low levels of pesticide this can be processed for consumption as flavours, but if it is too high, then it will have to go for a fragrance application. In addition, other physical tests are undertaken to determine the quality (e.g., density, refractive index, optical rotation, smell, and colour).

Over the past two decades agricultural residues (AR) in orange oil has become an increasingly important issue. Pesticides are used to eliminate the pests and diseases attacking the tree and the fruit – both aiming to raise productivity and improve the fruit's visual appearance. Pressure from consumers and processors has led to a reduction in the quantity of pesticide used – as well as a means of lowering costs. Fungicides are used post-harvest to prevent fungus development and prolong the life of the fruit. Often the fungicide is combined with wax to make the fruit look more attractive. There is an inherent conflict between fresh fruit customers and orange oil customers regarding ARs. Fresh fruit customers invariably require aesthetically pleasing fruit involving the use of agrochemicals while orange oil customers face increasingly strict specifications permitting only very low levels of ARs. As a result, those farmers and processors focusing on the fresh market have difficulty producing "clean" oil. Diligent testing protocol and continued AR reduction is vital for the future of the oil products.

Legislation and regulations on pesticides have become stricter and differ between countries. Also, industry requirements are often much stricter than the applicable legislation. Considerable efforts are being made to address these issues by the different processors in each producing origin and they are working closely with growers.

It has been suggested that reduced use of pesticides and herbicides is leading to lower productivity and less oil production but the reduction is difficult to quantify. Research is being undertaken using different planting techniques and rootstocks to increase oil yields per hectare while reducing the need for agrochemicals.

One challenge is that the oil is a good solvent for many of the pesticides and the oil is recovered from the surface of the fruit

and the oil often contains much of the pesticide residue on the fruit. Regulations are normally established for the fruit but the oil can often have higher levels due to the concentration effect of the relatively low level of oil.

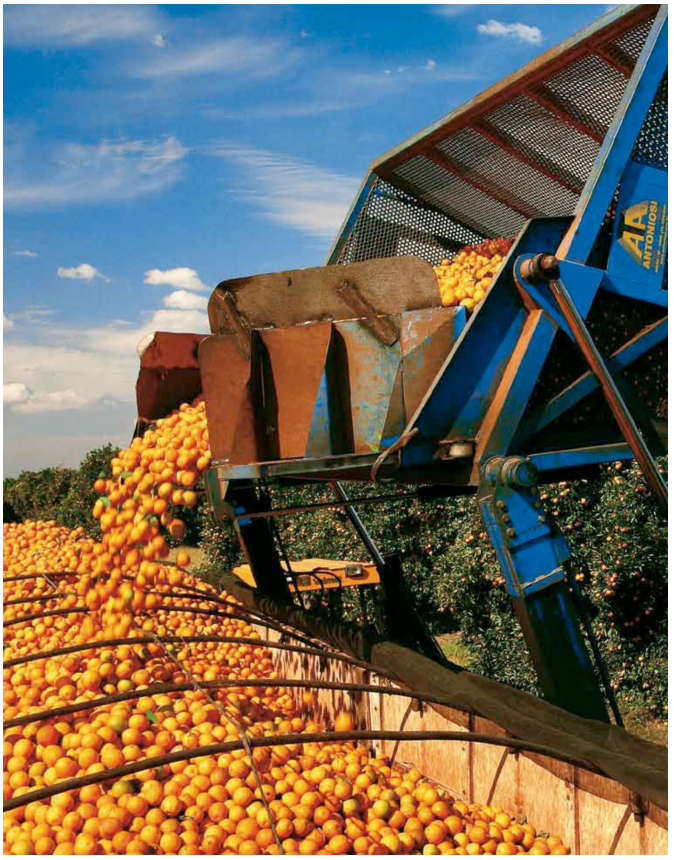
- ***Competition for land use*** - in Florida the population and urbanisation have increased, intensifying competition from the real estate sector. In Brazil land use competition comes from alternative crops particularly sugar cane, used for making biofuel. Moreover, sugar cane can provide a return within a year, whereas oranges not only have a gestation period of 3-4 years but also have added risks of greening and greater price volatility.

LEGISLATIVE AND REGULATORY ISSUES

Due to its many possible uses, orange oil and other by-products are regulated by a wide range of legislation in many countries covering its use in foods, fragrances, cosmetics, pharmaceuticals, aromatherapy, and chemical substances. A key challenge for the sector is adapting to the differing regulatory requirements between markets. Processors face the difficult task of producing high quality low residue orange oil and other products, while complying with regulations for all substances and countries, at an acceptable price. One example is the recent regulations restricting usage of pesticides, especially the banning of chlorpyrifos and chlorpyrifos-methyl in the USA, and limitations on their use in the EU. This has led to difficulties in selling significant volumes of orange oils into these markets, in part because orange oil is seen as a global product with similar specifications.

ORANGE OIL PRICES

There is considerable orange oil price volatility ranging from US$ 0.5/kg to a recent peak of US$ 19.00/kg. Many factors have impacted price levels: drought, frosts, hurricanes, global recession, reduced production and processing, disease, stock levels, increased production costs, currency fluctuations, the value of the US dollar, and economic and political instability in producing and consuming countries. Brazil and until recently the USA (Florida) dominate processing – normally accounting for more than 80% of global orange oil and d-limonene production. Thus, a major variation in either country's output has a serious impact on prices. In contrast, production trends in China, the world's second largest orange producer, do not have a major impact since it processes well below 5% of output. Ultimately prices will vary based on the supply-demand dynamics and stock levels. Since 2020 orange markets have remained firm, at least as far as the essential oils segment is concerned. Additional importance has been placed on aldehyde levels and pesticide levels, which can heavily dictate price points depending on quality and the sector (e.g., flavour and/or fragrance usage).



The relationship between the prices of various orange products is a complex one. The demand for folded orange oil tends to be fixed while that for orange terpenes is more elastic. Recently the spread between the value of orange oil and orange terpenes is so large that the cost of folded orange oils has been at an all-time high. The industrial alternative for d-limonene is turpentine based (dipentene) and other pine derivatives that are less expensive. This means that the gap between the value of CPOO is unlikely to narrow significantly - and the cost of folded oils is likely to remain high.

SOCIAL AND ECONOMIC CHARACTERISTICS

Oranges and their by-products are an important contributor to the health and wellbeing of much of the world's population. In addition, they make an important economic, social, and environmental contribution to the many countries where they are produced.

Orange oil production encompasses a wide range of economic activities including nurseries, planting, fruit production, harvesting, grading, packing, processing, juice extraction, distilling, input supplies (equipment, fertilisers, pesticides etc.), transportation, and shipping. The orange industry makes significant contributions in many other sectors due to supply chain linkages and spending incomes that have direct and indirect multiplier effects. The revenues and incomes generated are greatly influenced by the price of orange and its by-products which can be quite volatile. While some data are available on the economic and social impact of the orange sector in producing countries, orange oil and terpenes account for only a proportion of these impacts but given the overall size of the orange sector the contribution will be substantial and much larger than for any other essential oil. Moreover, the viability of the orange sector is dependent on the sizeable contribution made by orange by-products.

In all the major orange oil producing countries there are a variety of initiatives related to the production of these products that could have substantial socio-economic and environmental benefits for the producing regions and countries.

BRAZIL

Abecitrus, the Brazilian Association of Citrus Exporters, which represents the producer and export sector for concentrated orange juice in Brazil, recently reported that the sector directly employs around 400,000 people and is an essential economic activity for 322 municipalities in São Paulo and 11 in the Triângulo Mineirão region, and annually generates foreign exchange of the order of US$ 2.0 billion. Many hundreds of millions of dollars are paid in salaries and taxes by the sector. Moreover, whereas the orange sector generates one job for each 9 ha of production the equivalent figure for sugar cane is one job for 80 ha. Hand picking of oranges is a major employer of labour in the orange sector and as yet efforts at mechanical orange picking have not proven commercially viable.

Of course, orange by-products only account for a relatively small proportion of this overall contribution, but even if it is only 10% it would be substantial. Moreover, the contribution is rising not only because of inflation but also because the value of orange by-products has risen substantially in recent years. Thus, in 2022 the value of Brazilian orange oil exports was US$ 274 m and combined orange terpene and d-limonene exports totalled US$ 95 million.

USA

A recent major study estimated the regional economic contributions of the Florida citrus industry (Cruz et al 2023). Alongside its direct contribution through product value, employment and taxation was added to the multiplier effects measuring the economic activity in other sectors supported through supply chain spending and the spending of income directly or indirectly associated with the sale of Florida citrus products.

Orange dominates Florida citrus production and the study found that the value of citrus fruit production was nearly US$ 785 million, with fruit for processing valued at nearly US$ 673 million and fruit for fresh consumption valued at more than US$ 112 million, based on delivered prices. Florida citrus juice processors produced 666 million gallons of citrus juice in 2020-21, valued at US$ 2.983 billion (FOB price basis). Florida citrus processors also produced by-products of citrus pulp, meal, molasses, and essential oil and d-limonene, valued at nearly US$ 63 million. The analysis estimated total industry output contributions of US$ 6.94 billion, including US$ 1.43 billion from citrus fruit production (grower receipts), US$ 5.33 billion from citrus juice manufacturing, and US$ 177 million from packinghouse sales of fresh citrus. The citrus industry supported a total of 32,542 full-time and part-time jobs in the state. Total value-added contributions, estimated at US$ 2.84 billion, represent the industry's contribution to Gross State Product. Labour income contributions amounted to US$ 1.61 billion, representing earnings by employees and business owners. Total state and local tax contributions of the Florida citrus industry were US$ 151 million.

Over the past decade the trend in orange oil/terpene prices has been upward and these by-products have played an increasingly important role in the economics of orange production. On the heroic assumption that these products account for approximately 10% of the contribution of the orange sector then their economic contribution is of the order of $0.69 billion and over 3,000 employees. In addition, Californian orange production and processing would make an additional contribution, but at a lower level since the proportion of Californian oranges processed has been much less than Florida.

Spain

There are no exact numbers of the farmers and pickers who work in the Spanish orange orchards. Assuming one farmer can manage 25 ha then the 108,000 ha of sweet orange groves would need around 4,300 farmers to work in these orchards. In addition, there are substantially more pickers working in the sector. Assuming a person can pick 800 kg per day and the season lasts approximately 180 working days then there are between 26,000 and 30,000 pickers during the season for the fresh fruit and between 2,000 and 2,500 pickers for the industry fruit. Many additional people are employed in other parts of the value chain e.g., processing, transport, agricultural inputs, marketing, management, and finance.

Italy

In 2021 in Sicily there were some 42,500 citrus farms with 21,636 production workers and 9,900 processing workers. With more than 30,000 workers employed in Sicily then the total number in the Italian citrus sector was not less than 60,000 workers. In addition, a sizeable proportion of Italy's orange and by-product production is exported. As with other orange producers there is substantial employment in other parts of the value chain.

SOCIAL, ENVIRONMENTAL, AND SUSTAINABILITY INITIATIVES

Increasingly a large range of initiatives is being undertaken in the orange sector aimed at facilitating greater sustainability and helping to combat climate change. Since most production of processed orange products is undertaken by large, often multinational operations, they recognise that improving and multiplying social, economic, and environmental best practices is the most sustainable way to raise productivity and ensure the continuity of their operations and the planet. These companies, along with the companies purchasing their products, are often at the forefront of environmental and sustainability policy initiatives. They endeavour to ensure that production is socially just, environmentally sound, and economically viable. Their wide-ranging initiatives include commitments to reduce scarce water usage through more efficient utilisation as well as efforts at reducing emissions and CO_2 capture, and the achievement of a positive CO_2 balance.

Pressure to implement change has also come from consumers and end-use companies that are increasingly concerned about the environmental impact of their purchasing decisions, leading to the demand that products are sourced from sustainable farming practices and align with their values of sustainability, transparency, and health. As a result, companies involved in orange production, processing, packaging, and distributing are having to adapt their practices to meet these evolving expectations.

Brazil

Carbon Footprint

Since 2009 the Brazilian orange sector has been studying its carbon footprint with the objective of achieving a reduction. Following a 4-year study a detailed analysis was available which provided one of the most comprehensive analyses of the carbon footprint of the orange sector which influenced future policy decisions. Most industrial processes are powered by biomass to generate heat, steam, and electricity and few

industrial processes are powered by natural gas to replace oil. Most companies' light vehicles run on 100% ethanol and Brazilian diesel contains 5% of biodiesel for road transport. The energy matrix in Brazil is predominantly formed by renewable energy.

Land Use and Biodiversity

Brazil produces approximately two-thirds of the world's orange juice and by-products, using just over 1% of the total of Brazil's planted land. Moreover, the sector prioritises the occupation of land already degraded and is constantly raising productivity and lowering the area occupied. Orange production in the Citrus Belt has proven to be an important environmental asset. Fundecitrus, a research centre bringing together producers and the industry, has shown that the sector has greatly reduced its productive area while substantially increasing productivity. Over the past three decades, the producing area (i.e., trees of production age) has fallen by 40% from 631,000 ha in 1988 to 376,000 ha in 2019. During the same period, employing technologies and increasingly efficient planting systems, orange production has increased from 13.75 MT per ha to an average of 42.64 MT per ha - an increase of 210%. Meanwhile the average number of trees per hectare has more than doubled.

Another environmentally important role for the orange sector is the preservation of natural forest and biodiversity. Brazilian legislation is very strict and every producer must leave an area of 20% to native woodland to help preserve local flora and fauna. Moreover, since orange trees last approximately 20 years this favours the preservation of flora and fauna compared to greater disruption arising from less perennial crops. Fundecitrus data show that in the 2019/20 harvest, properties with citrus crops encompassed 181,750 ha of native forest. For every 2.52 ha planted with citrus crops, 1 ha corresponds to native forest areas. The sustainability and increased biodiversity of the sector is illustrated by growth during the past decade of honey production in orange producing areas of São Paulo State which grew by 136% encouraged by using technologies and the balanced application of pesticides. The Citrus Belt now accounts for a large proportion of the state's honey output.

Social Policies

The orange processing companies have adopted a wide range of economic and social policies to benefit the workforce and the communities where the orange plantations and processing operations are located. Besides creating well-remunerated employment and training programmes, they provide educational, health and sports facilities. In Brazil in 1977 a non-profit organisation, Fundecitrus, was established through a partnership between São Paulo State, orange growers, and juice industries to keep orange groves healthy and competitive and develop a social project maintaining supplementary education centres for children, an initiative that has received various awards.

Water Usage

Over the past decade, Brazilian companies, via CitrusBR and using Water Footprint Network methodology have investigated opportunities and adopted policies to substantially reduce water usage. More than 75% of the water used in industrial processes comes from the orange itself from the process of juice concentration. Irrigation and fertigation techniques have been developed and improved and relative to other crops (e.g., soy, coffee, and corn), oranges are a low water consumption crop. A high percentage of the orange groves, more than 70%, have their own irrigation systems and water storage with pipelines fed directly into the roots.

Agrochemical Usage

While the number of pests and diseases affecting orange groves has increased, extensive research and the adoption

of new technologies, has led to agrochemical usage and biological controls becoming much more rational and precise, thus lowering risks to the environment and humans. The agrochemicals allowed for use in citrus groves are listed in the PIC (Integrated Citrus Production) list, which is stricter than Brazilian legislation. Fundecitrus provides training, literature, and individual assistance to small and large growers.

Other good practices

Companies have adopted a series of other good practices in the groves, industries, and terminals such as: recycling, reforestation, and various socio-environmental certifications and codes of conduct using both international and national auditing organisations.

Many of the social, economic, and environmental policies adopted in Brazil have also been utilised in the other major orange producing countries.

Italy

In Sicily and Catania, a "Social Farming" project has used the orange sector to develop training programmes aimed at professional qualifications and social inclusion for young people, women, disadvantaged, and immigrants. Skills have been developed in the field of cultivation (including organic), tourist reception and rural tourism, water management, labelling of fresh and processed products, management of citrus by-products, communication, e-commerce, promoting product, process, and marketing innovations within the citrus supply chain.

Spain

Spain has been undertaking a range of sustainability initiatives covering environmental, social, and economic aspects. Initiatives on the environmental side include efforts to reduce scarce water usage, through more efficient utilisation, minimise the carbon footprint along the value chain, expand renewable energy use and reduce agrochemicals and pesticide use. Unfortunately, the Spanish orange sector does not have an organisation similar to AILIMPO in the lemon sector which provides a leading coordinating and disseminating role regarding best practices on economic, environmental, and social policies.

SOME CONCLUSIONS

The most lucrative part of the orange market is the sale of fresh oranges rather than orange juice or by-products generated from processing oranges. The market for orange by-products including orange oil and d'limonene is both a global and a volatile one with price levels similar throughout the world. Prices have increased significantly in the last few years. The combination of citrus greening, climatic factors, labour availability, competitive land usage, limited natural substitutes, rising production costs, lower aldehyde levels often below 1.1%, rising demand, and reduced stock levels all signal a paradigm shift in the market.

The industry faces a range of challenges, including:

- Climate change in the form of droughts, hurricanes, frosts, and unpredictable weather patterns is having a dramatic impact on production trends.
- Investment requirements are high, not only because of oranges' long gestation period before yielding fruit but also high capital costs (e.g., land, equipment for harvesting, and processing) and input costs (e.g., labour, water, agrochemicals).
- Citrus fruit diseases especially HLB – greening.
- Increasing demand for healthy, natural "green" products should facilitate growing consumption of orange products.
- The focus on fresh fruit markets has led to pesticide residues becoming a major concern regarding orange by-products as consumers become more quality conscious.
- Political and economic instability.
- Currency variability and price volatility for both the fresh fruit and orange oil and other by-products can create difficulties.
- Considerable competition from a range of producers and countries, with considerable variations in efficiency and productivity along the different supply chains. Some existing producers face pressures from land development, competitive crops, environmental issues, and input costs and may struggle to remain competitive.

Orange production and processing, including the production of orange oil/d'limonene and terpenes, make vital economic, social, and environmental contributions to the orange producing regions in producing countries, particularly São Paulo (Brazil), Mexico, until recently Florida (USA), Sicily and Catania (Italy), Valencia and Andalucía (Spain).

The industry provides livelihoods for hundreds of thousands of people as well as generating millions of US$ in sales and export revenues. In addition, the sector makes substantial environmental contributions, and initiatives are being adopted to combat climate change by capturing CO_2 as well as providing other environmental benefits.

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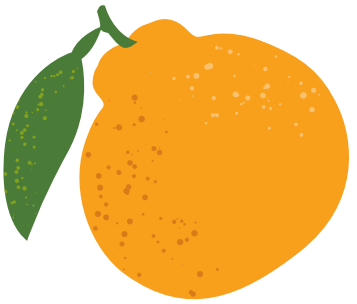
Glossary

CPOO	-	Cold Processed Orange Oil
FCL	-	Full Container Load
FCOJ	-	Frozen Concentrated Orange Juice
FOB	-	Free On Board
ha	-	Hectare
HLB	-	*Huanglongbing* ("greening")
M	-	Million
MMT	-	Million Metric Tonnes
MT	-	Metric Tonnes
NFC	-	Not From Concentrate
US$	-	United States Dollar



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