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U.S. PRODUCTION AND USE OF CITRUS OILS

by

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U.S. Production and Use of Citrus Oils

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Executive Summary

Citrus oils, extracted from the peels and other by-products of orange, lemon and grapefruit juice processing, are an important ingredient in many beverages, as well as in many other food and non-food products. This report develops estimates of U.S. production and use of citrus oils by species (orange, lemon and grapefruit) and by type of oil (cold-pressed, essence and distilled) in food and non-food products. These estimates are based on several sources, including a survey of known citrus oil producers, interviews with selected producers, interviews with users of citrus oils including representatives of the major flavor houses, published studies, and secondary data on citrus processing, soft drink consumption and international trade.

The study began with development of a list of 27 firms, believed to include all the major U.S. producers of citrus oils. Of these, 15 responded to a mail questionnaire, reporting their citrus oil production. The respondents account for approximately 27 percent of grapefruit oil production, 86 percent of lemon oil production, and 42 percent of orange oil production. Total production was estimated at over 46.7 million pounds, of which 6.5 percent was grapefruit oil, 10.0 percent was lemon oil, and 83.5 percent was orange oil. Most of the grapefruit and lemon oil is food-grade cold-pressed oil, while the majority of the orange oil production is distilled stripper oil.

Producers in the United States exported over half of their estimated 1994 lemon oil production; overall, exports accounted for about 30 percent of total citrus oil production (almost 14 million pounds). At the same time, the U.S. imported over 38 million pounds of citrus oils, with over 85 percent of the total being orange oil. The significant growth in citrus oil imports is in distilled orange oils, principally terpenes, which substitute for restricted petroleum-based chemicals in paint thinners, carpet cleaners, and other industrial uses.

As much as 16.6 million pounds, or 35.5 percent of total 1994 citrus oil production, was used in food and beverage products. Beverages account for most citrus oils used in food products. Food and beverage use of U.S.-produced citrus oils averaged less than 0.066 pounds per capita in 1994.

Acknowledgments

This report would not have been possible without the cooperation and assistance of the citrus-industry representatives who responded to our questionnaire. We benefited greatly from detailed information provided by Al Kruger, David Cline, Joe Shileah, James Doherty, Tim Angel, Ronald Bushman, Cliff Beasley, and Robert Braddock. In addition, Lex Kohngmebohl, Denny Nelson, Bert Carter, Charles Coggins, Paul Engler and John Wise offered helpful advice and encouragement throughout the study. Responsibility for the report, including any remaining errors, rests solely with the authors.

1 Introduction

Citrus oils, derived from the peels and other by-products of citrus juice processing, are an important ingredient in a number of food, beverage and non-food products. There are two major U.S. sources of citrus for processing that differ by production region. In Florida, citrus fruit (primarily oranges) are raised for processing and most citrus goes directly from the grove to the processing plant. In California and Arizona, however, as well as in the Florida grapefruit industry, the focus is on the fresh market; citrus fruit for processing is largely culled from the fresh packing operations.

The California Citrus Quality Council [CCQC] approached the Department of Agricultural Economics of the University of California,Davis, for assistance in estimating United States production and use of citrus oils. This report describes the results of a study of citrus oil producers and users carried out by members of the Department with the support of CCQC during early 1995.

The information used in this study comes from three main sources. First, published and other public-domain data on the citrus growing, citrus processing, and citrus oil industries, and on the main citrus-oil using industries, were assembled and used extensively. These data are cited when used, and their sources are included in the References listed at the end of this report. Second, a questionnaire was mailed to known U.S. citrus processors. This questionnaire, and the list of companies to whom it was sent, is included in Appendix A. Included in the questionnaire package was a Non-Disclosure Agreement, also included in Appendix A, which assured respondents that answers to the questionnaire would remain confidential, and that individual answers would not be disclosed; therefore, the results of the questionnaire are presented only as industry totals and averages, so that information about individual operations will not be revealed. The third source of information was individual and informal conversations with individuals active in the citrus-oil industry— producers, marketers, and users of citrus oils.

While the firms surveyed represent almost all U.S. citrus-oil production, some firms declined to participate in our survey. In addition to the survey results, we used other publicly available data on the citrus-processing industry to account for the missing firms, and thereby derive estimates of total U.S. production. In addition, public data on citrus oil imports and exports are included in order to document domestic citrus-oil use.

Citrus oil use in products for human consumption is estimated by food category and class of beverage. Beverage manufacturers, the largest citrus-oil users, were representative of the industry as a whole in their unwillingness to reveal individual formulations. This information is closely held and is considered proprietary. Instead, the large users provided estimates for classes of beverages, such as fruit juice, soft drinks, and teas. These responses, which were consistent from user to user, were combined to form a consensus of estimated concentration levels by major category.

Information specific to oils extracted from fruit of individual species was used in developing the estimates. For each of the three main species—oranges, lemons, and grapefruit—data were constructed for cold-pressed oils, essences, and distilled oils.

The remainder of the report is organized as follows. First, the three main classes of citrus oils are described, and their principal uses summarized. Second, estimates are derived for U.S. production of all citrus oils, and for U.S. use of citrus oils in edible and non-edible products.

2 An Overview of Citrus Oil Class, Production, and Use

There are three main classes of of citrus oils: cold-pressed, essence, and distilled. Each of these classes has its own method of production and pattern of use. This section reviews these methods and patterns.

2.1 Cold-Pressed Oils

Cold-pressed oils are mechanically extracted from citrus peels by processes that rupture the oil glands, allowing oil to be washed into water before final separation by centrifugation. After separation, the water is recycled. By this method, 85 to 95 percent of the oil is released into the water-oil emulsion, and 80 percent of the oil is recovered.

The amount of cold-pressed oils which can be recovered from a ton of fruit varies by fruit species, from between 5.6 and 6.5 pounds of oil per ton (depending on cultivar) for grapefruit, to over 15 pounds per ton for lemons (Kesterson and Braddock 1975). Valencia oranges have a potential yield of about 13.5 pounds per ton of oranges processed. Peel oil is directly correlated with the surface area of the fruit (Bitters and Scora 1970), so that smaller fruit (especially lemons) have a higher potential yield than larger fruit (especially grapefruit). Since oil extraction is costly, the potential oil yield is generally not achieved. Kesterson and Braddock (1975) suggest that "most citrus processors recover only 10–20% of the available oil." Conversations with processors currently active suggest rather higher rates of oil extraction, of about 8 pounds per ton for lemons, 4 pounds per ton for oranges, and 2 pounds per ton for grapefruit.

Single-strength cold-pressed citrus oil contains more than 200 components, which may be grouped into two fractions. A volatile fraction, which for orange oil comprises 97–98 percent of the oil weight, includes monoterpenes and sesquiterpene hydrocarbons, their oxygenated derivatives, and aliphatic aldehydes, alcohols, and esters. This volatile fraction is referred to as d-limonene or terpenes in this study. The non-volatile fraction (2–3 percent of orange oil) contains long-chain hydrocarbons, aldehydes, fatty acids, sterols, carotenoids, coumarins, psoralens, and flavanoids (Dugo, Mondello, Bartle, Clifford, and Breen 1994).

Some cold-pressed citrus oils are added to foods and beverages as single-strength cold-pressed

oils. Cold-pressed oil may be deterpenated or *folded* before addition to food. Terpenes are removed from the oil by distillation or extractive processes. Folding decreases the concentration of the terpene fraction. For example, single-strength orange oil contains 94 percent d-limonene (the dominant terpene) while five-fold oil contains approximately 70 percent terpenes. Five- or ten-fold products are the most common strengths of folded oils. Concentrations higher than 10-fold lose the fresh character of the original single-strength oil (Dugo, Mondello, Bartle, Clifford, and Breen 1994).

The terpenes that are removed in the folding process are themselves valuable products. Orange terpenes in particular have been replacing petroleum-based products as an ingredient in industrial products such as cleaners and paint thinners. The recent increase in demand for orange terpenes is due to rising preferences for biodegradable ingredients as well as to restrictions on petroleum-based products. The higher demand for orange terpenes has boosted their price per pound from $0.50 in 1993 to over $2 in 1995. Indeed, the price of terpenes has sometimes exceeded the price of single-strength cold-pressed orange oils, leading some processors to remove up to 95 percent of the terpenes from the original single strength orange oil. As a recent example, the value of five pounds of cold pressed orange oil was about $2.25 per pound, or $11.25. The oil could be deterpenated to produce one pound of five fold oil at $5 per pound plus four pounds of terpenes at $2.50 per pound for a value of $15, thus increasing the value of the initial five pounds by $3.75.[1]

It should be noted that the terpenes removed in the folding process are themselves food-grade products and can be (although often are not) used in edible products. Even though these oils may have been separated from the less volatile fractions using distillation, they are considered to be part of the cold-pressed market class, and are generally not referred to as distilled oils.

[1]Information provided by Lex Kongmebhol, Sunkist and Al Kruger, Coca Cola.

2.2 Essence Oils

Essence oils are the citrus oils which are found in citrus juices. These oils are stripped from the juice as water is evaporated during preparation of concentrated juice. Most, but not all, juice processors isolate essence oils. Essence oils, like cold-pressed oils, are food-grade products; all firms which reported essence production indicated that their essence oils were expected to be used in human-consumption products.

2.3 Distilled Oils

Distilled oils, often called stripper oils, are volatile oils, principally d-limonene, extracted directly from citrus peels, pulp, and other fruit parts. While stripper oils are chemically very similar to the distillates separated during folding operations—which are also primarily d-limonene—they are not food-grade products, and are destined for industrial and other non-edible uses.

To obtain the distilled oils, pulverized citrus parts are limed and pressed; the press fluid (which carries the oils) is concentrated by evaporation. The oil vapors are captured and condensed. The high temperatures involved degrade the aroma; the resulting oils are suitable for industrial uses, and are not generally used for human consumption. Information on these oils is included to give a more complete picture of the markets for citrus oils. In addition, production of distilled orange oils in Florida gives a good indication of the output of all classes of orange oils in that state, and helps in the development in the next section of an estimate of oils directed to human consumption.

3 U.S. Production of Citrus Oils

This section develops estimates of the U.S. production of citrus oils for the period 1990–94. The basis of these estimates is a survey of citrus processors and oil producers, conducted between

January and April, 1995. In addition, the results of earlier studies are reviewed and incorporated where appropriate.

In January, 1995, industry members supplied a list of 27 firms believed to be the major US producers of citrus oils. In February, study members called and mailed a questionnaire and statement of confidentiality to each of these firms. Copies of the questionnaire and of a typical confidentiality agreement (for a fictitious firm) are in Appendix A. Of the 27 firms, 15 firms responded and 12 did not. The 15 responding firms reported their levels of citrus oil production;[2] their reported total annual production for the reporting period is shown in table B-1 in Appendix B.

The survey formed a basis for estimating citrus oil production and use. To estimate total U.S. production, the ratio was found of citrus oil production to the tonnage of processed citrus fruit for selected major fruit processors.[3] This ratio was then multiplied by total U.S. tonnage of processed citrus fruit, as reported in USDA (1994). These oil yields, and fruit tonnage, are reported in table 1. The production reported by the processors responding to the survey accounts for 27 percent, 86 percent, and 42 percent, respectively, of the estimates of total oil production reported in table 1.

Multiplying estimated yields by national tonnage should give quite accurate estimates of oil production for both lemon and grapefruit oils since both oils are produced in relatively small volumes (due to the relatively small volume of processed lemons and grapefruit). In both industries, it is expected that all fruit processors actively extract oils from their fruit peels, juices, and residues; with similar extraction technology and markets available to all, the ratio of oil to fruit is expected to be similar for all producers. Thus, the ratio method was applied directly for both lemon and grapefruit oil to estimate total U.S. production. These estimates are reported in table 2, in the

[2]Since only one firm reported essence-oil production separately from cold-pressed, and then only for 1994, essence oils are not included in cold-pressed oils in this table.

[3]The ratio was calculated by dividing the reported oil production, from the survey, by tonnage of citrus processing in publicly-available reports. Revealing the identity of these reports would permit calculation of values reported in confidential survey responses.

Table 1: Estimated U.S. Citrus Oil Yields, and Total U.S. Volume of Citrus Fruit Processing, 1994 .

	Grapefruit	Lemon	Orange
Oil Production: Processing volume	— Pounds oil per ton fruit —		
Cold-pressed	2.00	8.04	3.97
Essence	0.04	0.27	0.13
Distilled	0.16	0.86	2.60
Volume: Processed fruit **(Thousands of Tons)**	**1,375**	**511**	**8,232**

[a] Data for Orange industry includes small quantities of tangerine and other citrus fruits.
Sources: Authors' survey, 1995; USDA (1994).

next section.

The situation is somewhat different for orange oils. Due largely to the large markets for orange juice, much larger volumes of fruit are directed to processing channels, especially in Florida where substantial acreage is devoted to oranges grown exclusively for the juice industry. With much higher volumes of oranges available for oil extraction, the prices of orange oils have been much lower than for lemon and grapefruit oils (Schnell 1995). Thus, the price and profitability of orange oil is marginal and extraction rates vary significantly by year and by firm. Since extraction rates for orange oil varies by firm, it may not be accurate to assume that the ratio of citrus oil to processed fruit is the same between firms. Additional information, needed to estimate the production of orange oil, is presented in the next section.

3.1 Production of Orange Oils

Interviews with industry participants indicate that prices are low enough to make orange oil production, especially of food-grade cold-pressed oils, a marginal proposition. Low cost producers, with modern equipment, will produce cold-pressed oils. Other juice processors will not, or will only manufacture oils when the price is high. If the firms for whom extraction ratios are calculated

are low-cost manufacturers, then their ratios will be higher than the industry average, and the production estimates based on the yields in table 1 will overstate true production.

At least within the survey sample, this appears to be the case. Survey respondents reported producing over 7 million pounds of cold-pressed orange oils in 1994, and over 9 million pounds of distilled (stripper) orange oils. Yet the calculated ratios, which are based on publicly available production data, suggest that production of cold-pressed oils was about 50 percent greater than production of stripper oils. The ratio for oranges for cold-pressed orange oils appears to be based on firms within the sample who are specialized in cold-pressed production.

An alternative procedure to estimate actual production of cold-pressed orange oils would be to assume that the ratio method gives a correct estimate of distilled orange oils, and that the ratio of cold-pressed to distilled oils found in the survey holds for the entire industry. Data from the survey and from reports on total fruit processing by selected individual processors suggests that 2.6 pounds of distilled oils are produced from each ton of oranges processed; in 1995 8.23 million tons of oranges were processed for juice and other products, so that 1994 distilled oil production is estimated at $2.6 \times 8.23 = 21.4$ million pounds. Among all firms responding to the survey, cold pressed orange oil production was about 77 percent as large as distilled orange oil production. Applying this ratio to the estimate of national distilled orange oil production, total cold-pressed orange oil production would be $0.77 \times 21.4 = 16.5$ million pounds, or about half as large as the unadjusted ratio-method estimate. Total U.S. cold-pressed oil production, for all species, would then be about 23.4 million pounds.

Our analysis uses the estimate based on the surveyed ratio of cold-pressed to distilled oil production, as shown in table 2. The surveyed ratio is likely larger than the true ratio for the entire industry, due to the presence in the sample of firms specializing in cold-pressed oil production. Against this must be weighed the possibility of a too-low estimate of distilled oil production. However,

since distilled oil production is largely independent of cold-pressed production, this consideration appears not to be important.

Table 2: Estimated U.S. Production of Citrus Oils, by Species and Class, 1994.

	Grapefruit	Lemon[a]	Orange[b]	All Citrus
	Thousands of Pounds			
Cold-pressed	2,750	4,108	16,523	23,381
Essence	55	138	1,070	1,263
Distilled	220	439	21,403	22,062
Total	**3,025**	**4,685**	**38,996**	**46,706**

Notes: [a]Including lime oil. [b]Including tangerine and other citrus oils.
Sources: Authors' survey, 1995; USDA (1994).

3.2 U.S. Trade in Citrus Oils

A substantial portion of the annual U.S. production of citrus oils is exported. As shown in Table 3, exports of all citrus oils in 1994 were almost 14 million pounds, representing about 30 percent of estimated domestic production. Over half of estimated lemon oil production was exported.

The United States imports substantial quantities of citrus oils, especially of lemon and orange oils. In recent years, imports of orange oils, in particular, have grown sharply, from about 14 million pounds in 1989 to over 33 million pounds in 1994 (see table 3). Industry participants indicated that the recent increase in citrus oil imports is largely accounted for by imports of distilled orange oils and terpenes, which substitute for restricted petroleum-based chemicals in various industrial products.

The substantial trade in citrus oils has various causes. First, lemon oils are almost always food quality. Oils from different regions and countries have unique flavors and fragrances, each with their own uses in recipes and formulations. Orange oils, in contrast, are most commonly

Table 3: U.S. Exports and Imports of Citrus Oils, 1989–94.

Year	Grapefruit	Lemon	Orange	Total
Exports:				
		1,000 lb		
1989	0	1,900	10,452	12,352
1990	0	2,055	8,369	10,423
1991	0	2,057	11,173	13,230
1992	0	2,429	9,343	11,773
1993	0	2,288	10,082	12,370
1994	0	2,427	11,519	13,946
Imports:				
		1,000 lb		
1989	132	2,985	14,061	17,178
1990	573	4,879	14,874	20,326
1991	650	5,412	8,706	14,769
1992	454	6,076	22,837	29,367
1993	395	4,769	27,039	32,203
1994	600	4,923	33,342	38,865

Source: (Department of Commerce 1995).

used in industrial products, and are essentially a homogeneous bulk chemical. The United States imports large volumes of stripper orange oils, in particular, from Brazil, which are then used in paint thinners, carpet cleaners, and other industrial uses. Exports of orange oils, in contrast, may include significant quantities of edible oils, particularly to markets in Asia.

3.3 Consumption of Citrus Oils in Edible Products

After extraction and processing, citrus oils are either sold directly by the oil producer to end users or are sold to the flavor houses that perform marketing and brokerage functions in the industry. In the survey responses, 52 percent of the 1994 oil sales were direct to flavor houses, while 24 percent of producer sales were to food and beverage manufacturers. The distribution of sales among user classes reported by survey respondents is shown in table 4.[4]

[4]Oil production differs from the figures reported in Table B-1 for 1994 by one firm's production of essence oils.

Table 4: U.S. Citrus Oil Production by Survey Respondents, by User Class and Species, 1994.

User class	Grapefruit	Lemon	Orange[a]	All Citrus
	Thousands of Pounds			
Food	0	410	676	1,086
Beverage	384	1,730	1,807	3,921
Flavor House ...	423	1,542	8,741	10,706
Nonfood	0	0	5,050	5,050
Total	**807**	**3,682**	**16,274**	**20,763**
	Percent			
Food	0	11	4	5
Beverage	48	47	11	19
Flavor House ...	52	42	54	52
Nonfood	0	0	31	24

Note: [a]Including tangerine and other citrus oils.
Source: Authors' survey, 1995.

Since over half of the annual production of surveyed oil producers is marketed by flavor houses, information about producers' direct sales must be supplemented by information from the flavor houses. Representatives of all the major flavor houses were contacted. While it was not possible to systematically survey the flavor houses, which are generally unable to provide detailed breakdowns of the uses to which their oils are put, flavor-house representatives as well as employees of several oil producers did provide useful information. This information, in combination with detailed information about the orange oil industry and the beverage industry (the principal human-consumption user of citrus oils), permits estimation of human consumption of citrus oils in the United States. These estimates are presented in table 5; the remainder of this section discusses their derivation.[5]

Lemon and grapefruit oils are high-value products, and are used almost entirely in food and beverage products, either directly as single-strength or folded oil, or as part of a flavoring package assembled and marketed by a flavor house. We assumed that 97 percent of grapefruit oils, and 95

[5]It should be noted that table 5 excludes imported oils, which are reported in table 3. While it is thought that most imports of citrus oils are for non-food uses, some imports are undoubtedly destined for food products. Similary, some citrus-oil exports are certainly food-grade. See section 3.2. A comparison of tables 2 and 5 shows that a substantial part of U.S. citrus-oil production goes to non-food uses. These uses are discussed further in section 3.6.

Table 5: Use of U.S. Citrus Oil in Edible Products, 1994.

	Grapefruit	Lemon[a]	Orange[b]	All Citrus
	Thousands of Pounds			
Cold-pressed ...	2,668	3,903	9,088	15,659
Essence	53	131	107	291
Distilled	213	417	0	630
Total	**2,934**	**4,451**	**9,195**	**16,580**

[a]Includes lime oil. [b]Includes tangerine and other citrus oils.
Source: Authors' survey, 1995, communications with industry participants, and table 2.

percent of lemon oils, were directed to human-consumption uses. These figures probably overstate human-consumption uses, since they are applied to distilled oils as well as to cold-pressed oils.

The bulk of U.S. citrus oil production and use is of the orange oils, which are byproducts of the large orange juice and juice concentrates industry. To estimate human consumption of orange oils, a detailed breakdown of the orange oil classes was used, based on information from flavor houses and oil producers.

A substantial portion of the cold-pressed single-strength, folded and distilled oils, as well as most essence and stripper oils, are directed to industrial and other non-food uses. Of the cold-pressed oils, 35 percent leave the oil producers as single-strength oils; it is assumed that all of the single-strength oils are used in food products. The remaining 65 percent of cold-pressed production is then deterpenated; one quarter of the volume of deterpenated oils is sold as folded oil, while three-quarters are distillates. It is estimated that 90 percent of the folded-oil volume, and 10 percent of the distillates from the deterpenation, are used in food products. Thus, 35 percent of cold-pressed oils enter edible products directly as cold-pressed oils, while about 15 percent ($= .65 \times .25 \times .9$) enter as folded oils, and about 5 percent ($= .65 \times .75 \times .1$) enter as distilled orange terps; food use of cold-pressed orange oils was therefore estimated as 55 percent ($= .35 + .15 + .5$) of total U.S. use of cold-pressed orange oils. Edible uses of orange essences are estimated at 10 percent of

total use; essences are processed into 10 percent folded oil, for human consumption, and 90 percent inedible distillates. We assume no edible use of stripper oils derived from processed oranges; the large supplies of cold-pressed distillates make it unlikely that any stripper oils are used in flavoring packages or other edible products.

Previous surveys by the National Academy of Sciences between 1970 and 1987 (National Academy of Sciences 1987) have reported the amounts of citrus oils used in edible products. The results of these surveys are shown in table 6. The NAS reports, for 1987, about 48 percent of the total edible use estimated for 1994 in this report (table 5). The NAS data describe the oil use of 42 of the largest 100 food companies; they are thus broadly consistent with the results reported here.

Table 6: Use of Citrus Oils by Food Processors, 1970–87.

	1970	1975	1976	1982	1987
	Thousands of Pounds				
Cold-pressed ...	3,315	3,944	1,252	4,540	6,459
Essence	0	240	0	306	47
Distilled	353	519	182	1,953	1,450
Total	**3,699**	**4,703**	**1,434**	**6,799**	**7,957**

Source: National Academy of Sciences (1987).

3.4 Citrus-Oil Use in the Beverage Industry

The estimates of use of citrus oils in food products presented in table 5 are based on the information collected from citrus-oil producers and users, and are considered to be our best estimates, based on the available information. To verify these estimates, data were assembled on the beverage industry, which is the dominant channel through which citrus oils enter the U.S. diet. These data, which are discussed in the rest of this section, demonstrate that this report's estimates are reasonable, but on the high side of actual consumption.

To develop an independent estimate of oil consumption in beverages, information was assembled describing the concentration of oils in various beverages. Multiplying these concentrations by estimates of the consumption of different beverages gives a range of values for the consumption of citrus oils in beverages.

Three sources of information were used in this exercise. First, the Flavoring Extract Manufacturer's Association (FEMA) has published tolerances for flavorings, including citrus oils (FEMA 1965). These concentrations give an upper bound on the use of oils in soft drinks, as manufacturers do not exceed these concentrations. Second, inquiries were made of knowledgeable participants in the beverage industries, to create more accurate information regarding citrus oil concentrations in beverages. This information was supplemented by a 1972 study of oil levels in orange juice concentrate (USDA 1972). Third, information was assembled describing the consumption of different beverages in the United States (Beverage Marketing Corp. 1994). A concentration level was chosen for each beverage class, which was then multiplied by beverage volume to calculate total citrus oil usage in beverages. In this report, a maximum usage figure is calculated by using the highest concentration identified by an industry participant, and a minimum concentration, identified similarly.[6] The concentrations, and consumption estimates, are listed in Table 7.

The citrus oil concentrations are multiplied by the volumes of beverages consumed to obtain the volumes of citrus oil consumed in beverages. Using the maximum reported concentrations of citrus oils in beverages, some 2.8 million gallons of citrus oils, or about 20 million pounds, could have been used in beverages. It should be noted that this is significantly above estimated U.S. use in edible products of domestically-produced citrus oils, indicating that the actual concentrations of

[6]For soft drinks, most flavor houses described a range of concentrations, which reflects the different beverage formulas used for different products. Rather than choosing the lowest concentrations from these ranges, we used the lowest average reported.

Table 7: Concentrations and Total Use of Citrus Oils in Beverages .

Source	Fruit Drinks	Orange Juice	Soft Drinks	Tea	Wine Coolers	All Beverages
			Parts per Million			
Flavor House			40–100	20–200		
Flavor House	150–200	150–200	20–100			
Flavor House	50	180	50			
Producer		160	110–115			
Producer	100–150				100	
Max. concentration	200	200	115	200	100	
Min. concentration	50	150	50	20	100	
Beverage volume						
Millions of gallons	595	2,685	13,275	2,876	100	19,531
Maximum oil volume						
Thousands of Gallons	119	537	1,527	575	10	2,768
Thousands of pounds	844	3,807	10,826	4,077	71	19,625
Minimum oil volume						
Thousands of Gallons	30	402	664	57	10	1,163
Thousands of pounds	213	2,850	4,708	404	71	8,246

Sources: (USDA 1972), (Beverage Marketing Corp. 1994), author interviews.

citrus oils lie below the maximum values reported in table 7. Using the minimum concentrations, less than 9 million pounds of citrus oils would have been used in beverages. Our estimates of food-product uses are consistent with oil concentrations intermediate to the minimum and maximum concentrations reported in table7. Total beverage sales for branded beverages are presented in table B-2 in Appendix B.

3.5 Other Food uses

The amount of citrus oils added to foods is not directly estimated because citrus oil is contained in many distinct foods and concentrations vary across and within categories of food. The maximum concentrations of citrus oils found in foods was reported in the 1965 FEMA report (see table 8). For beverages, the reported concentrations were over twice the levels reported by Flavor Houses; the levels reported for foods should also significantly exceed average concentrations.

Table 8: Estimated Maximum Citrus-Oil Concentrations in Selected Food Products.

Food	Grapefruit	Lemon	Orange
	parts per million		
Cakes	370	580	430
Cereals		140	49
Chewing gum	1,500	1,900	4,200
Confectionary (candy)	630	1,100	1,000
Cookies	370	580	430
Gelatins	250	340	1,300
Ice Cream	180	380	330
Puddings	250	340	1,300
Syrup		65	
Toppings	400		

Source: (FEMA 1965).

3.6 Non-food Uses

Table 2 gives 1994 estimated total U.S. use of domestically produced citrus oils as 46.7 million pounds. As much as 16.6 million pounds, or 35 percent, was used in edible products. The remaining 30.1 million pounds (or more: the edible-products estimate is an upper bound) are ingredients in non-edible products. Non-food oil use in 1994 is presented in Table 9. Comparing table 9 to table 2, more than 76 percent of orange oil purchases are for non-food uses, while about 3 percent and 5 percent of grapefruit and lemon oils, respectively, go to non-food uses. The non-food use of citrus oils, which is most marked in the large orange-oil industry, is an important recent trend in the citrus-oil industry.

Citrus oils are widely used in fragrances, lipstick, and other cosmetics, primarily to impart scent. The amounts contained in individual products are closely-guarded secrets, so that it is impossible to determine the amounts of oils in individual products or classes of products. In addition, cosmetic products are rapidly replaced: one major oil-user in the cosmetics industry markets somewhere between 3,500 to 10,000 products, each with an average product life-span of eighteen months. No

Table 9: Estimated U.S. Use of Domestic Citrus Oils in Non-edible Products, 1994.

	Grapefruit	Lemon[a]	Orange[b]	All Citrus
	Thousands of Pounds			
Cold-pressed ...	82	205	7,435	7,722
Essence	2	7	963	972
Distilled	7	22	21,403	21,432
Total	**91**	**234**	**29,801**	**30,126**

[a]Includes lime oil. [b]Includes tangerine and other citrus oils.
Source: Calculated by subtracting table 5 from table 2.

FDA approval is necessary for products that "cleanse or beautify," as skin penetration of these products is assumed to be negligible. There is optional FDA registration of cosmetics, which is met by about 20 percent of all cosmetic products.

Oils are used in a variety of other products, mainly industrial in nature. In most of these products the oil ingredients are distillates and orange terpenes, which are used for their solvent characteristics. These products are now the largest market for orange oils. Smaller quantities of oils are used for their scent properties. A number of oil-containing industrial products are listed in table 10.

Table 10: Industrial Products containing Citrus Oils.

Adhesives	Fragrance
Air fresheners	Furniture polishes
Cleaning agents	Resins
automotive cleaner	Paint thinner
hand cleaner	Paint bases
metal cleaner	Post-it notes
Detergents	Soap
Disposable diapers	Solvents

4 Conclusion

This report has assembled information and developed estimates to show that about 16.6 million pounds of U.S.-produced citrus oils were used in edible products in 1994. Almost 65 percent of total oil production is directed to non-food uses. Orange oil, in particular, is primarily an industrial product: over three-quarters of 1994 production was used in such products as cleaning solutions, paint thinners, and other solvents. Even the food-class cold-pressed oils are heavily used in industry: 45 percent of the cold-pressed orange oils had non-food uses.

Per-capita use in food and beverage products of domestic citrus oils in the United States is less than .066 pound. It is possible to use these figures, in combination with information about the concentration of residues in the oils derived from treated fruit, to assess the average daily intake of pesticide residues found in citrus oils due to the consumption of oil-containing food and beverage products.

A The U.C. Davis Survey

A.1 The Sample

The primary information used in this study was a survey, administered to a list of citrus producers provided by CCQC. These companies are listed below. The assistance and cooperation of the companies which responded is greatly appreciated. A survey sample is shown following the company list.

Agrigold Juice Products
Corona, CA

Alcoma Packing Company
Lake Wales, FL

Berry Citrus Products
LaBelle, FL

CCPI/Valley Foods, Inc.
Lindsay, CA

Cargill Citro-America, Inc.
Minneapolis, MN

Caulkins Indiantown Citrus Co.
Indiantown, FL

Citrus Belle
LaBelle, FL

Citrus World, Inc.
Lake Wales, FL

Coca Cola Foods
Houston, TX 77056

Florida Juice, Inc.
Lakeland, FL

Golden Gem Growers, Inc.
Umatilla, FL

Holly Hill Fruit Product Co., Inc.
Davenport, FL

Indian River Foods, Inc.
Fort Pierce, FL

Lykes Pasco, Inc.
Dade City, FL

Orange-Co, Inc.
Bartow, FL

Paramount Citrus
Mission Hills, CA

Peace River Citrus Prod
Ft. Pierce, FL

Silver Spring Citrus Coop
Winter Garden, FL

Southern Gardens Citrus
Clewiston, FL

Sunkist Growers, Inc.
Ontario, CA

Sun Pac Foods, Inc.
Winter Haven, FL

Sunpure, Ltd.
Avon Park, FL

Texas Citrus Exchange
Mission, TX

Tropicana Products, Inc.
Bradenton, FL

Ventura Coastal Corp.
Ventura, CA

Vita-Pakt Citrus Prod Co.
Covina, CA

Winter Garden Prod Coop
Winter Garden, FL

A.2 Sample Questionnaire

Survey of US Citrus Oil Producers, 1995

Survey by the UC-Davis Department of Agricultural Economics, sponsored by the California Citrus Quality Council (CCQC). All responses are confidential. Your cooperation is appreciated.

I. What are your firm's total annual production of cold pressed citrus oils?

	Volume (gallons)				
Year	Grapefruit Oil	Lemon Oil	Orange Oil	Other Citrus Oil	Total
1990					
1991					
1992					
1993					
1994					

II. What are your firm's total annual production of citrus oils other than cold pressed (production of delimonenes and citrus terps)?

	Volume (gallons)				
Year	Grapefruit Oil	Lemon Oil	Orange Oil	Other Citrus Oil	Total
1990					
1991					
1992					
1993					
1994					

III. For 1994 (or 1993 if 1994 data is not yet available), please list the volumes of citrus oil your firm sold to each class of customer. If possible, subdivide customers into more detailed classes.

Year_____

	Volume (if volume is unknown, estimate percent of total).				
Class	Grapefruit Oil	Lemon Oil	Orange Oil	Other Citrus Oil	Total Citrus Oil
Food					
Beverage					
Flavor House					
Nonfood					
Other_____					
Total					

A.3 Sample Non-Disclosure Agreement

XYZ Company ("XYZ")
NON-DISCLOSURE AGREEMENT

Each of the undersigned individually agrees that if he or she is given access to XYZ information pertaining to ***citrus oil production and marketing data including but not limited to production volumes, market segments or customer lists*** ("Information"), all such information received from XYZ is the Trade Secret of XYZ, according to the definition in §3426.1(d) of the California Civil Code. By execution of this Agreement, each of the undersigned and ***the Department of Agricultural Economics, University of California, Davis*** ("RECIPIENT"), individually and collectively, agrees to the following restrictions in respect to all such Information.

Except as to Information which RECIPIENT can prove, by clear and convincing evidence, that (a) it possessed prior to access given by XYZ without any non-disclosure requirement from XYZ; (b) it obtained from a third party with no obligation to XYZ; (c) it developed entirely independently of any contact with XYZ; or (d) XYZ published or otherwise caused to be generally known in the relevant trade or industry, RECIPIENT and each of us agrees and guarantees that *none* of the Information will:

1. Be disclosed to anyone within RECIPIENT who does not have a "need to know" in direct connection to the Principal Purpose, as defined below;

2. Be disclosed to anyone outside RECIPIENT, except as specifically authorized in advance and in writing by XYZ; or

3. Used for any purpose, except in reasonable furtherance of ***academic research, and/or the preparation of a scholarly paper which does not reveal any of the Information*** (collectively, "Principal Purpose").

These obligations will exist for a period of five (5) years from the date given below, as the date when this Agreement is first executed by the undersigned, and are enforceable under the terms of California Civil Code §§3426, *et seq.*, and all other applicable Law and regulations.

Executed at Davis, California, this FIRST day of FEBRUARY 1995, and thereby binding each of the undersigned individuals and the aforementioned RECIPIENT to each and every term of the above Agreement.

_____
HOY F. CARMAN

_____
JASON E. CHRISTIAN

_____
RAYMOND J. VENNER

B Supplementary Data

Table B-1: U.S. Production of Citrus Oils in 1995 Survey, by Class[a] and Species, 1990–94.

class/species	1990	1991	1992	1993	1994
	Thousands of Pounds				
Cold-pressed oils:					
Orange[b]	5,179	4,070	6,152	6,587	7,070
Lemon.....	1,919	1,600	2,273	3,413	3,553
Grapefruit	380	418	454	557	737
Total.....	**7,478**	**6,088**	**8,879**	**10,557**	**11,360**
Distilled oils:					
Orange[b]	4,615	5,468	5,631	9,072	9,065
Lemon.....	0	0	0	0	19
Grapefruit	20	20	49	25	48
Total.....	**4,635**	**5,488**	**5,680**	**9,097**	**9,132**

[a] Excludes essence oils. [b]Orange oil includes small amounts of tangerine and other citrus oils.
Source: Authors' survey, 1995.

Table B-2: U.S. Consumption of Soft Drinks and Fruit Juices, by Brand, 1993.

Soft Drinks

Brand	Volume (million gal.)	Brand	Volume (million gal.)
Coca-Cola Classic	2,621.1	Mr. Pibb	54.2
Pepsi-Cola	2,066.3	Safeway Select	50.8
Diet Coke	1,267.5	Diet Minute Maid	49.6
Dr Pepper	767.6	Crush	47.1
Diet Pepsi	760.3	NuGrape	46.0
Mountain Dew	682.6	Mug	38.2
Sprite	580.6	President's Choice	38.0
7UP	380.5	Coke II	37.6
Caffeine-Free Diet Coke	264.8	Sun-drop	28.2
Shasta	164.6	Cherry 7UP	25.0
Caffeine Free Diet Pepsi	152.7	Diet Slice	22.5
RC Cola	149.0	Vernors	21.5
Diet Dr Pepper	143.7	Country Time	19.2
Slice	126.8	Hires	18.0
Caffeine Free Pepsi	105.8	Fresca	17.9
Sam's Choice	104.0	Diet A&W Root Beer	16.7
Diet 7UP	99.3	Diet Rite Flavors	16.3
Diet Sprite	97.1	Tab	15.8
Cherry Coke	94.6	Canada Dry Seltzer	14.3
Mello Yello	89.0	Caffeine Free Diet Dr Pepper	14.1
Dad's	88.0	A&W Diet Creme Soda	14.0
Canada Dry Ginger Ale	85.2	Nesbitt's	13.5
Diet Mountain Dew	85.0	World Classics	13.2
Sunkist	83.1	Caffeine-Free Mountain Dew	12.1
A&W Root Beer	82.4	Diet Cherry Coke	10.8
Fanta	73.9	Dr. Wells	10.5
Schweppes	70.8	Canada Dry Tonic	10.4
Minute Maid	69.4	Diet Dad's	10.1
Caffeine-Free Coca Cola Classic	69.3		
Squirt	66.2		
Diet Rite	63.4	Other Soft Drinks	749.4
Faygo	63.2	Total Soft Drinks	12,720.6

Fruit Beverages

Brand	Volume (million gal.)	Brand	Volume (million gal.)
Sunny Delight	100.4	Squeezit	9.3
Gatorade	71.7	Five Alive	7.2
Private Label	57.6	Tropicana	6.4
Minutes Maid	48.9	Mondo	6.2
Hi-C	48.7	Powerade	4.8
Tampico	30.6	Veryfine	4.6
Hawaiian Punch	26.4	Welch's Orchard	3.1
Ocean Spray	24.3		
Boku	2.6		
Capri Sun	22.9		
Snapple	16.7	All Other Fruit Beverages	2.6
Tropicana Twister	12.3	Total Fruit Beverages	629.9
Kool Aid Bursts	10.6		

Source: Nielson North America, *Beverage World*, January, 1995.

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