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Table 1. Consumption and Imports: 1995

Juice	Consumption (gallons per person)	Total Consumption (millions of gallons)	Total Consumption (millions of liters)	Imports (millions of liters)	Import Share (percent of total)
Orange	5.45	1417.0	5363.3	829.1	15.5
Grapefruit	0.64	166.4	629.8	3.3	0.5
Lemon	0.12	31.2	118.1	33.6	28.5
Lime	0.02	5.2	19.7	n.e.s.	n.e.s.
Apple	1.79	465.4	1761.5	874.3	49.6
Grape	0.29	75.4	285.4	90.7	31.8
Pineapple	0.35	91.0	344.4	308.7	89.6
Prune	0.04	10.4	39.4	n.e.s.	n.e.s.
Tomato (vegetable)	0.30	78.0	295.2	1.3	0.4
Other	n.a.	n.a.	n.a.	159.4	n. a.
Total juice	9.00	2340.0	8856.8	2300.4	26.0

Sources: Putnam and Alehouse 1997; *The Almanac of the Canning, Freezing, Preserving Industries* 1996.

Table 2. Beverage Consumption by Type

Product	Annual Consumption (gallons per person)	Total Consumption (billions of gallons)	Total Consumption (billions of servings)
Major Beverages	158.3	41.2	659
Carbonated Soft Drinks	51.2	13.3	213
Milk	24.4	6.3	101
Alcoholic Beverages	25.1	6.5	104
Coffee	20.5	5.3	85
Bottled Water	11.6	3.0	48
Tea	8.7	2.3	36
All Juice Drinks	7.8	2.0	32
Fruit and Vegetable Juices	9.0	2.3	37
All Orange Juice	5.5	1.4	23
Non-Heat-Treated Orange Juice	0.05	0.012	0.187
All Apple Juice	1.8	0.5	7
Non-Heat-Treated Apple Juice	0.10	0.026	0.416

Sources: Putnam and Alehouse 1997; *The Almanac of the Canning, Freezing, Preserving Industries* 1996; U. S. Apple Association 1997a; Nielsen SCANTRACK.

Table 3. Production

Step 1. Growing	Step 2. Harvesting	Step 3. Washing and Culling
	A. Hand B. Mechanical - quicker and more economical.	Quality of fruit A. Damage by harvesting a potential problem. B. Fruits and vegetables inspected to eliminate products with insect damage, mold, off-color, rot, etc. Only good quality fruits used for juices. C. Fruits and vegetables brushed and cleaned with detergent and chlorinated water.

Step 4. Extraction	Step 4. Extraction, continued	Step 4. Extraction, continued	Step 5. Pressing
A. Milling 1. Hammer mill. 2. Grinder mill - rotating head which forces fruit over a set of fixed knives. 3. Stoned fruit mill-crushes fruit without damaging stones. 4. Grape mill (de-stalker)	5. Citrus mill a. FMC juice extractor - a serrated cup positions fruit, a round steel tube is inserted into fruit. Pressure is applied to fruit, forcing its contents out through inserted tube. b. Brown extractor - juice is obtained by cutting fruit in half, with halves given pressure over reamers. The juice is transferred in one direction and hulls in the other direction. 6. Mash transport - pipe using pumps to move mash.	B. Enzymes - used to break down mash to simpler substances - increases juice yield. Some enzyme products can almost liquefy mash. 1. Pectinase. 2. Cellulose and hemicellulase. C. Press aids - improves pressing of fruits - adds bulk. 1. Wood fibers. 2. Paper. 3. Rice hulls. D. Leaching - the addition of water or low Brix juice - lower quality juice and additional water to eliminate.	Press types A. Rack and frame. B. Bladder press - press aid may be used. C. Screw press - continuous operation - press aid used - operating cost low. D. Counter current extractor - removes juice by leaching - requires firm fruit - time required to start up and shut down means machine should be run for several weeks - press aid used. E. Horizontal basket press (Bucher press) - press aid used. F. Belt press - press aid used. G. Decanter centrifuge - use centrifugal force to separate the solids from juice.

Step 6. Clarification and Filtration	Step 7. Juice De-aeration	Step 8. Heat Treatments	Step 9. Concentration
A. Screening. B. Pectinase - used to reduce viscosity and clarify juice. C. Gelatins - used to remove tannins or proteins. D. Bentonite - used to remove excess proteins. E. Filtration 1. Diatomaceous earth filtration 2. Plate and frame press 3. Horizontal filter 4. Vacuum filters 5. Cartridge filters F. Ultra-filtration. G. Micro-filtration.	Some juices, such as orange, trap air and are de-aerated by being sprayed into vacuum de-aerator. This process reduces vitamin C destruction and other changes due to oxygen.	A. Juices are heated to decrease microbial growth and to inactivate natural enzymes. B. Sugar solutions (frozen fruit) reduce dissolved oxygen. C. Lemon juice, ascorbic acid, sulfur dioxide, sulfites, other chemical agents can be used.	Juices are low in solids, so it is common to concentrate many of them. A. Evaporation - water is removed by boiling. An evaporation plant consist of: 1. an evaporator, where the juice evaporates by using the heat provided (usually steam). 2. a separator, where the concentrate is separated from the vapors, and 3. a condenser, where the vapors are condensed. B. Reverse Osmosis - the suspended solids are removed by centrifugation or ultra-filtration and the clear serum is concentrated by reverse osmosis. C. Freeze concentration - high quality juice concentrations can be made. Concentrate to maximum Brix 50°; operation has high capital and operating costs.

Step 10. Preservation	Step 11. Juice from Concentrate	Step 12. Packaging
A. Refrigeration (0-2.2°C) B. Freezing C. Pasteurization D. Chemical treatment Benzoic acid, sulfur dioxide E. Membrane filtration F. Drying G. Other potential treatments 1. Irradiation 2. Ultraviolet light sterilization 3. High-intensity pulse-light pasteurization 4. Electric pulse and poration 5. Microwave pasteurization 6. Surface pasteurization 7. High-pressure pasteurization	Concentrate is pumped into blending tank where treated water, essence (and oil in the case of citrus fruit) and probably pulp is added. This reconstituted juice is pasteurized, chilled, packaged and shipped.	A. Hermetically (air and moisture sealed): 1. Glass 2. Cans 3. Aseptic packaging into: tetra Pak, Combibloc, PurePak, Elopak, etc. B. Not hermetically sealed 1. Polyethylene (PET) plastic bottles (sizes fl oz: 4, 8, 16, 32, 64, 128) 2. Polyvinyl chloride (PVC) bottles 3. Plastic bags in fiberboard boxes (4-5 gal) 4. composite paperboard cartons

Table 4. Heat-Treatable Microbial Hazards

Evidence from outbreaks

Year	Juice	Hazard	Cases	Cause	Source
1975	Apple cider	*Salmonella typhimurium*	296	Drop apples; orchard fertilized with cow manure; unpasteurized	CDC 1975
1976	Tomato juice	*Clostridium botulinum*	1	Home-made	CDC Foodborne Outbreak Surveillance System
1979	Tomato juice	*C. botulinum*	1	Home-made	CDC Foodborne Outbreak Surveillance System
1981	Tomato juice	*C. botulinum*	1	Home-made	CDC Foodborne Outbreak Surveillance System
1983	Tomato juice	*C. botulinum*	1	Home-made	CDC Foodborne Outbreak Surveillance System
1991	Apple cider	*Escherichia coli* O157:H7	23; 6 hospitalized; 4 HUS	Drop apples; unpasteurized	Besser et al. 1993
1991	Coconut milk	*Vibrio cholerae* O1	4 (6 consumed product)	Heavy contamination during manufacturing in Thailand; unpasteurized	Taylor et al. 1993
1993	Apple cider	*Cryptosporidium parvum*	160	Apples contaminated with calf feces; unpasteurized	Millard et al. 1994

Year	Juice	Hazard	Cases	Cause	Source
1995	Orange juice	*Salmonella* Hartford, Gaminara, Rubinslaw	62	Inadequate sanitation and cleaning; unpasteurized	Cook et al. 1996
1996	Apple juice	*E. coli* O157: H7	66; 14 HUS; 1 death	Unpasteurized	CDC 1996b CDC 1997
1996	Apple cider	*E. coli* O157: H7	14; 7 hospitalized; 3 HUS	Drop apples; unpasteurized	CDC 1997
1996	Apple cider	*E. coli* O157: H7	6	Apple cider made at church event	Griffin 1996
1996	Apple cider	*C. parvum*	31	Unpasteurized; well water used for rinsing contained coliforms	CDC 1997

Evidence from recalls

Year	Juice	Hazard	Cases	Cause	Source
1992	Orange Julius drink	*Salmonella* agona	25	Orange Julius compound contaminated with *Salmonella* spp.	FDA recall data
1993	Flavored drinks	*C. parvum*	Cannot be separated from water-borne cases	From contaminated city water supply	FDA recall data
1994	Orange juice	*Bacillus cereus*; yeast	85 cases	Fermented; juice left at room temperature	FDA recall data

Evidence from state investigations

Year	Juice	Hazard	Cases	Cause	Source
1989	Orange juice	*Salmonella typhi*	69; 21 hospitalized	Infected worker	Personal communication with Mike Cambridge, New York State Health Dept., January 22, 1997
1993	Carrot juice	*C. botulinum*	1 hospitalized	Home-made	Personal communication with Patty Walker, Washington State Health Dept., January 15, 1997
1993	Orange juice	Yeast or unknown toxicant	23; 1 person saw physician	Improper storage time and container	Personal communication with Sharon Karam, Ohio State Health Dept., January 21, 1997
1993	Watermelon drink	*Salmonella* spp.	18	Home-made	Personal communication with Roberta Hammond, Florida State Health Dept., January 21, 1997
1996	Apple cider	*E. coli* O157:H7 (suspected)	1	Cow manure on clothes of farmer making cider	Personal communication with Marshall Deasy, Pennsylvania State Health Dept., January 15, 1997

Table 5. The Annual Number of Illnesses Associated with Juice Consumption

(1) Pathogen	(2) Lower Bound	(3) Upper-Bound Estimate I	(4) Upper-Bound Estimate II
a. Non-Heat-Treated			
Salmonella	16	4900	7600
E. coli O157: H7	22	2200	4300
C. parvum	48	4800	4800
b. Heat-Treated			
B. cereus	21	2000	33900
Unknown	6	600	600

Notes to Table 5:

Column (1). We classified the pathogens associated with illness according to whether or not the juice vehicle was heat-treated. The illnesses caused by the pathogens listed under the non-heat-treated heading (part (a)) all were associated with the consumption of non-pasteurized juices. The illnesses listed under the heat-treated heading (part (b)) all were associated with the consumption of pasteurized juices.

Column (2). The lower-bound numbers are the annual average confirmed illnesses for 1993-1996 from CDC outbreaks, state outbreak investigations, and FDA recall data.

Column (3). The estimated number of cases is based on Bennett et al. (1987) and CAST (1994). To get these numbers, we multiplied the confirmed cases from column (2) by 307 for *Salmonella*, 100 for *E. coli* O157: H7, 100 for *C. parvum*, 96 for *B. cereus*, and 100 for the unknown pathogen.

Column (4). The estimated number of cases is based on Todd (1989) and CAST (1994). To get these numbers, we multiplied the actual cases from column (2) by 474 for *Salmonella*, 195 for *E. coli* O157: H7, 100 for *C. parvum*, 1,615 for *B. cereus*, and 100 for the unknown pathogen.

Table 6. Human Health Effects

Hazard	Distribution of cases by severity (percent)	Characteristics of mild case	Characteristics of moderate case	Characteristics of severe case
Escherichia coli O157:H7	Mild: 50 Moderate: 27-32 Severe: 18-23	Nausea, cramping, or diarrhea; lasts less than 4 days	Nausea, cramping, or diarrhea, possible headache, muscle pain, fever, abdominal pain, dehydration; lasts 4 days or more	Hospitalization; some cases develop HUS or TTP; case fatality rate = 1-2.5 percent; 1.2 percent of outbreak cases have been fatal; HUS and hemorrhagic colitis each account for half of fatalities
Salmonella (non *typhi*)	Mild: 60-70 Moderate: 20-30 Severe: 5-15	Diarrhea, nausea, vomiting, abdominal cramping; lasts 1-2 days	Same as mild, but lasting up to one week	Headache, possible fever, hospitalization; case fatality rate = 0.1 percent of all cases
Cryptosporidium parvum	Mild: 90 Moderate: 9 Severe: 1	Watery diarrhea, lasting one day to several weeks, abdominal cramping, nausea	Same as mild, but lasting longer	Hospitalization
Bacillus cereus	Mild: most cases Moderate: rare	Diarrhea, abdominal cramping	Same as mild, with vomiting	

Sources: Council for Agricultural Science and Technology 1994; Griffin 1995; Mauskopf et al. 1988; Martin et al. 1993; Haddix 1997; U. S. Food and Drug Administration 1997.

Table 7. Not Heat-Treatable Hazards

Year	Product	Hazard	Cases	Cause	Source
		Evidence from outbreaks			
1967	Orange juice	Virus (unidentified; other contaminants possible)	5200 (estimated)	Contaminated water added to orange juice concentrate	Schmelzer et al. 1967; Tabershaw et al. 1967
1969	Canned tomato juice	Tin	113	Nitrate in soil incorporated in tomato and corroded cans	Barker and Runte 1972
1984	Elderberry juice	Poisonous parts of plant	11		CDC 1984
		Evidence from state investigations			
1989	Orange juice	Virus		Ill food handlers	Personal communication with Pam Shillam, Colorado State Health dept., January 17, 1997
1990	Guanabana juice	Toxic seed material	9		Personal communication with Dr. Hendricks, Texas State Health Dept., January 16, 1997

Evidence from recalls

Year	Product	Hazard	Cases	Cause	Source
1988	Fruit punch drink	Tin	2	Acidity of punch reacted with tin coating of cans (used wrong cans for packaging juice drink)	FDA recall data
1990-1991	Fruit juice and fruit drinks	Natamycin		Added as a preservative	FDA recall data
1991	Fruit drink	Sulfites		Inadvertently added	FDA recall data
1991	Fruit Punch	Glass		Packed in glass bottles	FDA recall data
1991-1992	Fruit drinks	Sodium hydroxide	3; 1 hospitalized (in 1992)	Sanitizing agent got into product containers during cleaning	FDA recall data
1990s	Fruit drinks	FD&C yellow #5 dye		Undeclared dye	FDA recall data
1992	Fruit juices	Lead	1	Leached from can seams by low pH	FDA recall data
1993	Orange juice	Milk		Filler lines not cleaned between milk and juice production	FDA recall data
1993	Orange flavored soft drink (with pear juice)	Copper	2	Cracks in heat exchanger allowed product to come in contact with copper pipe fitting	FDA recall data
1994	Fruit flavored juice beverage	Glass		Unknown	FDA recall data

Year	Product	Hazard	Cases	Cause	Source
1994	Lemon juice and grape juice	Sulfites		Added	FDA recall data
1995	Tomato juice	Salt	1	Undeclared	FDA recall data
1996	Apple-prune juice and prune juice	Lead	No illness; chronic hazard	Contaminated imported prune juice; possibly came in large drum	FDA recall data
1996	Fruit drink	Plastic	3 (complained of choking)	Plastic bags draped over side of bottle loading bin	FDA recall data
1997	Orange juice	Glass		Packed in glass bottles	FDA recall data
1997	Pineapple juice	Tin		Undeclared	FDA recall data

Evidence from FDA investigations

Year	Product	Hazard	Cases	Cause	Source
1997	Apple juice concentrate	Patulin		Undeclared	FDA analysis

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