recycled film, the yields were not significantly different. The multilayer cover has the potential to provide the biological requirements of a tomato crop for only one growing season (7 months), whereas the traditional monolayer film is effective as a cover for two or more growing seasons.

The results of this research proved that waste recycling offers an attractive solution to nuisance environmental problems. However, subsequent work should be focused on the increase of useful lifetime of the film by controlling the thermo-oxidative degradation.

Literature Cited

Ali, M., A. Qataneh, and S. Mehyar. 1990. A marketing study of multilayer polyethylene films in Egypt, Jordan, Iraq, Syria and Turkey. Royal Scientific Society, Jordan.

Amin M., G. Scott and L. Tillekeratne. 1975. Mechanism of the photo-initiation process in polyethylene. European Polymer J. 2:85.

Brown, J.E. and W.E. Splittstoesser. 1991. Plasticulture. Disposal problems limit its commercial uses. Proc. Natl. Agr. Plastics Congr. 23:35-38.

Charkraborty K. and G. Scott. 1977. Effects of the thermal processing on the thermal oxidative and photo-oxidative stabilities of low density polyethylene. European Polymer J. 13:731-737.

Cordonnier, M. 1987. LLDPE and UV aging. Plastics and Rubber Processing and Applic. 8: 23-27.

Ennis, R.S. 1987. Plastigone™ a new, time-controlled, photodegradable, plastic mulch film. Proc. 20th Natl. Agr. Plastics Congr. p. 83-90.

Fontes, M.K. 1973. Controlled environment horticulture in the Arabian Desert at Abu Dhabi. HortScience 8(1):13-16

Glen, J. 1990. Curbside recycling reaches 40 millions. Biocycle 3(7):30-37.

Khraishi, N. 1993. Multilayer polyethylene films (final report). Royal Scientific Society, Amman, Jordan.

Khraishi, N. and A. Al-Robaidi. 1991. Effect of weathering on UV stabilized low density polyethylene film for a multilayer greenhouse cover. Polymer Degradation and Stability 32:105-114.

Leaversuch, R.D. 1991. Chemical recycling brings real versatility to solid-waste management. Modern Plastics 68(7):40-43.

Mukhopadhyay, G. and M. Banerjee 1987. Popular Plastics, July. 15.

Wittwer, S.H. 1993. World-wide use of plastics in horticultural production. HortTechnology 3(1):6-19.

Comparing Objective Quality Attributes of Grapefruit Imported Into Europe

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Additional index words. *Citrus paradisi* Macf., peel thickness, juice volume, total soluble solids, total acid

Summary. Grapefruit (*Citrus paradisi* Macf.) were sampled biweekly from importers in Rotterdam, the Netherlands, from Oct. 1992 through Sept. 1993. For each sample, fruit size, weight, peel thickness, internal pulp color, juice weight, total soluble solids (TSS), and total acid (TA) were measured. Three grapefruit cultivars—'Marsh' white, 'Ruby Red', and 'Star Ruby'—were sampled from 12 countries of origin. Florida fruit weighed more, had the thinnest peel, the most juice, the lowest TA, and the highest TSS/TA ratio for all three cultivars compared to all other origins, except for 'Ruby Red' grapefruit from California, which had a lower TA and a higher TSS/TA ratio. Turkish 'Ruby Red' and Spanish 'Star Ruby' fruit weighed the least and had the least amount of juice compared to fruit from other origins. Turkish fruit had the highest TA and the lowest TSS/TA ratio for all three cultivars from all origins. Israeli 'Marsh' white and 'Star Ruby' had the highest TSS. Overall, the internal quality characteristics of Florida fruit was high compared to fruit from other origins.

In 1992, imports of fresh grapefruit into the European Economic Community (EEC) totaled 470,000 metric tons from more than

U.S. Department of Agriculture, Agricultural Research Service, European Marketing Research Center, Rotterdam, the Netherlands.

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30 countries of origin (Eurostat, 1993). The five leading countries that exported fresh grapefruit to the EEC were the United States, Israel, Cyprus, South Africa, and Argentina, which accounts for ≈80% of the total. The next five countries, in descending order (Turkey, Honduras, Cuba, Uruguay, and Swaziland), exported ≈12% of the total. The United States and Israel accounted for ≈48% of the total imports into the EEC. However, Cuba's export to the EEC is increasing rapidly, as is production in Spain and Turkey. The United States exported ≈98,000 metric tons to the EEC, mostly from Florida, which exported 7.1 million boxes (≈72,000 metric tons), or about 18% of the total imports into the EEC.

External visual quality is very important to most European importers, but internal quality characteristics such as juice volume and sweetness are gaining in importance. Consumers are selecting more products because of better taste and/or flavor and are shifting gradually from only external quality characteristics as the major buying criteria. Palatability of grapefruit depends on the sweetness and a high ratio of TSS/TA (Harding, 1952; Long et al., 1959). In addition to TSS/TA ratio, juice volume is used as a basis for determining maturity and palatability (Harding and Fisher, 1945).

An earlier study was conducted on the variation of three physical and three chemical characteristics related to quality of fresh grapefruit originating from 13 countries and imported into the EEC (Hillebrand et al., 1978). That study indicated that 'Marsh' white grapefruit from Florida had the thinnest peel, highest percent of juice, lowest percent of TA, and highest TSS/TA ratio compared to fruit from most other origins. Another study conducted on only early season (October/November) grapefruit arriving from Florida, Cuba, Mexico, and Honduras into the Rotterdam Fruit Auction showed that Florida fruit compared favorably to fruit from the other origins (Hoogendoorn and Miller, 1986). Most of the grapefruit in that study was 'Ruby Red', and the study was conducted only during a 6-week period in Oct. and Nov. in 1984 and 1985.

The objective of this study was to compare selected physical and chemical characteristics of the grapefruit cul-

tivars arriving in Rotterdam, the Netherlands, from all origins during a whole marketing year.

Materials and methods

Beginning in Oct. 1992 and ending in Sept. 1993, grapefruit samples were collected at random from lots displayed at the Rotterdam Fruit Auction. Samples were collected biweekly on auction days, which were generally twice a week. Each lot or shipment was sampled only once. In addition, samples were also collected at several receivers' warehouses in the Rotterdam area. These samples consisted of grapefruit from some countries that normally did not sell fruit at the auction.

A five-fruit sample is considered a standard sample as described by Soule et al. (1967). Size 56 grapefruit was selected because it is the preferred size for the European market. Each producing country's fruit size 56 or count 56 per box may be somewhat different in diameter. A total of 359 samples was collected from 17 countries of origin. Fruit of several countries (Mexico, Bahamas, Swaziland, and Mozambique) could not be included in the analyses because of limited sample numbers, while other samples had to be discarded due to cultivar differences and limited number of comparisons. A total of 12 cultivars was sampled, but only 'Marsh' white, 'Ruby Red', and 'Star Ruby' were used to make comparisons among countries. Israeli 'Sunrise' was compared to 'Star Ruby' from other countries because the parentage is the same. Samples from the United States were broken down further into those from California and Florida. There were not enough samples from Texas to be included in the study.

The following data were collected for each sample:

Fruit size: The diameter of each

fruit was measured with a caliper to the nearest millimeter at the equator.

Fruit weight: The total weight of each five-fruit sample was determined to the nearest gram.

Peel thickness: The thickness of the peel of each fruit was measured with a caliper to the nearest millimeter after cutting transversely at the equator.

Pulp color: The interior pulp color (Hunter L*, a*, b* values) was measured using a Minolta Chroma Meter (Model CR-300, Minolta Camera Co., Osaka, Japan) on two areas of pulp on each grapefruit after slicing in half. Chroma (C) and hue (h) values were calculated from the a* and b* values.

Juice weight: The five-fruit sample was juiced with a Sunkist Juice Extractor (Model 8S, Sunkist Growers, Overland Park, Kan.). The juice was strained through a 1.2-mm strainer to separate the seeds and pulp from the juice. The composite strained juice sample was weighed to the nearest gram.

Total soluble solids: The TSS were determined with an Atago refractometer (Model PR-1, Atago Co., Ltd., Tokyo, Japan), with a range of 0% to 32%.

Total acid: TA was measured by titrating a 25-ml juice sample with a sodium hydroxide solution (0.4063 N) to the phenolphthalein endpoint and is expressed as percent anhydrous citric acid.

In addition to these measurements, the percent juice and the TSS/TA ratio were calculated from the means of the individual factors.

All data were subjected to analysis of variance procedures using statistical comparison of means by Tukey's multiple comparison procedure for un-even treatment means.

Results and discussion

'Marsh' white. Grapefruit from

Argentina and Cyprus were the largest in size, but Florida fruit weighed the most (Table 1). Israeli and South African fruit were the smallest, and Israeli fruit weighed the least. Florida fruit had the thinnest peel and Cyprian fruit had the thickest peel. Internal pulp color for Florida fruit was L* = 45.23, a* = -2.30, b* = 9.50 (C = 9.78, h = 103.61), and for Cuban fruit it was L* = 46.60, a* = -1.92, b* = 10.10 (C = 10.28, h = 100.76), which were not significantly different. The pulp color of Uruguayan fruit was significantly more yellow [L* = 52.75, a* = -3.81, b* = 15.90 (C = 16.32, h = 104.48)] than all other fruit (data not shown). The juice content and the percent of juice of Florida fruit was the highest, and Uruguayan fruit was the lowest. Florida fruit had ≈20% more juice than Cuban fruit, the next highest country, and ≈70% more than Uruguayan fruit. TSS were highest for fruit from Israel and the lowest for fruit from Brazil. Florida fruit had the least amount of TA and Turkish and Cyprian fruit had the highest. The TSS/TA ratio was the highest for Florida fruit and the lowest for Brazilian and Turkish fruit.

'Ruby Red.' Florida fruit followed by fruit from Cuba, Argentina, Honduras, and Turkey were larger than fruit from Israel and Spain (Table 2). Florida fruit weighed the most and Turkish fruit the least. The peel thickness of Florida and Argentine fruit was less than the peel thickness of Turkish, Spanish, and California fruit. Florida fruit had the most juice and was significantly higher than fruit from all other sources, except for Cuban fruit. Florida fruit had ≈10% more juice than Cuban fruit and ≈70% more juice than Spanish fruit. The percentage of juice-to-weight was also the highest (51.8%) for the Florida fruit and the lowest (42%) for Spanish fruit. Israeli internal pulp color was the reddest [L* = 39.13,

Table 1. *Physical and chemical characteristics of 'Marsh' white grapefruit sampled during the 1992-93 marketing season, Rotterdam, the Netherlands*

Country	No. samples	Size (mm)	Wt (g)	Peel (mm)	Juice (g)	Juice (%)	TSS (%)	TA (%)	TSS/TA
Argentina	14	91.4 a ^z	1441 bc	6.4 ab	594 c	41.16 cd	10.02 ab	1.95 ab	5.11 cd
Brazil	6	87.6 bc	1315 cd	5.6 bc	608 bc	46.18 bc	7.53 c	1.64 bc	4.59 d
Cuba	17	89.6 ab	1490 ab	6.4 ab	687 b	46.08 bc	9.54 b	1.41 cd	6.67 ab
Cyprus	14	91.3 a	1317 cd	7.4 a	559 cd	42.38 cd	10.97 a	2.05 ab	5.31 cd
Florida	15	89.6 ab	1570 a	4.4 d	817 a	51.97 a	9.67 b	1.27 d	7.57 a
Israel	17	84.5 d	1187 e	5.7 b	496 d	41.69 cd	11.09 a	1.8 5 ab	5.92 bc
South Africa	13	85.1 cd	1278 d	4.8 cd	624 bc	48.75 ab	9.55 b	1.44 cd	6.60 ab
Turkey	9	89.2 ab	1271 de	6.4 ab	549 cd	41.87 cd	10.01 ab	2.17 a	4.59 d
Uruguay	7	87.5 bc	1268 de	5.3 bc	482 d	37.89 d	9.59 b	1.90 ab	5.04 cd

^zMeans within a column followed by different letters are significantly different at the 5% level according to Tukey's multiple comparison procedure.

Table 2. *Physical and chemical characteristics of 'Ruby Red' grapefruit sampled during the 1992-93 marketing season, Rotterdam, the Netherlands*

Country	No. samples	Size (mm)	Wt (g)	Peel (mm)	Juice (g)	Juice (%)	TSS (%)	TA (%)	TSS/TA
Argentina	39	89.4 a ^z	1460 bcd	4.5 b	740 b	50.65 ab	8.32 b	1.46 bc	5.73 c
California	6	87.4 ab	1418 bcd	5.7 a	641 bc	45.60 bc	9.56 a	1.09 d	8.86 a
Cuba	17	89.9 a	1548 ab	5.2 ab	757 ab	49.10 ab	9.41 a	1.30 cd	7.27 b
Florida	70	90.3 a	1597 a	4.2 b	827 a	51.77 a	9.63 a	1.19 d	8.06 a
Honduras	8	89.0 a	1497 abc	5.2 ab	694 b	46.28 bc	9.33 ab	1.64 b	5.65 c
Israel	3	85.3 b	1255 de	4.8 ab	570 c	45.41 bc	9.28 ab	1.56 bc	5.83 c
South Africa	4	87.8 ab	1337 cde	5.4 ab	665 bc	49.70 ab	8.89 ab	1.50 bc	5.94 c
Spain	5	84.2 b	1234 de	5.7 a	488 c	42.00 c	9.21 ab	1.61 b	5.74 c
Turkey	9	88.3 a	1163 e	6.4 a	521 c	42.26 c	9.91 a	2.16 a	4.59 d

^zMeans within a column followed by different letters are significantly different at the 5% level according to Tukey's multiple comparison procedure.

a* = 9.70, b* = 11.06 (C = 14.71, h = 48.74)] and Spanish fruit was the least red [L* = 45.04, a* = -0.95, b* = 15.56 (C = 15.59, h = 93.49)]. Florida pulp color [L* = 41.47, a* = 3.50, b* = 9.63 (C = 10.25, h = 70.02)] and Cuban pulp color [L* = 40.65, a* = 5.57, b* = 9.43 (C = 10.95, h = 59.39)] was about the same, but was redder than fruit from Argentina, California, South Africa, and Spain. Total soluble solids of Turkish, Florida, California, and Cuban fruit were significantly higher than fruit from Argentina. However, TA of Turkish fruit was significantly higher than fruit from all other sources. Total acid in Florida and California fruit was significantly lower than fruit from all other sources, except Cuba. The TSS/TA ratio for California and Florida fruit was significantly higher than fruit from all other sources, and California fruit had 9% higher TSS/TA than Florida fruit.

'Star Ruby'. California fruit was the largest and Spanish fruit was the smallest (Table 3). However, Florida fruit weighed the most and was significantly heavier than fruit from all other sources, except California and Cuba. Florida and South African fruit had the thinnest peel, which was significantly thinner than fruit from all other sources,

except California, Cuba, and Brazil. Turkish fruit's internal pulp color [L* = 38.29, a* = 15.30, b* = 11.38 (C = 19.07, h = 36.64)] was the reddest, and California fruit the least red [L* = 39.82, a* = 9.42, b* = 14.00 (C = 16.58, h = 56.06)]. Florida fruit's internal pulp color was L* = 36.36, a* = 12.51, b* = 10.05 (C = 16.05, h = 38.78), and Cuba fruit's internal pulp color was L* = 34.94, a* = 14.37, b* = 9.50 (C = 17.23, h = 33.47) and statistically was the same as Turkish fruit, but was significantly more red than California fruit. Florida fruit had significantly more juice than fruit from all other sources, except for Cuba, California, and South Africa. Florida fruit had 5% more juice than Cuban fruit and 70% more juice than Spanish fruit.

The percent of juice by weight was the highest for South African fruit, followed by Florida and Cuban fruit, and these were significantly higher than fruit from all other sources, except Argentina and Brazil. Israeli fruit had the highest TSS and Argentine and Brazilian fruit the lowest. Florida fruit had the lowest TA and Turkish and Uruguayan fruit had about twice as much acid as Florida fruit. Fruit from Florida had the highest TSS/TA ratio,

followed by fruit from California, and their ratios were significantly higher than fruit from most other origins.

Conclusions

Florida fruit weighs the most, has the thinnest peel, the most juice, the lowest TA, and the highest TSS/TA ratio compared to the fruit from all other origins, except for 'Ruby Red' grapefruit from California, which had a lower TA and higher TSS/TA ratio. The California and Florida citrus industry should be able to use these results to promote their fruit in international markets. Palatability of grapefruit is generally related to high TSS, low TA, and a high TSS/TA ratio, which both California and Florida fruit exhibited. Also, Florida fruit generally weighed the most and had the most juice, which are also important quality factors that should be considered. However, this study did not attempt to measure any sensory preferences of European consumers.

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Table 3. *Physical and chemical characteristics of 'Star Ruby' grapefruit sampled during the 1992-93 marketing season, Rotterdam, the Netherlands*

Country	No. samples	Size (mm)	Wt (g)	Peel (mm)	Juice (g)	Juice (%)	TSS (%)	TA (%)	TSS/TA
Argentina	4	90.2 ab ^z	1432 bc	5.2 ab	702 bcd	49.08 ab	8.02 c	1.70 bc	4.75 cde
Brazil	4	87.7 abc	1395 bc	4.8 bc	675 bcde	48.42 ab	8.41 bc	1.39 cd	6.07 bcd
California	3	92.3 a	1594 ab	4.2 bc	746 abc	46.84 b	10.37 ab	1.37 cd	7.58 ab
Cuba	3	90.0 ab	1590 ab	5.0 bc	824 ab	51.86 a	8.76 abc	1.35 cd	6.48 bc
Florida	23	89.4 ab	1637 a	4.0 c	862 a	52.72 a	9.59 ab	1.16 d	8.36 a
Israel ^y	18	85.8 bc	1284 c	5.2 ab	595 cde	46.45 b	10.50 a	1.65 c	6.40 bc
South Africa	5	86.4 bc	1380 bc	4.0 c	739 abc	53.55 a	9.59 ab	1.40 cd	6.89 bc
Spain	8	83.9 c	1161 d	6.8 a	506 g	43.68 b	9.19 abc	1.80 bc	5.10 cd
Turkey	6	90.6 ab	1364 bc	6.9 a	596 cde	44.19 b	9.21 abc	2.34 a	3.95 e
Uruguay	4	88.3 ab	1269 cd	6.0 ab	554 def	43.65 b	10.47 a	2.22 ab	4.73 cde

^zMeans within a column followed by different letters are significantly different at the 5% level according to Tukey's multiple comparison procedure.

^yIsraeli grapefruit was of the 'Sunrise' cultivar.

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Literature Cited

Eurostat. 1993. Monthly EC External Trade.

Harding P.L. 1952. Evaluating palatability

in Florida citrus fruit. *J. Amer. Soc. Hort. Sci.* 59:303-306.

Harding, P.L. and D.F. Fisher. 1945. Seasonal changes in Florida grapefruit. *USDA Tech. Bul.* 886.

Hillebrand, F.M., L.A. Risse, and A.J. Bongers. 1978. Quality of grapefruit imported into Western Europe. *USDA Mktg. Res. Rpt.* 1093.

Hoogendoorn, H.M. and W.R. Miller. 1986.

Observation of early season grapefruit imported into Rotterdam. *Proc. Fla. State Hort. Soc.* 99:112-114.

Long, W.G., P.L. Harding, J.J. Soule, Jr., and M.B. Sunday. 1959. Variations in quality of Marsh grapefruit. *USDA AMS-336.*

Soule, J.J., W. Grierson, and J.G. Blair. 1967. Quality tests for citrus fruit. *Univ. Fla. Expt. Ser. Inst. Food Agr. Sci. Circ.* 315.