tipping fee and require minimal permitting paper work. Guidelines to protect ground and surface waters are included in the regulations. A copy of the regulations may be obtained by calling the DEQ in Richmond, Va.

Organic matter is required in most horticultural enterprises. YWC is an economical soil amendment that can be produced and marketed for less cost than comparable organic materials. Nurseries and landscape businesses are natural locations for compost facilities because much of the finished product could be used "in-house" for potting mixes, in field-grown nursery crops as a soil amendment, and in turf establishment and renovation. Operating a facility would allow nurseries to supplement their income by accepting organic materials from municipalities for a tipping fee, and, in cooperation with municipalities, the nursery industry could play a major private sector role in the implementation of a statewide YWC program.

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Physical and Chemical Characteristics of Apples in European Markets

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Additional index words. *Malus domestica* Borkh., shape, external defects, internal defects, water core, bruises, firmness, color, soluble solids, acid, starch, vitamin C

Summary. Comparisons were made of the major physical and chemical characteristics of seven cultivars of apples (*Malus domestica* Borkh.) produced and imported into Western Europe from 13 origins. During the 1990-91 marketing season, 'Delicious', 'Golden Delicious', 'Granny Smith', 'Elstar', 'Jonagold', 'Gala', and 'Fuji' apples were included in the study. Physical characteristics evaluated were length-to-diameter ratio, shape, external defects, internal defects, water core, bruises, firmness, blush surface, and color. Chemical characteristics evaluated were starch, juice content, soluble solids, acids, and ascorbic acid. Significant differences in some of these quality characteristics were found between the different origins. Apples produced in the United States, particularly 'Delicious', had some superior quality characteristics compared to fruit from other origins.

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The European Union (EU) is one of the world's major producers of apples. However, the EU also imports apples from many sources. The largest producers within the EU are Italy, France, Germany, and Spain. Major exporters to the EU are Chile, South Africa, New Zealand, Argentina, and the United States.

Most of the published data on chemical composition and physical characteristics of apple quality are found in miscellaneous reports that describe the direct effects of either the cultivar, mineral nutrition, climate, maturity, or time of storage (Olsen, 1969; Pattee, 1985; Watada et al., 1980, 1981). These reports are concerned with aspects of fruit quality as influenced by the environment of relatively small areas of production. There are no reports that clearly describe the difference in quality of different apple cultivars from the major producer countries in the world when the apples are available to the consumer. In this study, selected apple cultivars from various countries were compared for the principal physical and chemical characteristics related to condition and quality.

Materials and methods

Apple samples were collected at 12 monthly intervals from lots arriving on the wholesale markets or importers' warehouses in Rotterdam, the Netherlands; Cologne, Germany; Paris, France; and 1 month in London, England, over a period of one marketing season (1990-1991). A total of 1066 samples of apples from 13 different origins were collected during the survey. The following cultivars were sampled: 'Delicious', 'Golden Delicious', 'Granny Smith', 'Elstar', 'Jonagold', 'Gala', and 'Fuji'. Samples of 'Empire' were also taken; however, not enough samples were collected for analyses. One standard package of median-size apples was selected from each new lot that had arrived during the monthly periods. Lots were separated according to brand or packer/grower. A 10-fruit sample was selected at random from the package and returned to the laboratory. The 10-fruit sample was divided in two subsamples of five fruit for further evaluation of all factors. For statistical analysis, the average value of the five fruit was used as one sample.

Size. Size was determined by measuring the diameter of the fruit to the nearest millimeter at the equator. Length of the fruit was determined by

measuring the fruit to the nearest millimeter from the stem end to the blossom end. Length/diameter (LD) ratio was calculated by dividing the length by the diameter.

Shape. The shape was evaluated on each fruit of the five-fruit sample according to the shape characteristics of the cultivar (Norton and King, 1987; Watkins and Smith, 1982). The following ratings were used:

- 1 = Well-formed—normal shape characteristic of the cultivar.
- 2 = Fairly well-formed—slightly abnormal shape, but not affecting appearance.
- 3 = Slightly deformed—irregular shape, slightly affecting appearance.
- 4 = Moderately deformed—moderately misshapen, affects appearance.
- 5 = Seriously deformed—badly misshapen, severely affecting appearance.

External defects. External defects were rated on each fruit with none = 1 through severe = 5. All external defects, other than bruises and mechanical damage, were rated and totaled.

Internal defects. On each fruit, internal defects, except water core, were totaled and rated with none = 1 through severe = 5.

Water core. The center part of the fruit (Fig. 1, Cut A) was used to rate water core (Apple Maturity Program, 1986). The initial stages of water core were observed as swelling of the vascular bundles, or a slight coalescing of cells in the core area. These cells appear translucent or water-soaked. The following ratings were used:

- 1 = Clear—no water core.
- 2 = Initial—swollen or water-soaked vascular bundles.
- 3 = Slight—vascular bundles swollen to ≈ 6.4 mm or smaller area water-soaked.
- 4 = Moderate—vascular bundles swollen 6.4–12.7 mm and some coalescing of the area between vascular bundles.
- 5 = Severe—core area water-soaked and extending to vascular bundles, including cortex tissue.

Bruises. Bruises and mechanical damage were scored by observation of each fruit (Dewey et al., 1972). Any bruises or cuts through the skin were rated as 5. The following ratings were used:

- 1 = None—diameter < 6.4 or < 12.7 mm of aggregated area.
- 2 = Trace—diameter of 6.4 to 12.7

Fig. 1. Sectioning of fruit.

- mm of single bruise or 12.7 to 19.1 mm of aggregated area.
- 3 = Slight—diameter of 12 to 19.1 mm of single bruise or 19.1 to 25.4 mm of aggregated area.
- 4 = Medium—diameter of 19.1 to 25.4 mm of single bruise or 25.4 to 31.8 mm of aggregated area.
- 5 = Severe—diameter > 25.4 mm of single bruise or > 31.8 mm of aggregated area.

Firmness. A semiautomatic electronic pressure tester (Model EPT-1, Lake City Technical Products, Kelowna, B.C., Canada) was used to measure firmness (Blanpied et al., 1978; Bongers, 1992). Firmness was measured on the blush and the non-blush sides with the skin removed. The average of the

two maximum force measurements (one on the blush and one on the non-blush side) were used as the firmness value for each apple.

Color. Blush surface was determined visually and recorded as percentage of the total surface of the apple that showed a good color characteristic for the cultivar (USDA, 1972). For the red, green, and yellow cultivars, the percentage stated refers to the area of the surface in which a good shade of, respectively, red, green, and yellow predominated over other colors. For the striped cultivars, the percentage refers to the area of the surface of which stripes of a good shade blush color characteristic of the cultivar predominated over stripes of other colors.

Color values were measured with a Colorgard System 45 (Specific Science, Silver Spring, Md.). Two measurements, one on the blush and one on the non-blush side, were made on each apple to determine the color value of the main color and the ground color (Gardner Lab., 1978).

Juice content. Two wedge-shaped sections of fruit (Fig. 1, section D) were cut from each apple and passed through an ACME Supreme juicerator. The sections included part of the core, but did

not include the pressure test areas. Juice content was calculated on a juice-to-weight basis ($\text{ml} \cdot \text{g}^{-1}$). This juice, well-mixed, was used for further analyses.

Starch content. A slice of fruit tissue (Fig. 1, section A) was taken, and the surface (Fig. 1, section C) brushed with a 2% potassium iodide-iodine (KI-I) solution (Apple Maturity Program, 1986). The following rating scale was used:

- 1 = Trace of starch just under the skin, basically fruit free of starch.
- 2 = Half of cortex, between vascular

bundles and the outer skin clear of starch.

3 = Area including vascular bundles clear of starch.

4 = Core area clear of starch.

5 = Full surface contains starch.

Solublesolids (SS). Soluble solids were determined from a sample of well-mixed juice using an Atago, Model ATC-1, refractometer with a range of 0% to 32% (Atago Co. Ltd., Japan).

Titrateable acid (TA). Titrateable acid content was determined by

Table 1. *Physical characteristics of apples by variety and country of origin acquired from wholesale markets in Cologne, London, Paris, and Rotterdam, 1990–1991.*

Origin	No. samples	Average diam. of sample (mm)	Length-to-diam. ratio	Shape	External defects ^z	Internal defects ^z	Watercore ^z	Bruises	Firmness (N)	Blush surface (%)	Color intensity ^y	
											Blush side	Non-blush side
<i>Delicious</i>												
Argentina	30	76.1	0.86 d ^x	2.17 a	1.30 ab	1.79 a	1.00 a	1.57 a	62.77 bc	75.2 c	2.15 e	0.58 d
Chile	70	74.9	0.95 b	1.58 c	1.41 a	1.49 a	1.06 a	1.50 a	59.07 cd	86.2 b	2.67 d	0.71 cd
France	48	76.0	0.91 c	1.73 bc	1.41 a	1.34 a	1.02 a	1.45 ab	58.55 cd	91.5 ab	3.42 b	1.27 b
New Zealand	14	72.8	0.90 c	1.70 bc	1.21 bc	1.34 a	1.00 a	1.61 a	55.72 d	92.7 ab	4.28 a	1.37 b
South Africa	6	79.8	0.92 bc	2.18 a	1.36 ab	1.70 a	1.00 a	1.65 a	63.94 a–c	92.8 ab	3.06 b–d	1.26 b
U.S. NE	12	74.9	0.92 c	1.76 bc	1.32 ab	1.13 a	1.07 a	1.47 ab	62.89 bc	95.1 a	5.24 a	2.06 a
U.S. NW	108	72.3	0.98 a	1.48 d	1.14 c	1.13 a	1.01 a	1.31 b	67.72 a	90.9 ab	3.04 cd	1.04 bc
<i>Golden Delicious</i>												
Belgium	22	72.0	0.97 a	1.56 a	2.18 a	1.00 a	1.00 a	2.07 a	59.96 a	98.68 a	–0.19 b	–0.27 a–c
France	112	74.7	0.95 b	1.51 ab	2.06 a–c	1.02 a	1.00 a	1.84 ab	55.55 b	95.30 b	–0.12 a	–0.20 a
Germany	14	72.5	0.95 ab	1.49 ab	2.10 a–c	1.00 a	1.00 a	1.57 b	59.41 a	98.43 a	–0.23 bc	–0.30 bc
Italy	20	73.3	0.94 bc	1.52 ab	1.80 bc	1.00 a	1.00 a	1.66 b	54.86 b	99.60 a	–0.30 c	–0.34 c
Netherlands	62	73.3	0.96 a	1.55 a	1.79 c	1.01 a	1.00 a	1.59 b	57.18 ab	97.21 a	–0.16 ab	–0.26 ab
South Africa	14	75.3	0.91 cd	1.50 ab	2.01 a–c	1.01 a	1.07 a	1.70 ab	56.36 ab	96.21 ab	–0.22 bc	–0.31 bc
U.S. NW	16	71.5	0.91 d	1.35 b	1.45 d	1.00 a	1.00 a	1.73 ab	56.67 ab	99.25 a	–0.23 bc	–0.30 bc
<i>Granny Smith</i>												
Argentina	36	75.6	0.88 bc	1.38 b	1.28 c	1.06 a	1.02 a	1.56 a	66.82 c	99.06 a	–0.41 b	–0.47 a
Chile	48	76.1	0.91 a	1.40 b	1.23 c	1.02 a	1.01 a	1.47 a	73.10 b	98.38 a	–0.41 b	–0.46 a
France	78	77.1	0.90 ab	1.48 b	1.56 ab	1.07 a	1.01 a	1.33 b	70.95 bc	92.47 b	–0.30 a	–0.43 a
Germany	4	77.2	0.92 a	1.35 b	1.13 c	1.00 a	1.00 a	1.40 ab	82.31 a	89.75 b	–0.21 a	–0.43 a
Italy	4	78.1	0.86 cd	1.55 ab	1.87 a	1.00 a	1.00 a	1.39 ab	66.27 c	95.00 ab	–0.36 ab	–0.46 a
South Africa	24	77.4	0.91 a	1.65 a	1.33 bc	1.01 a	1.00 a	1.61 a	67.84 bc	97.29 ab	–0.38 b	–0.47 a
Spain	4	72.2	0.87 b–d	1.61 ab	1.97 a	1.00 a	1.05 a	1.92 a	66.89 bc	97.50 ab	–0.33 ab	–0.50 a
U.S. NW	6	75.1	0.84 d	1.50 ab	1.61 ab	1.00 a	1.00 a	1.32 b	66.49 c	96.17 ab	–0.34 ab	–0.43 a
<i>Elstar</i>												
Belgium	12	71.2	0.82 a	1.53 a	2.60 a	1.02 a	1.00 a	1.52 a	54.63 a	62.83 a	1.72 a	–0.00 ab
France	20	73.2	0.81 a	1.55 a	2.24 a	1.02 a	1.00 a	1.56 a	51.07 ab	57.50 a	1.43 a	0.01 a
Germany	18	73.9	0.83 a	1.73 a	2.49 a	1.00 a	1.00 a	1.70 a	49.38 b	59.50 a	1.45 a	–0.02 ab
Netherlands	52	72.1	0.83 a	1.58 a	2.59 a	1.00 a	1.00 a	1.56 a	53.34 a	60.90 a	1.62 a	–0.05 b
<i>Jonagold</i>												
Belgium	32	77.0	0.86 a	1.61 a	2.04 a	1.06 a	1.00 a	1.87 a	58.07 a	56.41 a	1.61 a	–0.09 a
France	38	80.3	0.87 a	1.59 a	1.64 b	1.01 a	1.00 a	1.38 c	50.50 b	58.53 a	1.26 b	–0.08 a
Germany	24	79.8	0.87 a	1.55 a	1.50 b	1.03 a	1.00 a	1.81 ab	54.31 a	55.63 a	1.23 b	–0.20 b
Netherlands	68	79.9	0.87 a	1.65 a	1.59 b	1.03 a	1.00 a	1.64 b	55.26 a	48.25 b	1.12 b	–0.16 b
<i>Gala</i>												
Brazil	8	70.5	0.90 a	1.53 a	2.18 a	1.00 a	1.00 a	1.58 a	64.51 b	71.75 a	2.31 a	0.20 a
France	10	75.9	0.90 a	1.30 a	1.46 b	1.00 a	1.00 a	1.54 a	72.61 a	64.60 a	1.41 b	0.18 a
New Zealand	20	72.7	0.87 b	1.34 a	1.32 b	1.03 a	1.00 a	1.35 a	58.50 c	70.90 a	1.78 b	0.37 a
<i>Fuji^w</i>												
Brazil	2	83.4	0.90	2.10	2.00	1.20	1.20	1.80	61.65	84.00	1.98	0.33
New Zealand	8	78.5	0.85	1.66	1.25	1.28	1.10	1.33	61.18	67.38	1.85	–0.02
U.S. NW	2	69.7	0.80	2.00	1.50	1.00	1.00	1.20	71.93	70.00	0.21	–0.15

^zRating scale 1–5.

^yRatio Cielab a*/b*.

^xMeans per variety within a column followed by a different letter are significantly different at the 5% level.

^wNumber of samples too small for reliable analyses.

titrating 10 ml of juice from the well-mixed juice with 0.1 N NaOH (sodium hydroxide) to the phenolphthalein end point (pH = 8.2). TA is expressed as the percentage of malic acid (AOAC, 1990; Barakat et al., 1973).

Ascorbic acid. Ascorbic acid was determined by AOAC method 967.21. Vitamin C (ascorbic acid) in vitamin preparations and juices. 2,6-dichloro-indophenol titrimetric method (AOAC, 1990).

Results

Physical characteristics. Table 1 shows the distribution of the various physical characteristics of the varieties.

'Delicious' (RD) from the northwestern United States were the most uniformly shaped when evaluated by the length-to-diameter ratio. External defects were also the lowest from this area, while, for internal defects, no significant differences were detected.

Water core was insignificant in fruit from any origin. Bruises were lowest in those from the northwestern United States, which may be related to the significantly higher firmness compared to fruit from all other origins. Argentina shipped significantly less red-colored apples than the other countries. Redness on the blush side of RD samples from the northwestern United States and New Zealand was significantly higher than all other countries.

Table 2. *Chemical characteristics of apples by variety and country of origin, acquired from wholesale markets in Cologne, London, Paris, and Rotterdam, 1990–1991.*

Origin	No. samples	Avg. diam. of sample (mm)	Juice (ml·g ⁻¹)	Starch (1–5)	Soluble solids (%)	Total acid (%)	Solid-to-acid ratio	Ascorbic acid (mg/100 g)
<i>Delicious</i>								
Argentina	30	76.1	0.67 a ^z	2.40 a	12.53 c	0.31 a	41.1 d	0.46 b–d ^y
Chile	70	74.9	0.68 b	1.53 b	12.90 b	0.24 d	53.6 ab	0.48 bc
France	48	76.0	0.64 c	1.30 c	14.15 a	0.28 ab	50.2 bc	0.55 a
New Zealand	14	72.8	0.67 bc	1.24 c	12.85 bc	0.23 d	55.9 a	0.39 d
South Africa	6	79.8	0.69 ab	1.31 bc	14.15 a	0.28 a–c	50.9 a–c	0.39 cd
U.S. NE	12	74.9	0.68 b	1.14 c	12.78 bc	0.27 bc	46.8 c	0.45 b–d
U.S. NW	108	72.3	0.71 a	1.14 c	12.40 c	0.26 c	48.6 c	0.53 ab
<i>Golden Delicious</i>								
Belgium	22	72.0	0.64 c	1.12 a–c	14.08 a	0.41 ab	34.50 ab	1.77 a
France	112	74.7	0.67 b	1.14 ab	13.64 a	0.38 bc	36.19 ab	1.03 bc
Germany	14	72.5	0.65 bc	1.21 a	12.78 b	0.43 a	29.44 c	1.10 bc
Italy	20	73.3	0.69 a	1.00 c	11.25 c	0.35 cd	31.78 a–c	0.82 bc
Netherlands	62	73.3	0.66 b	1.02 bc	12.90 b	0.40 a–c	32.43 ac	1.83 a
South Africa	14	75.3	0.67 ab	1.01 bc	13.35 ab	0.40 a–c	33.21 a–c	0.68 c
U.S. NW	16	71.5	0.67 ab	1.01 bc	11.37 c	0.31 d	36.21 a	0.85 bc
<i>Granny Smith</i>								
Argentina	36	75.6	0.68 a	1.33 a	11.84 b–d	0.66 a	18.00 b	1.28 c
Chile	48	76.1	0.67 a	1.37 a	12.11 b–d	0.66 a	18.39 b	1.73 bc
France	78	77.1	0.67 a	1.42 a	12.36 a–c	0.71 a	17.31 b	2.28 a
Germany	4	77.2	0.68 a	1.00 b	12.43 ab	0.75 a	16.54 b	2.12 ab
Italy	4	78.1	0.68 a	1.00 b	11.64 b–d	0.60 a	19.50 ab	2.15 ab
South Africa	24	77.4	0.67 a	1.01 b	12.61 a	0.60 a	21.04 a	1.61 bc
Spain	4	72.2	0.66 a	2.00 a	12.33 a–d	0.78 a	15.74 b	1.86 a–c
U.S. NW	6	75.1	0.67 a	1.00 b	11.41 d	0.69 a	16.47 b	1.39 bc
<i>Elstar</i>								
Belgium	12	71.2	0.61 b	1.32 a	15.48 a	0.75 a	20.62 a	4.22 a
France	20	73.2	0.63 b	1.23 a	14.90 ab	0.75 a	19.94 a	2.75 b
Germany	18	73.9	0.64 ab	1.33 a	14.38 b	0.74 a	19.57 a	4.69 a
Netherlands	52	72.1	0.66 a	1.49 a	14.15 b	0.68 b	21.35 a	4.27 a
<i>Jonagold</i>								
Belgium	32	77.0	0.67 c	1.00 b	14.58 a	0.50 a	29.40 b	3.38 a
France	38	80.3	0.69 b	1.09 a	13.76 b	0.43 c	31.99 a	1.56 c
Germany	24	79.8	0.71 a	1.03 b	12.68 c	0.44 bc	28.76 b	2.18 b
Netherlands	68	79.9	0.69 b	1.03 b	13.49 b	0.47 ab	28.77 b	2.90 a
<i>Gala</i>								
Brazil	8	70.5	0.66 b	1.45 b	14.16 a	0.39 a	36.04 a	0.50 a
France	10	75.9	0.69 a	2.16 a	12.54 b	0.39 a	32.15 b	0.23 c
New Zealand	20	72.7	0.69 a	1.12 b	11.91 b	0.31 b	38.92 a	0.31 b
<i>Fuji^x</i>								
Brazil	2	83.4	0.70	1.00	15.60	0.29	54.17	0.33
New Zealand	8	78.5	0.71	1.00	13.64	0.24	55.89	0.25
U.S. NW	2	69.7	0.67	1.00	15.10	0.28	54.32	0.53

^zMeans within a column followed by different letters are significantly different at the 5% level.

^yValues of ascorbic acid are low compared to other published data; however, many samples came from longtime storage.

^xNumber of samples too small for reliable analysis.

Non-blush side of Argentine and Chilean RD had less intense red color than other sources.

'Golden Delicious' (GD) from the northwestern United States had the best shape index and the fewest external defects. Water core was only present in GD from South Africa; however, not significantly higher than fruit from other origins. The German and Dutch GD were the least-bruised apples. Belgian and German GD were the firmest. All origins had a high percentage of the typical green/yellow color, except France.

'Granny Smith' (GS) from South Africa were the poorest-shaped fruit. Spanish and Italian fruit had the most external defects. Internal defects and water core were not significantly different from all origins. Spanish GS had the most bruises, with northwestern United States the least. German GS were the firmest, with Italian the softest. Argentine GS were almost 100% green, with the German GS the least.

'Elstar' from the four countries studied had very similar physical characteristics. Except for firmness, there was no significant difference between all factors evaluated. 'Elstar' from Belgium and the Netherlands were firmer than fruit from Germany. The high level of external defects indicates that this cultivar is sensitive to adverse growing conditions.

'Jonagold' (JG) from the different origins were not significantly different for L/D ratio, shape, internal defects, and water core. Belgian JG had significantly more external defects than those from other origins. French JG were significantly softer than all other origins. Color of the Dutch JG was significantly less than fruit from other sources.

'Gala' from Brazil had the most external defects and were softer than 'Gala' from France, but firmer than New Zealand 'Gala'. Brazilian 'Gala' had the most intense red-colored blush.

'Fuji' cultivar samples were limited due to very low supply; therefore, no reliable analysis could be made. Samples collected from the northwestern United States were the firmest; however, they were very low in red color intensity.

Chemical characteristics. Table 2 shows the distribution of the various chemical characteristics for the different varieties. Vitamin C (ascorbic acid) levels decreased during storage and

fluctuated considerably, depending on season and growing area (Hansen and Bokling, 1984; Singh and Lund, 1987; Visser, 1984).

'Delicious' (RD) from the northwestern United States had significantly more juice than all other countries, except South Africa. Argentina RD contained the highest amount of starch, indicating that the apples may be harvested too immature. French RD were higher in ascorbic acid than other countries, except those from the northwestern United States.

'Golden Delicious' (GD) showed small, but significant, differences in juice content. Soluble solids were significantly lower in apples from Italy and the northwestern United States than other sources. Fruit from the northwestern United States had lower acidity than all other sources. 'Golden Delicious' from the Netherlands and Belgium had more ascorbic acid than those from all other countries.

'Granny Smith' (GS) from all sources were very consistent in the amount of juice. Starch of GS from Spain, Argentina, Chile, and France was significantly higher than the other countries. Ascorbic acid was the highest for French GS; however, not significantly different from German, Italian, and Spanish GS.

'Elstar', a relatively new variety, came from production areas within the EU. The Dutch and the German 'Elstar' contained the most juice. The Dutch 'Elstar' were the lowest in acidity and lowest in total soluble solids; however, the ratio was not significantly different from other sources. Ascorbic acid of French 'Elstar' was significantly lower than the other countries. 'Elstar', in general, had the highest ascorbic acid content compared to all other varieties.

'Jonagold' (JG) came from only European countries, with those from Germany the juiciest, while those from France had the highest starch content and a very low ascorbic acid content. French JG showed the highest solid-to-acid ratio, mainly due to the low acid level.

'Gala' from France had a very low ascorbic acid content and a very high starch content compared to Brazil and New Zealand.

'Fuji', in general, had no starch, low acidity, high soluble solids, and low ascorbic acid content.

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