HortScience 18(3):310–312. 1983.

Quality of Strawberries Packed in Different Consumer Units and Stored Under Simulated Air-Freight Shipping Conditions

W.R. Miller[1], P.L. Davis[2], and A. Dow[3],
Agricultural Research Service, U.S. Department of Agriculture, 2120 Camden Road, Orlando, FL 32803.

A.J. Bongers[4]
European Marketing Research Center, U.S. Department of Agriculture, Rotterdam, The Netherlands, AK 3029

Additional index words. *Fragaria* X *ananassa*, transportation, packaging, quality

Abstract. **Strawberries, *Fragaria* X *ananassa* Duchesne cv. Tufts, were packaged in 3 different consumer units and evaluated following storage at simulated air-freight time/temperature conditions during shipment to Western Europe. Berries in a rigid plastic basket with solid plastic cover lost significantly less weight than those stored in mesh plastic baskets with and without covers. There were no significant differences in pulp firmness among the packaging treatments. For all treatments, there was less berry deterioration after storage for 48 hours than for 72 hours at both 1.1° and 4.4°C, but in all units a high percentage of berries developed serious expressions of bruising during storage.**

Air shipment to Western Europe is a relatively new marketing development for the Florida strawberry industry. Current strawberry packaging practices for this market are the same as those used for the domestic market. Pickers place twelve 0.47-liter (1 U.S. pint) plastic mesh baskets in a shipping container (flat) and overfill until the top edges of individual baskets are covered (Fig. 1a). A 1980 survey (2) of 15 European receivers of U.S. strawberries in 5 countries found that most preferred that berries be packaged in 10 to 12 individually covered consumer units per shipping container, with net weights of either 250 or 500 g/unit, and with the net weight per unit guaranteed on delivery.

Moulton in 1947 (3) and Anderson and Hardenburg in 1959 (1) reported on the effects of packaging strawberries in various types of baskets and film overwraps to improve freshness and shelf-life. During the past 2 decades, many changes have occurred in both the materials available for prepackaging and in transportation modes for distribution of strawberries. In addition, many improved cultivars are now available.

The objectives of this study were to determine: 1) the time/temperature profile to which Florida strawberries are subjected between packinghouse and Western European destinations; and 2) the effects of various consumer packaging units on berry quality when subjected to 4 time/temperature schemes simulting export distribution.

Air temperatures were monitored during handling and shipping from packinghouse to destination in Western Europe in 4 different air shipments. The berries were placed in cold storage at about 3°C immediately after harvest. For transport, 208 flats of berries were loaded into a model LD–3 air-freight shipping container, which was also precooled in the same cold-storage facility prior to loading with berries. Two Ryan temperature recorders were placed in each shipment, one in a flat of berries 3 layers from the bottom and the other in a flat 3 layers from the top. The boxes were stacked 14 layers high and those with temperature recorders were located at the vertical center of the LD–3. After filling, the LD–3 remained in cold storage until transport by refrigerated truck to the Miami, Fla. airport. Time of arrival and length of time at each transfer point were recorded. Temperature recorders were recovered during unloading at each European destination.

To achieve the 2nd objective, strawberries were obtained from a commercial grower/shipper at Dover, Fla. Berries used in the 3 tests were harvested from the same field, but at different pickings. The field was picked at 3-day intervals, but test berries were obtained at 6-day intervals.

Berries less than three-quarters red (sur-

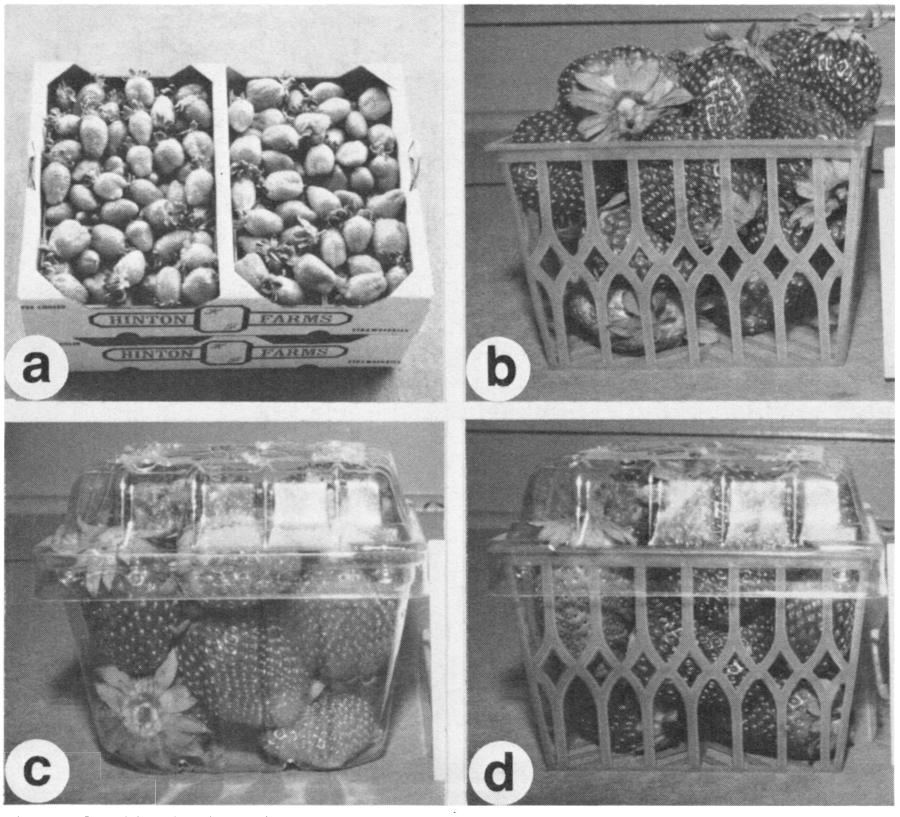

Fig. 1. Traditional and experimental strawberry packages. **a** Traditional packing of Florida strawberries. **b** PT-1: rigid plastic mesh basket with no cover. **c** PT-2: solid-oriented polystyrene plastic basket and cover. **d** PT-3: rigid plastic mesh basket with solid-oriented polystyrene plastic cover.

Received for publication December 1, 1982. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable. The authors are grateful to K.A. Munroe and T. Moffitt for their technical assistance and to T.V. Chew for statistical expertise. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Agricultural Marketing Specialist.
[2]Research Chemist.
[3]Biological Laboratory Technician.
[4]Agricultural Research Specialist.

Table 1. Strawberry exposure temperatures[z] and time at transfer points during distribution from shipping point to destination.

Time lapse (hr)	Transfer point	Avg. air temp. (°C)			
		Upper area of LD–3	Air temp. range	Lower area of LD–3	Air temp. range
0	Berries placed in LD–3[y]	10.0	9.4–11.0	8.3	7.2–9.4
5	LD–3 placed in truck	7.2	5.0–9.4	7.2	5.0–9.4
10	LD–3 placed in truck	7.2	4.4–10.0	6.7	3.3–9.4
15	LD–3 placed in truck	7.2	4.4–11.0	6.1	3.3–8.9
20	LD–3 removed from truck[x]	10.0	7.2–13.0	6.7	3.3–9.4
25	LD–3 left Miami by air	14.0	10.0–18.0	8.3	5.6–11.0
30	LD–3 arrived destination[w]	15.0	12.0–18.0	11.0	7.8–16.0
35	LD–3 arrived destination[w]	14.0	11.0–18.0	12.0	7.8–16.0
40	Berries cleared Customs from LD–3[v]	14.0	13.0–16.0	10.0	8.3–12.0

[z]Avg. of 4 shipments.
[y]Berries placed in LD–3 at cold storage facility of shipper, remaining in cold storage until loading in refrigerated truck for transport to Miami airport.
[x]Berries not held under refrigeration after removal from truck.
[w]Three shipments to Frankfurt, West Germany, and one to London, England.
[v]At Frankfurt, berries removed from LD–3 immediately after clearing Customs; at London, berries removed about 4 hr after clearing Customs.

face area), less than 1.3 cm diameter, seriously misshapen, or with observed physical damage were culled from the test lot. Remaining berries were randomly divided into one of the following packaging treatments: a rigid plastic mesh basket without cover (PT1) (Fig. 1b); a solid-oriented polystyrene (OPS) basket and cover (PT2) (Fig. 1c); and a rigid plastic mesh basket with solid plastic OPS cover (PT3) (Fig. 1d). All baskets contained 0.47 liters (about 300 g of berries) and measured about 10.2 × 10.2 ×6.7 cm in length, width, and depth, respectively. Solid plastic baskets had eight 0.5-cm ventilation holes equally spaced at the perimeter of the bottom edge. Covers had 8 similar holes on the top surface.

Twelve baskets of each type were prepared in each of the 3 test replications. Baskets were filled, but not overfilled, to prevent berry damage when the covers were secured. Baskets without covers were filled, but not so much that berries would shake off during routine handling. After filling, each basket was weighed.

Berries were held at 4 different time/temperature regimes: a) 24 hr at 1.1°C plus 24 hr at 10°; b) 24 hr at 1.1° plus 48 hr at 10°; c) 24 hr at 4.4° plus 24 hr at 10°; and d) 24 hr at 4.4° plus 48 hr at 10°.

Moisture loss was determined as weight loss during storage. Relative humidity ranged from 88 to 92% in cold-storage rooms. Fruit firmness was determined using a Chatillon (model DDP–5) penetrometer equipped with a 0.64-cm (0.25 in.) V-shaped chisel head, which was inserted to a depth of 0.64 cm at one flat side of the wedge-shaped strawberry. All berries were tested for firmness, averaging 24 per sample.

Bruising was scored as slight, moderate, or serious (slight = one bruise less than 0.64 cm^2 in area; moderate = one bruise greater than 0.64 cm^2, but less than 1.27 cm^2 in area, or 2 or more bruised areas affecting up to 1.27 cm^2 area accumulatively; serious = accumulative area greater than 1.27 cm^2). Berries visually free of bruising were scored as sound.

Cursory observations were made of all berries individually to determine appearance (freshness) differences, such as surface gloss, color, severity of tissue breakdown at sites of bruises, and wilting of sepals (caps).

The time/temperature profile developed from averaging air temperatures of 4 LD–3 shipments is shown in Table 1. Temperatures shown are those to which berries were exposed while enclosed within the environment of the LD–3. Berries were precooled to about 4.4°C prior to being placed in the LD–3. During transit, temperatures in the top area were generally higher than those recorded in the bottom area of the LD–3, starting when the LD–3 was loaded into the truck for transport to the airport. This difference increased rapidly from less than 1° at 10 hr to about 6° at 25 hr after loading in the LD–3. Temperatures increased only about 2° in the bottom, while increasing about 7° in the top area during this time period, then tended to stabilize during the 8-hr transatlantic flight.

The time and temperature regime of 24 hr at 4.4°C plus 24 hr at 10° was used to simulate export shipping conditions in the stationary test. The 4.4° temperature was about 3.0° less than the average shown in Table 1, but 4.4° is assumed to be the lowest feasible temperature that commercial operations are currently willing to maintain. The additional 24 hr at 10° simulated a reasonable distribution and marketing period at destination.

There was no significant difference in berry firmness due to packaging treatment, except when berries were held initially for 24 hr at 4.4°C plus 24 hr at 10° (Table 2). Berries held in PT2 lost significantly less weight than those in PT1 and PT3 in all simulated conditions.

Berries rated moderately and seriously

Table 2. Pulp firmness, weight loss, and unacceptable bruising of strawberries in 3 different packages when stored for different lengths of time at different temperatures.

Package treatment[z]	24 hr at 1.1°C plus						24 hr at 4.4°C plus					
	24 hr at 10°			48 hr at 10°			24 hr at 10°			48 hr at 10°		
	Firmness (N)	Weight loss (%)[y]	Unaccept. bruised[x] (%)	Firmness (N)	Weight loss (%)	Unaccept. bruised (%)	Firmness (N)	Weight loss (%)	Unaccept. bruised (%)	Firmness (N)	Weight loss (%)	Unaccept. bruised (%)
PT-1	3.11 a[w]	2.15 a	56 a	3.74 a	3.23 a	75 a	3.07 a	2.35 a	56 a	3.78 a	3.29 a	70 a
PT-2	3.60 a	0.87 b	54 a	4.05 a	1.16 b	68 a	3.51 b	0.81 b	59 a	3.96 a	1.07 b	71 a
PT-3	3.34 a	2.03 a	52 a	3.78 a	2.45 a	72 a	3.02 a	2.02 a	67 a	3.78 a	2.87 a	79 a

[z]See Fig. 1.
[y][Weight change (g)/fresh weight (g)] × 100.
[x]Moderate and severe bruising ratings were combined and judged unacceptable for marketing.
[w]Mean separation within columns by Duncan's multiple range test, 5% level.

bruised were judged to be unacceptable for marketing. The percentage of unmarketable berries for each PT was not affected by treatment (Table 2). In lots held 24 hr at 1.1 and 4.4°C plus 48 hr at 10°, there were considerably fewer marketable berries than in those held 24 hr at 10°. Deterioration of surface tissue at apparent sites of bruising was the most common cause of berries being rated as not acceptable after storage. Watery, dull, pinkish, slightly indented areas developed, although the berries were visually free of bruising when prepared for testing. Most of this bruising apparently occcurred during the picking operation, but was not visible until the berries were kept at 10°. No decay was detected at this final evaluation.

Freshness, based on visual subjective impressions, was not different among treatments at each of the time/temperature storage periods; however, berries held at 1.1°C for 24 hr plus 24 hr at 10° appeared fresher than those held at 4.4° for 24 hr plus 24 hr at 10° for each packaging treatment.

The ambient temperatures during the Florida strawberry season may consistently be in the 27°C range; therefore, it is important to precool strawberries to 4° and maintain that temperature until berries are loaded on board air freighters. Pulp temperatures may well approach 16° on arrival in Western Europe, even when berries are precooled to 4° prior to shipping. Therefore, berries should be handled as rapidly as possible at transfer points and during other operations when they are not held under controlled refrigeration. Berries shipped in PT2 should arrive in Western European markets with less weight loss than those shipped in PT1 or PT3.

Literature Cited

1. Anderson, R.E. and R.E. Hardenberg. 1959. Effect of various consumer baskets, film wraps, and crate liners on quality of strawberries. Proc. Amer. Soc. Hort. Sci. 74:394–400.
2. Miller, W.R. and A.J. Bongers. 1982. European preferences for sizing, packaging and unitizing selected fresh fruits and vegetables. USDA-ARS-NE Rpt. No. NRR- . (In press)
3. Moulton, J.E. 1947. The effect of pre-packaging and refrigeration of strawberries on the water loss, spoilage, vitamin C content, and sugar–acid ratio of the fruit. Proc. Amer. Soc. Hort. Sci. 50:263–268.

HortScience 18(3):312–313. 1983.

Cultivar Variation in Yield Components of Strawberries

J.F. Hancock[1], J.H. Siefker[2], and N.L. Schulte[2]

Department of Horticulture, Michigan State University, East Lansing, MI 48824

Additional index words. *Fragaria* X *ananassa*, matted rows

Abstract. **Differences were observed both within and between strawberry cultivars in the relative importance of yield components. Most cultivars had high coefficients among yield, crown density at harvest, and fruit number/crown, but there was variation among cultivars in the coefficients between yield and fruit weight.**

Several population and growth characteristics may influence strawberry yield, including density, yield/plant, fruit number/plant, fruit size, crowns/plant, and peduncles/plant (4, 7, 10, 11, 12). These have been shown to be under both genetic (1, 8) and environmental controls (2, 3, 4, 13).

Crown density is often the most critical determinant of total yield in a strawberry field, but fruit numbers and fruit size have also been shown to be important (3, 4). In this study, we examined the composition of yield in 12 strawberry cultivars that are grown in the eastern and midwestern United States. We were interested in whether the relative importance of different yield components vary across cultivars traditionally grown in matted rows.

Received for publication October 18, 1982. Journal paper No. 10761 of the Michigan State University Agricultural Experiment Station. This work was partially supported by a grant from the American Strawberry Growers Association, Inc. Discussions with James Flore, John Moon, and Marvin Pritts aided in the preparation of the manuscript. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Assistant Professor.

[2]Graduate Research Assistant.

The experiments were performed at the Sodus Horticultural Research Farm of Michigan State Univ. at Sodus. A complete description of the site has been reported previously (5).

On April 15 and 16, 1980, dormant, spring-dug plants of 12 cultivars were planted in 3-m plots at spacings of 45, 60, and 75 cm within rows and 1.5 m between rows. Flowers were removed in the first year and the plants were trained to 35-cm-wide matted rows. A randomized block design was used with 4 replicates of each treatment. The cultivars were grown according to conventional cultural practices (6).

In the first bearing year, fruit was picked and counted every 4–5 days and berry weights were determined from a randomly selected 25 fruits. Crown numbers were also counted in each of the matted rows immediately after harvest. Yield components were analyzed using the path-coefficient procedure of Wright (14), where path coefficients are calculated as standardized regression coefficients (9). Five variables were included in the analysis: 1) total yield; 2) crown numbers at planting; 3) crown numbers at harvest; 4) fruit numbers; and 5) mean fruit weight. The hypothesized causal relationships are: Crown numbers at planting, 1 → Crown numbers at harvest, 2 → Fruit number, 3 → Fruit weight, 4 → Total yield, 5. Crown numbers at harvest included original mother plants, branch crowns, and rooted runners. Cultivar means were calculated for each of the above-listed variables and these were compared using analysis of variance procedures. No attempt was made to measure daughter plant size and date of rooting, although there appeared to be a relationship between plant density and plant size.

There were significant differences among cultivars in crown number, fruit number, fruit weight, and yield (Table 1). Plots of 'Badgerbelle', 'Scarlet', and 'Stoplight' had significantly higher crown densities than did the other cultivars. 'Bounty' and 'Redchief' had the most fruits/plant, while 'Badgerbelle', 'Scarlet', and 'Stoplight' had the fewest. Fruit of 'Delite', 'Guardian', 'Holiday', and 'Scarlet' were the heaviest and those of 'Earliglow', 'Midway', and 'Redchief' were the lightest.

There was also substantial variation in path coefficients among cultivars (Table 2). 'Midway' and 'Badgerbelle' showed little relationship between initial and final crown numbers (P_{12}), while 'Delite', 'Earliglow', 'Raritan', and 'Scott' had significant associations. Initial crown numbers were not associated significantly with fruit weight (P_{14}) in 'Guardian', 'Holiday', 'Raritan', and 'Scarlet'. The coefficients between fruit number/crown and mean fruit weight (P_{34}) were negative in 'Badgerbelle', 'Bounty', and Scarlet', and positive in 'Earliglow' and 'Midway'. Initial crown numbers were associated significantly with fruit numbers/crown (P_{13}) in 'Delite', 'Scott', and 'Stoplight'. 'Badgerbelle', 'Delite', 'Earliglow', 'Guardian', 'Redchief', and 'Scott' had significant negative relationships between final crown density and fruit number/plant (P_{23}).

All the cultivars showed strong relationships between yield and initial crown numbers (P_{15}), final plant numbers (P_{25}), and fruit numbers (P_{35}). Only 'Bounty' and 'Scarlet' had significant coefficients between fruit weight and yield (P_{45}). The coefficient between fruit numbers and yield (P_{35}) was highest in 'Badgerbelle', 'Earliglow', 'Delite', 'Guardian', 'Midway', 'Redchief', 'Scarlet',