Quality of Supersweet Corn Film-overwrapped in Trays

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Abstract. Quality changes of supersweet corn (*Zea mays* L.) were monitored during storage at 1, 4, or 10C, unwrapped or wrapped in stretch or shrink film. Film-wrapping maintained freshness and reduced moisture loss better than lack of wrapping. Wrapping in shrink film resulted in lower O₂ and higher CO₂ concentrations within packages than wrapping with stretch film. Film-wrapping in shrink film maintained total soluble solids content better than stretch-wrapping or no wrapping.

The recommended storage and transit temperature for fresh sweet corn is 0C at 95% to 98% RH; its respiration rate is one of the highest of all fresh fruits and vegetables (Hardenburg et al., 1986). Storage for more than a few days results in serious deterioration and loss of tenderness and sweetness. The sugar content, which largely determines quality, decreases relatively slowly at ≈ 0C (Appleman and Arthur, 1919), being about one-fourth as rapid at 0C as at 10C (Evensen and Boyer, 1986). Denting is also an indication of loss of quality. A loss of 2% moisture from sweet corn may result in objectionable kernel denting (Sims et al., 1971). Long shanks and flag leaves should be trimmed before marketing because they induce denting of the kernels by drawing moisture from them (Showalter, 1967).

The advent of supersweet corn cultivars

(Rhodes et al., 1982), with sugar content increased from 3% to 5% for standard cultivars to 7% to 10% for new cultivars, has increased the sweetness of sweet corn drastically. Also, if handled properly, these new cultivars lose their sweetness more slowly during marketing than standard cultivars. Modified-atmosphere storage, i.e., adjusting gas composition and relative humidity in addition to refrigeration, is more advantageous than cooling alone (Kader, 1986), but it is costly. A less-costly method of modified-atmosphere storage is the use of plastic film to wrap produce (Ben-Yehoshua, 1985). Deak et al. (1987) reported that shrink-wrapping of sweet corn in bags and storing it at 10 or 20C and 65% and 55% RH, respectively, reduced the changes associated with senescence and postharvest deterioration relative to nonwrapped samples.

We determined the effects of two types of film wrapping on the quality of supersweet corn stored at low to moderate temperatures.

Fresh, bicolor 'Candy Store' (*su, se*) sweet corn was obtained from a local grower in Orange County, Fla., for three tests at bi-weekly intervals, initiated in late May. The corn was trimmed, packed, and placed in storage within 4 hr of harvest, without pre-cooling. Three treatments were used for each test: 1) Control-unhusked and unwrapped;

Fig. 1. Carbon dioxide concentrations (%) in atmosphere within the shrink-wrapped packages (O) and stretch-wrapped packages (□) stored at 1, 4, or 10C for 7, 14, or 21 days plus simulated retail display-5 days at 10C (●, ■). Differences between shrink- and stretch-wrapped significant at 1% for all storage temperatures.

2) stretch-wrapped-partially dehusked; 3) shrink-wrapped-partially dehusked. There were 14 packages per treatment in each test. All shanks were cut to at least 1 cm from the ear. The unwrapped corn was not cut at the silk end of the ear. Partially dehusked ears were obtained by pulling a window 2.5 to 4 cm wide of husks from the ears, as practiced commercially.

The corn was stored at 1, 4, or 10 ± 0.5C for 7, 14, or 21 days at 85% ± 5% RH, plus an additional 5 days at 10C to simulate retail display (SRD). Corn stored at 4 and

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Table 1. Effect of package on percent total soluble solids for corn stored at 1C for 7, 14, or 21 days or at 4 and 10C for 7 and 14 days, all at 85% $\pm$ 5% RH plus simulated retail display (SRD) for 5 days at 10C (three tests, 1988).^a

Treatment	Days in storage						Mean
	7	7 + SRD	14	14 + SRD	21	21 + SRD	
	Total soluble solids (%) ^b						
Control	14.3 b	11.8 b	12.7 b	10.5 b	14.4	12.9	12.8 b
Stretch-wrapped	14.0 c	11.6 b	12.4 b	10.5 b	14.5	12.9	12.7 b
Shrink-wrapped	14.6 a	12.4 a	13.4 a	11.8 a	14.5	13.0	13.3 a

^aMean separation within columns by Duncan's multiple range test, $P = 0.05$. Each datum is the mean of 18 samples.

^bThe initial value was 16.3%.

Fig. 2. Oxygen concentrations (%) in atmosphere within the shrink-wrapped packages (O) and stretch-wrapped packages (□) stored at 1, 4, or 10C for 7, 14, or 21 days plus simulated retail display-5 days at 10C (●, ■). Differences between shrink- and stretch-wrapped significant at 1% for all storage temperatures.

10C was only held for 14 days plus SRD.

The stretch-wrapped film (Crump Co., Daytona Beach, Fla.) was polyvinylchloride, nominal thickness of 0.015 mm with O₂ and CO₂ permeability of 800 and 3200 cm³/645 cm² per 24 hr per atm (23C at 50% RH), respectively, and moisture vapor transmission 13 g/645 cm² per 24 hr per atm based on ASTM procedures (information furnished by supplier). This film, with 16 machine-made pinholes per package, was applied over

the tray of corn, folded underneath, and placed on a hot plate for sealing. The shrink-wrapped film was a biaxially oriented, heat-shrinkable, copolymer film (Cryovac Division, W. R. Grace, Duncan, S.C.), 0.015 mm thick with O₂ and CO₂ permeabilities of 11,000 and 33,000 cm³/645 cm² per 24 hr per atm (23C at 50% RH), and moisture vapor transmission 1.5 g/545 cm² per 24 hr per atm based on ASTM procedures (information furnished by supplier). This film, with one pinhole per package made with a needle, was applied to the trays of corn by using a hot-wire sealer and a heat tunnel (Weldotron Corp., Piscataway, N.J.). Travel time through the tunnel was $\approx$ 7 sec at 163 to 177C.

Gas samples (O₂ and CO₂) were taken after 2, 3, 7, 14, and 21 days during storage and after SRD by inserting a hypodermic needle through the film and into the void space within the package to withdraw a 1-ml gas sample with a syringe. The samples were analyzed by means of a gas chromatograph equipped with a thermal conductivity detector.

At the inspections following 7, 14, 21 days of storage plus SRD, the ears of corn were completely stripped of leaves and silks before texture was measured. A Food-Testing System (Model 1132, Instron Corp., Canton, Mass.) was used to measure the puncture-resistance of a single kernel of corn by applying a load that was transmitted with a flat-ended penetrating pin (2 mm in diameter). Calibration was at 0 to 10 kg at a constant speed of 5 cm·min⁻¹. At each sampling, puncture measurements were made on 15 kernels (five kernels on three equally spaced rows around the ear and midway between the ends) on each of two ears per treatment. The measurement was the amount of force (Newtons) required to rupture the kernel pericarpium (Deak et al., 1987).

Juice was extracted from kernels of corn with a food press and poured into an S-ml centrifuge tube ($\approx$ 6 ml). The tubes were centrifuged for 10 min at 14,000 $\times$ g and the percentage of total soluble solids (TSS) in the supernatant measured on a refractometer (Model 10480, AO Scientific Instruments, Buffalo, N.Y.).

At each inspection, visual observations of the corn were made for denting, discoloration of husks and corn, microbial growth, and general appearance. Corn was considered unacceptable if husks were dry and brown or black and the kernels were dry and dented.

Data were statistically analyzed using

analysis of variance and Duncan's multiple range test.

Visual appearance. After storage at 1C, both the wrapped and nonwrapped corn were rated acceptable after 21 days of storage, but, after SRD, the unwrapped corn husks appeared drier. Where mechanical damage had occurred to corn during harvesting and packing, the damaged areas turned brown or black during SRD. At 4C, the wrapped and nonwrapped corn were rated acceptable after 7 days, but the wrapped corn stored for 14 days was fresher, greener, and showed less drying than nonwrapped corn. During SRD, the appearance of the corn deteriorated rapidly, particularly after 14 days of storage at 4C. Some slight denting of kernels was noted on the unwrapped corn. The appearance of all samples deteriorated rapidly at 10C. After 14 days of storage, denting was observed on the unwrapped corn and, to a lesser extent, on the stretch-wrapped corn. However, after 14 days plus SRD, denting was observed on all treatments, but more so with nonwrapped corn. The husks on the nonwrapped corn dried out and turned brown. Mold growth was observed on all treatments, particularly where damage had occurred. Damaged kernels of corn turned brown or black more rapidly at 10C than at other storage temperatures. Damaged kernels also turned brown or black and had more mold and/or decay when wrapped than when nonwrapped, presumably due to high relative humidity within the package. The wrapped corn stored for 7 days at 10C was barely acceptable visually, but appeared fresher than nonwrapped corn. In general, wrapped corn appeared fresher, less dried, and had less denting than nonwrapped corn; corn stored at 1C was in better condition than corn stored at 4 or 10C.

Atmospheric composition. The amount of CO₂ increased rapidly from 0% at time of packing to 2% to 8% after 2 days, depending on storage temperature, then stabilized (Fig. 1). There was a positive relation between storage temperature and CO₂ concentration. The atmosphere within the shrink wrap contained almost twice as much CO₂ as that within the perforated stretch wrap at all storage temperatures. By the end of SRD of corn initially stored at 1 or 4C, the amount of CO₂ increased rapidly and was about equal to that of corn initially stored at 10C. The amount of O₂ was lower for the shrink-wrapped corn than for stretch-wrapped corn for all storage conditions and lower after 10C than after 1 or 4C storage (Fig. 2).

Physical and chemical analysis. Textural quality of the corn generally decreased with increasing storage temperature and time, as indicated by the greater force required for penetration by the needle. After 7 days of storage plus SRD, it required slightly more force to rupture the kernels of the corn initially stored at 10C than at 1 or 4C storage. However, packaging method did not influence textural quality, even though wrapped corn appeared fresher and had less denting than nonwrapped corn (data not shown). This difference may be explained by the fact that storage rooms were maintained at 85% $\pm$

5% RH, and in the package RH was 95% to 100% (unpublished data).

After most storage times, corn that was shrink-wrapped had higher TSS content than either the nonwrapped corn or the corn that was stretch-wrapped (Table 1). However, this positive difference of $\approx 0.5\%$ most likely would not have affected eating quality. The TSS, initially 16.3%, decreased rapidly with increased storage temperature and time, except at 1C. At 10C storage, corn lost $\approx 47\%$ of its TSS content during 14 days of storage plus SRD, while corn stored for 21 days at 1C storage plus SRD lost only $\approx 22\%$.

Postharvest deterioration of 'Candy Store' supersweet corn was evident even with recommended postharvest handling practices of good temperature, relative humidity control, and packaging. A consistently low storage temperature (0 to 1C) and high relative humidity (95% to 100%) are the most important postharvest factors in maintaining quality of supersweet corn, just as with regular sweet corn. During relatively long storage periods of 14 to 21 days, storage at 1C was superior to 4 or 10C in maintaining such quality factors as TSS and freshness. If stored at 1C for 21 days plus SRD, 'Candy Store' supersweet corn will lose only $\approx 25\%$ of its TSS, i.e., from 16% to $\approx 12\%$.

The beneficial effect of modified-atmosphere within the package of sweet corn was not evident in this study, agreeing with earlier studies (Deak et al., 1987; Spalding et al., 1978). However, temperature had a major effect on atmospheric composition within the package. Film-wrapping maintained the freshness of sweet corn by maintaining a high relative humidity within the package, but also accelerated microbial growth in the presence of damaged husks or kernels of corn.

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