

EFFECT OF STORAGE TEMPERATURE, WRAPPING FILM AND STORAGE PERIOD ON SWEET CORN EAR BEHAVIOUR DURING STORAGE

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ABSTRACT

The present study was undertaken at the postharvest laboratory, Horticulture Research Institute, Giza and development of horticulture, Ain Shams University, during 2002, 2003 and 2004 seasons to evaluate storability and maintain the physical and visual quality of sweet corn ears of Endeavor F₁ hybrid were picked at 25 day after silking (the optimum harvest stage) using cleaning stretch film and polyolefin film wrapping films at 0 and 5°C storage temperature at different storage periods. The main results showed that holding the ears at 5°C storage temperature increased the weight loss percent, denting, decay and reduced the visual quality values compared to holding at 0°C. Carbon dioxide percent inside the package was higher when ears were stored at 5°C compared to 0°C and when ears were wrapped with polyolefin film. Wrapping films reduced the weight loss percent of ears compared to unwrapping, the lowest values were by polyolefin film. In addition, wrapping with polyolefin film decreased kernel denting but the decay value was higher with polyolefin film compared to cleaning stretch film. Also, unwrapped ears had higher total sugar percent compared to ears wrapped with polyolefin film or cleaning stretch film. Cleaning stretch film, generally, gave best visual appearance during storage. Wrapping ears with polyolefin film maintained the sucrose percent higher than those of cleaning stretch film or check treatments. Sweet corn ears held at 0°C had higher percent of non-reducing sugars compared to 5°C. Storing ears at 0°C maintained higher TSS compared to 5°C. With prolonging the storage period, weight loss, decay, denting and discoloration for cut ends were increased. But, visual quality, TSS, total and non-reducing sugars were decreased.

Keywords: Sweet corn, Storage temperature, Storage period, Wrapping films, TSS, Sugars, Visual quality.

INTRODUCTION

Fresh sweet corn (*Zea mays* L. var. *Saccharata*) is a recently promising annual vegetable crop grown in Egypt. Sweet corn eating quality is associated with the consumer performance of kernel flavour, texture and aroma. Sweetness in sweet corn is closely related to kernel sucrose content and constituents most of what the average consumer perceives as flavour. The fresh sweet corn ear is a perishable food product prone to fast post-harvest deterioration caused by kernel desiccation, loss of sweetness and moisture, husk discoloration and development of pathogens. Several techniques are used to preserve post-harvest quality. These techniques provide presumed optimal temperature, humidity and atmospheric modification. In this respect, Showalter (1967) found that ear weight loss for ears with no trimming were rapid and averaged nearly 22% after 6 days

storage. Film packaging of husked ears provided protection against kernel denting and moisture loss equal to that of ears in the husk with shanks and flags removed. Moreover, Hardenburg (1971) stated that in a tight package all the free oxygen is used in a short time, respiration becomes an aerobic and alcohol and carbon dioxide are produced. This can be demonstrated easily by sealing sweet corn in a pliofilm bag. In a tight bag free oxygen is quickly used up but CO₂ is still being produced. Injurious CO₂ concentrations of 20% or higher are frequently found in tight packages at root temperature.

Ben-Yehoshua (1985), on seal-packaging in plastic film, stated that the conventional practice of waxing could be eliminated, since its function of preventing shrinkage and reducing weight loss would be increased 5 to 10 times by the film. Besides, it offers an attractive appearance and characteristics. Deak *et al.* (1987), on sweet corn, found that wrapping essentially eliminated moisture loss and resulted in elevated carbon dioxide and decreased oxygen concentrations within packages. These effects, together with refrigeration markedly reduced the changes associated with senescence and post-harvest deterioration, and hence resulted in at least a three-fold extension in shelf life. Risse and McDonald (1990), on a super sweet corn cultivar, found that film-wrapping maintained freshness and reduced moisture loss better than lack wrapping. Wrapping in shrink film resulted in lower O₂ and higher CO₂ concentrations with packages than wrapping with cleaning stretch film. Film wrapping in shrink film maintained total soluble solids content better than stretch-wrapping or no wrapping. Rodov *et al.* (2000) stated that retail packages of sweet corn (film-wrapped trays containing a pair of trimmed cobs) were stored at 2°C within additional plastic liners. The modified atmosphere, generated in these nested packages by corn respiration, complied with the recommended range 5-10 kPa CO₂ and inhibited mould growth. Opening the liner after transfer to non-refrigerated conditions compensated for the respiration rise caused by elevated temperature maintained the desirable modified atmosphere range and prevented fermentation and off-flavour development.

Concerning storage temperature and storage period, Cherry (1974), on sweet corn, found that grain sucrose content decreased most rapidly with the conversion of starch during the first 24 h of post-harvest storage at 25°C. Evenson and Boyer (1986) evaluated sweet corn for sensory quality and carbohydrate composition at harvest and after storage at 0°C or 10°C for two weeks. They found that total sugars (reducing sugars and sucrose) declined more quickly during storage at 10°C than at 0°C in all cultivars. In addition, Lee *et al.* (1987a) stated that at the temperature below 10°C, contents of soluble solids and total sugars and flavour rate of sweet corn were not changed significantly, but at the temperature higher than 15°C they decreased as storage temperatures increased and duration extended. Moreover, Deak *et al.* (1987) mentioned that unwrapped de-husked white corn held at 20°C dried within 3-4 days and was unpalatable. Unwrapped yellow corn with husks intact stored at the same temperature dried within two weeks by showing little spoilage. Shrink-wrapped de-husked white ears showed visible signs of microbial growth within five days and yellow ears with

husks showed deterioration within ten days at 20°C. Kernels became discoloured, slimy and moldy in appearance. Shrink-wrapped white corn stored at 10°C developed a sweet off-odor and spoiled after two weeks storage. Shrink-wrapped yellow corn stored at 10°C remained in a good condition for four weeks. Unwrapped de-husked white corn lost its moisture at a much more rapid rate when stored at 20°C compared to storage at 10°C.

Risse and McDonald (1990) found that the visual appearance was rated acceptable with both wrapped and non-wrapped corn up to 21 days of storage at 1°C. Whereas, at 4°C the wrapped and unwrapped corn were rated acceptable after seven days, denting was observed on the unwrapped corn and to a lesser extent on the stretch wrapped corn. In general, wrapped corn appeared fresher; less dried and had less denting than non-wrapped. The amount of CO₂ increased rapidly from 0% at time of packaging to 2-8% after 2 days, depending on the storage temperature, then stabilized. There was a positive relation between storage temperature and CO₂ concentration. After most storage times, corn that was shrink wrapped had higher TSS content than either the non-wrapped corn or the corn that was stretch-wrapped. Aharoni *et al.* (1996) mentioned that the packages affected the amount of CO₂ and O₂ measured within them during 12-day storage at 1°C and additional two days at 20°C as a shelf life. The amount of CO₂ and O₂ remained almost constant during 12 days storage. During the two days shelf life, the CO₂ significantly increased to 15%, while O₂ significantly decreased to 3%.

This study was, therefore, performed to determine the optimum storage temperature and packing materials of ears as well as delaying the deterioration of ears during storage.

MATERIALS AND METHODS

Seeds of sweet corn endeavor F₁ hybrid (sh₂) obtained from Asgrow Co. USA., was sown in 19 August during 2002 and 2003 at Qaha Experimental Station, Vegetables Research Department, Ministry of Agriculture.

Seeds of sweet corn were sown (Direct seed) in hills spaced 25 cm apart on rows of 70 cm. The recommended culture practices of sweet corn production were followed. Ears were harvested on 18, 15 November in the first and second seasons, respectively, after 25 days from silking in milky stage when the pollination silks are dried and the kernels are still immature. The husk leaves remain tigh and have a good green appearance. The kernels are plump and appear milky, and not doughy, when squeezed (the optimum harvest date for this hybrid, El-Seidy, 2006). Ears were picked and placed on Plastic crates and transported in a refrigerated truck at (0°C ± 2) immediately to the postharvest laboratory, Horticulture Research Institute, Giza. Within 1.5h, two wrapping films were used (cleaning stretch film and polyolefin film) manufactured by (Huckster packing supply Co. LTD. USA.). Their physical properties are summarized in Table (1).

Both polyolefin film and cleaning stretch film classified as a special material for food packing are using in food packing (both wrapping films were used according to requirements of EEC council directive 90/128/EEC, Barkai-

Golden, 1990, and therefore they considered as environment-friendly packing films.

Table (1): physical properties of the two used films.

Property	Polyolefin film	Cleaning stretch film
Thickness (micron)	20	0.90 (90GA)
Premmapelity :		
Oxygen (ml/m ² 24h atm)	11000	17000
Carbon dioxide (ml/m ² 24h atm)	7000	120000
Color	Clear	Clear
Grade (using for...)	Food packing	Food packing

Uniform ears as uniform as possible in ears diameter (46mm) and length (16cm) in two seasons of all harvesting were hydro-cooled to approximately (0°C) with ice cold water after 3 hours from picking, then dried by air plower and kept overnight at 0°C with 95-98% RH up to the following morning.

The shanks of ears were trimmed at least 1 cm from the ear base, the silk ends were cut to the end of ears and the outer leaves were removed, maintaining the leaves, which were attached to the ear with pulling a window of 2.5 to 4cm wide of husks from the ears as practiced commercially. Then ears were placed on a foam tray (two ears/try) and over wrapped with cleaning stretch film (0.9 micron), low-density polyolefin film (20micron), or unwrapped (check treatment). Wrapped and unwrapped ears were weight, lapped and placed in carton boxes (two trays/box) then stored at either 0°C and 95-98% RH, 5°C and 95-98% RH storage conditions. Four trays samples from the stored ears were taken, each with two ears, at 5, 10, 15 and 20 days from storage and subsequently transferred to 10°C (simulated retail display) for 24 hours to record the physical and chemical characters of ears to check the storability during the storage period and to record the following physical and chemical changes for each treatments:

A. Physical changes:

(1) Weight loss% was expressed as the percentage of loss from the initial weight according to the following equation:

$$\text{Weight loss\%} = [\text{Initial weight} - \text{weight of ears at sampling treatment} / \text{Initial weight of ears}] \times 100$$

(2) Denting was determined as a score system of 1 = None; 2 = Slight; 3 = Moderate; 4 = moderately severe; 5 = severe.

(3) Decay were determined as a score system of 1 = None; 2 = Slight; 3 = Moderate; 4 = moderately severe; 5 = severe.

Decay incidence was evaluated separately for the flag leaves, cut ends and kernels, once mycelia appeared on each of them, and was expressed as a score system for the total amount of ears that were reated decayed.

(4) Visual quality general appearance was graded on a scale of 1-9, with 9 = excellent quality, 7 = good, 5 = fair, 3 = poor and 1 = unusable (dry and brown flag leaves associated with fungal growth).

This scale depends on the morphological defects such as wilted husks, color changes of husk and kernels, and presence of physiological defects.

B. Chemical changes:

- (1) Total sugar and non-reducing sugars (sucrose) percent were determined colorimetrically using spectrophotometer model 6305 UV/visible range with 520 nm wave length according to Somogyi (1952) and Nelson (1974).
 - (2) Dry matter one hundred gram of fresh kernels were weighed and then dried at 70°C until a constant weight was obtained, the dry matter was then calculated.
 - (3) Total soluble solids (TSS) were measured with a hand refractometer
- C. Gases:** Carbon dioxide inside package was determined in (0) time and during storage every 5 days until the end of storage period by using CO₂ analyzer Mod. 902 D.

The experimental design: Completely randomised design in a factorial experiment with three factors (storage temperature, wrapping film and the storage period), in four replications, was used in this experiment. Statistical analysis was performed according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

1. Physical characters

1.1. Weight loss %

Data presented in Table (2) showed that the weight loss percent of ears increased significantly when stored at 5°C compared to at 0°C in both seasons. As for wrapping film, weight loss percent of ears decreased significantly by using wrapping film and the most decreasing was by polyolefin film. This result was true for both seasons. Similar results were reported by Showalter (1967), Ben-Yehoshua (1985), Risse and McDonald (1990), Othieno *et al.* (1995) and Aharoni *et al.* (1996). They reported that using different kinds of over-wrapping film decreased the moisture and weight losses from the ears.

Concerning the storage period, the weight loss percent of ears increased with prolonging the storage period in both seasons. Regarding the interactions, the lowest significant values of weight loss during storage were observed for sweet corn ears wrapped with polyolefin film at any storage period, whereas the highest values of loss in weight were noticed in sweet corn ears stored up to 20 days at 5°C without wrapping (check treatment). These results were true in both seasons. This highest weight loss may be attributed to the highest transpiration as well as respiration rates under the higher temperature (5°C) in the unwrapped sweet corn ears at any storage period compared to those held at 0°C and wrapped with polyolefin film.

1.2. Denting

Data in Table (3) indicated that denting of kernels increased with increasing the storage temperature, regardless of wrapping or storage period in the two seasons. Wrapping with polyolefin film decreased denting significantly compared to cleaning stretch film or check treatments, irrespective of storage temperature or period in both seasons. Regarding the storage period, denting increased with prolonging the storage period, regardless of wrapping or storage temperature.

Table (2): Effect of storage temperature (at RH % = 95-98%), wrapping film and storage period on weight loss% of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days					
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean
0	Stretch	0.00	1.79	2.25	3.09	4.19	2.26	0.00	1.68	2.29	3.09	3.93	2.19
	P.O.	0.00	0.57	0.58	0.80	1.09	0.60	0.00	0.48	0.63	0.78	1.26	0.63
	Check	0.00	6.92	9.64	11.79	16.13	8.89	0.00	7.06	9.54	12.89	14.92	8.88
	Mean	0.00	3.09	4.16	5.23	7.14	3.92	0.00	3.07	4.15	5.59	6.70	3.90
5	Stretch	0.00	1.91	2.47	3.87	5.21	2.69	0.00	1.94	2.57	4.02	4.85	2.68
	P.O.	0.00	0.67	0.79	0.95	1.27	0.73	0.00	0.67	0.77	1.15	1.18	0.75
	Check	0.00	7.57	9.94	14.13	19.84	10.29	0.00	7.91	10.90	15.19	21.44	11.09
	Mean	0.00	3.38	4.40	6.32	8.77	4.57	0.00	3.51	4.75	6.79	9.16	4.84
Mean	Stretch	0.00	1.85	2.36	3.48	4.70	2.48	0.00	1.81	2.43	3.56	4.39	2.44
	P.O.	0.00	0.62	0.69	0.88	1.18	0.67	0.00	0.57	0.70	0.97	1.22	0.69
	Check	0.00	7.24	7.79	12.96	17.99	9.59	0.00	7.49	10.22	14.04	18.18	9.99
	Mean	0.00	3.24	4.28	5.77	7.96	4.57	0.00	3.29	4.45	6.19	7.93	4.57
LSD at 5% level forTemp (T)		0.21						0.29					
Film (F)		0.26						0.35					
T x F		0.37						0.49					
Storage period (S)		0.33						0.45					
T x S		0.47						0.64					
F x S		0.58						0.79					
T x F x S		0.82						1.12					

P.O. = polyolefin film

Table (3): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on denting (score values) of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days						
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean	
0	Stretch	1.00	1.00	1.00	1.50	2.00	1.30	1.00	1.00	1.00	1.50	2.25	1.35	
	P.O.	1.00	1.00	1.00	1.00	2.00	1.20	1.00	1.00	1.00	1.00	2.00	1.20	
	Check	1.00	1.25	1.75	2.50	3.75	2.05	1.00	1.25	2.00	2.75	4.00	2.20	
	Mean	1.00	1.08	1.25	1.67	2.58	1.52	1.00	1.08	1.33	1.75	2.75	1.58	
5	Stretch	1.00	1.00	1.50	2.25	3.75	1.90	1.00	1.00	1.50	2.00	3.50	1.80	
	P.O.	1.00	1.00	1.00	1.00	2.75	1.35	1.00	1.00	1.00	1.00	3.00	1.40	
	Check	1.00	1.75	2.75	3.75	5.00	2.85	1.00	1.50	3.00	4.00	5.00	2.90	
	Mean	1.00	1.25	1.75	2.33	3.83	2.03	1.00	1.08	1.33	1.75	2.75	2.03	
Mean	Stretch	1.00	1.00	1.25	1.87	2.87	1.60	1.00	1.00	1.25	1.75	2.87	1.57	
	P.O.	1.00	1.00	1.00	1.00	2.37	1.27	1.00	1.00	1.00	1.00	2.50	1.30	
	Check	1.00	1.50	2.25	3.12	4.37	2.45	1.00	1.37	2.50	3.37	4.50	2.55	
	Mean	1.00	1.17	1.50	2.00	3.21		1.00	1.17	1.83	2.33	3.83		
LSD at 5% level for Temp (T)			0.12						0.09					
Film (F)			0.15						0.12					
T x F			0.21						0.16					
Storage period (S)			0.19						0.15					
T x S			0.27						0.21					
F x S			0.33						0.26					
T x F x S			NS						0.37					

Denting score: 1: none, 2: slight, 3: moderate, 4: moderately severe, 5: severe.

P.O. = polyolefin film

As for interactions, the highest value of denting was recorded in unwrapped ears held at 5°C at 20 day storage period. While the lowest kernel denting values were recorded in ears wrapped with polyolefin film held at any storage period. These results were true in both seasons. The recorded denting values may due to highest loss of moisture content in check ears held at the higher temperature after 20 days of storage.

1.3. Decay

As shown in Table (4), the decay increased with increasing the storage temperature in the two studied seasons, regardless wrapping or storage period. Ears stored at 5°C temperature expressed higher decay values than the ears held at 0°C temperature. As for wrapping film, polyolefin film increased the value of decay significantly when compared with cleaning stretch film or check treatment. This was true in the two studied seasons, regardless storage temperature or period. Cleaning stretch film recorded, in general, the lowest value of decay. Similar results were reported by Aharoni *et al.* (1996). Regarding the storage period, the decay was increased with lengthening the storage period. As for the interaction, the highest value of decay was recorded, in general, in ears wrapped with polyolefin film in both studied seasons. However, the interaction among storage temperature, wrapping and storage period was significant in both seasons.

1.4. Visual quality

Data shown in Table (5) indicated that visual quality score of ears was higher during storage at 0°C compared to those held at 5°C, irrespective of wrapping or storage period in both seasons. These results are in agreement with those of Risse and McDonald (1990). Wrapping the sweet corn ears with cleaning stretch film resulted, in general, in the best visual appearance compared to other wrapping treatments. The check (unwrapped ears) had the lowest visual quality scores in both seasons. These results were true regardless of storage temperature or period. Similar results were reported by Showalter (1967), Ben-Yehoshua (1985), Deak *et al.* (1987), Makino and Hirata (1997) and Rodov *et al.* (2000), who found that film packaging maintained freshness, reduced toughening, weight loss, microbial spoilage, moisture loss, senescence and denting, the parameters which affect positively the visual quality. Regarding the storage period, data showed that visual quality was decreased with extending the storage period. Concerning the interactions, sweet corn wrapped with cleaning stretch film showed the highest visual quality score during storage at 0°C up to 20 days compared to other combination treatments in both seasons, however, the significance was true for one season.

1.5. CO₂ percent inside the package

Data presented in Table (6) showed that CO₂ percent inside the packages was higher when ears were stored at 5°C compared to 0°C, irrespective of wrapping film or storage period, in both seasons. Wrapping ears with polyolefin film or cleaning stretch film increased the CO₂ percent inside the package compared with unwrapping check treatment. In addition, wrapping with polyolefin film gave significantly the highest CO₂ values.

Table (4): Effect of storage temperature (at RH % = 95-98%), wrapping film and storage period on decay (score values) of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days					
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean
0	Stretch	1.00	1.00	1.25	1.25	2.00	1.30	1.00	1.00	1.00	1.25	2.00	1.25
	P.O.	1.00	1.00	2.00	2.75	2.75	1.90	1.00	1.00	2.00	2.75	3.00	1.95
	Check	1.00	1.00	1.00	3.00	3.50	1.90	1.00	1.00	1.00	3.00	3.75	1.95
	Mean	1.00	1.00	1.42	2.33	2.75	1.70	1.00	1.00	1.33	2.33	2.92	1.72
5	Stretch	1.00	1.25	1.00	2.00	3.75	1.80	1.00	1.00	1.00	2.00	4.00	1.80
	P.O.	1.00	1.00	2.00	3.00	4.25	2.25	1.00	1.00	2.00	3.00	4.25	2.25
	Check	1.00	1.00	1.00	2.50	3.00	1.70	1.00	1.00	1.00	2.50	3.50	1.80
	Mean	1.00	1.08	1.33	2.50	3.67	1.92	1.00	1.00	1.33	2.50	3.92	1.95
Mean	Stretch	1.00	1.12	1.12	1.62	2.87	1.55	1.00	1.00	1.00	1.62	3.00	1.52
	P.O.	1.00	1.00	2.00	2.87	3.50	2.07	1.00	1.00	2.00	2.87	3.62	2.10
	Check	1.00	1.00	1.00	2.75	3.25	1.80	1.00	1.00	1.00	2.75	3.62	1.52
	Mean	1.00	1.04	1.37	2.42	3.21		1.00	1.00	1.33	2.42	3.42	

LSD at 5% level for Temp (T)	0.16	0.08
Film (F)	0.14	0.10
T x F	0.20	0.14
Storage period (S)	0.18	0.13
T x S	0.26	0.18
F x S	0.32	0.22
T x F x S	0.45	0.31

Decay score: 1: none, 2: slight, 3: moderate, 4: moderately severe, 5: severe.

P.O. = polyolefin film

Table (5): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on visual quality (score values) of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days					
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean
0	Stretch	9.00	9.00	9.00	9.00	8.50	8.85	9.00	8.50	6.50	5.00	4.75	6.75
	P.O.	9.00	9.00	8.75	7.25	6.50	8.10	9.00	5.50	4.25	3.75	1.00	4.70
	Check	9.00	6.00	4.00	3.00	1.00	4.60	9.00	5.00	3.50	3.25	2.50	4.65
	Mean	9.00	8.00	7.25	6.42	5.25	7.18	9.00	6.33	4.75	4.00	2.75	5.37
5	Stretch	9.00	7.00	5.00	4.00	2.00	5.75	9.00	7.00	5.50	4.25	3.25	5.80
	P.O.	9.00	8.50	6.00	5.00	2.50	6.20	9.00	5.00	3.00	2.50	1.00	4.10
	Check	9.00	5.00	3.00	2.50	1.00	4.10	9.00	4.50	3.25	1.50	1.00	3.85
	Mean	9.00	6.83	4.83	4.00	2.08	5.35	9.00	5.50	3.92	2.75	1.75	4.58
Mean	Stretch	9.00	8.00	7.25	6.75	5.50	7.30	9.00	7.75	6.00	4.62	4.00	6.27
	P.O.	9.00	8.75	7.37	6.12	4.50	7.15	9.00	5.25	3.62	3.12	1.00	4.40
	Check	9.00	5.50	3.50	2.75	1.00	4.35	9.00	4.75	3.37	2.37	1.75	4.25
	Mean	9.00	7.40	6.04	5.21	3.67		9.00	5.92	4.33	3.37	2.25	
LSD at 5% level for Temp (T)		0.29						0.30					
Film (F)		0.36						0.37					
T x F		0.51						NS					
Storage period (S)		0.46						0.48					
T x S		0.65						NS					
F x S		0.80						0.83					
T x F x S		1.13						NS					

Visual quality score: 9: excellent, 7: good, 5: fair, 3: poor and 1: unsolable.

P.O. = polyolefin film

Table (6): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on CO₂% inside package of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days						
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean	
0	Stretch	0.03	3.90	4.52	4.57	4.85	3.58	0.03	3.85	4.11	4.32	4.50	3.36	
	P.O.	0.03	6.70	6.80	8.57	9.05	6.23	0.03	6.45	7.20	8.45	8.90	6.21	
	Check	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
	Mean	0.03	3.54	3.78	4.39	4.64	3.28	0.03	3.44	3.78	4.27	4.48	3.20	
5	Stretch	0.03	4.01	4.50	4.87	5.00	3.68	0.03	3.95	4.10	4.52	4.70	3.46	
	P.O.	0.03	9.15	9.22	9.47	10.35	7.65	0.03	8.12	9.97	10.39	10.57	7.82	
	Check	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
	Mean	0.03	4.39	4.58	4.79	5.13	3.79	0.03	4.03	4.70	4.98	5.10	3.77	
Mean	Stretch	0.03	3.96	4.51	4.72	4.92	3.63	0.03	3.90	4.10	4.42	4.60	3.41	
	P.O.	0.03	7.92	8.01	9.02	9.70	6.94	0.03	7.28	8.58	9.42	9.73	7.01	
	Check	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
	Mean	0.03	3.97	4.18	4.59	4.88		0.03	3.74	4.24	4.62	4.79		
LSD at 5% level for Temp (T)			0.17						0.13					
Film (F)			0.21						0.16					
T x F			0.30						0.23					
Storage period (S)			0.27						0.21					
T x S			0.39						0.29					
F x S			0.48						0.36					
T x F x S			0.67						0.51					

P.O. = polyolefin film

Similar results were reported by Hardenburg (1971), Deak *et al.* (1987), Risse and McDonald (1990), Aharoni *et al.* (1996), Makino and Hirata (1997) and Rodov *et al.* (2000), who found that using different kinds of films in packaging sweet corn generated modified atmosphere inside the package by elevating CO₂ amount and decreasing the amount of free oxygen. As for storage period, CO₂ percent in the package increased during storage by extending the storage period where the highest percent of CO₂ was found after 20+1 days. Concerning the first order interactions, the highest CO₂ percent inside package during storage was produced by sweet corn ears wrapped with polyolefin film at 5°C, prolonging the storage period at 5°C up to 20+1 days or wrapping with polyolefin film up to 20 days. For interaction among temperature, wrapping film and storage period, the sweet corn ears wrapped with polyolefin film after 20+1 days storage at 5°C produced the highest percent of CO₂ inside the package. These results were true in both seasons.

2. Chemical analyses

2.1. Total sugar percent

Data presented in Table (7) showed that there was no significant difference in total sugar percent of sweet corn ears stored at 0 and 5°C in both seasons. These results were true regardless of wrapping film or storage period. As respecting the wrapping film, the unwrapped ears had the highest value of total sugar percent compared to other wrapping treatments, whereas those wrapped with cleaning stretch film had the lowest value. As for storage period, it was noticed that total sugar percent decreased with prolonging the storage period in both seasons. These results were true irrespective of storage temperature. Similar results were reported by Winter *et al.* (1955), Evenson and Boyer (1986), Lee *et al.* (1987b), and Olsen *et al.* (1990), who found that total sugar concentration was affected by storage time. Concerning the interaction, the combination between storage temperatures and wrapping film showed that check (unwrapped ears) held at 5°C contained the highest value of total sugars, in the two studied seasons. The interaction between storage period and temperature was not significant in the two studied seasons. The interaction among temperature, film and storage period showed that the highest value of total sugars after 20+1 days were found with unwrapped ears (check) stored at 5°C.

2.2. Non-reducing sugars (sucrose) percent

Data shown in Table (8) indicated that sweet corn ears held at 0°C had higher percent of non-reducing sugars in both tested seasons. Concerning the wrapping film, data showed that polyolefin film increased the value of non-reducing sugars in kernels of sweet corn ears in both seasons, this was true irrespective of storage temperature or period.

Concerning the storage period, the sucrose percent decreased significantly with lengthening the storage period, the lowest values were detected after 20+1 days. This was true during both seasons, regardless of wrapping film or storage temperature. These results are in agreement with those reported by Cherry (1974), Garwood *et al.* (1976), Carey *et al.* (1982), Evenson and Boyer (1986) and Olsen *et al.* (1990), who found that sucrose content decreased rapidly during storage.

Table (7): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on total sugars % (g/100 g fresh weight) of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days					
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean
0	Stretch	4.56	4.32	4.14	3.90	3.65	4.11	4.76	4.80	4.69	4.22	4.02	4.50
	P.O.	4.56	4.81	4.70	4.46	4.20	4.55	4.76	4.80	4.74	4.27	4.08	4.53
	Check	4.56	4.59	4.40	3.89	2.97	4.08	4.76	4.82	4.27	4.00	3.72	4.31
	Mean	4.56	4.57	4.41	4.08	3.61	4.25	4.76	4.81	4.57	4.17	3.94	4.45
5	Stretch	4.56	4.80	4.35	3.77	3.60	4.22	4.76	4.68	4.33	4.80	3.20	4.16
	P.O.	4.56	4.75	4.09	3.95	3.74	4.22	4.76	4.63	4.37	4.01	3.42	4.24
	Check	4.56	4.74	4.36	4.82	5.80	4.86	4.76	4.77	4.17	5.77	6.07	5.11
	Mean	4.56	4.76	4.27	4.18	4.38	4.43	4.76	4.69	4.29	4.53	4.23	4.50
Mean	Stretch	4.56	4.56	4.24	3.84	3.62	4.16	4.76	4.74	4.51	4.01	3.61	4.33
	P.O.	4.56	4.78	4.39	4.21	3.97	4.38	4.76	4.72	4.55	4.14	3.75	4.39
	Check	4.56	4.66	4.38	4.36	4.39	4.47	4.76	4.80	4.22	4.99	4.89	4.71
	Mean	4.56	4.67	4.34	4.13	3.99		4.76	4.75	4.43	4.34	4.09	

LSD at 5% level for Temp (T)

NS

NS

Film (F)

0.28

0.31

T x F

0.39

0.43

Storage period (S)

0.36

0.39

T x S

NS

NS

F x S

NS

0.69

T x F x S

0.88

0.97

P.O. = polyolefin film

Table (8): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on non-reducing sugars% (sucrose) (g/100 g fresh weight) of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days						
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean	
0	Stretch	3.85	3.59	3.11	2.79	1.99	3.07	3.93	3.60	3.46	3.17	2.01	3.23	
	P.O.	3.85	3.67	3.41	3.16	2.54	3.32	3.93	3.79	3.56	3.01	2.66	3.39	
	Check	3.85	3.38	2.86	2.42	1.83	2.87	3.93	3.43	3.36	3.02	1.61	3.07	
	Mean	3.85	3.55	3.12	2.79	2.12	3.09	3.93	3.61	3.46	3.07	2.09	3.23	
5	Stretch	3.85	3.67	3.04	2.88	2.34	3.16	3.93	3.65	3.23	2.83	2.25	3.19	
	P.O.	3.85	3.71	3.34	2.80	2.42	3.22	3.93	3.74	3.54	2.83	2.57	3.32	
	Check	3.85	3.65	2.20	1.97	1.82	2.69	3.93	3.41	2.83	2.32	1.88	2.87	
	Mean	3.85	3.67	2.86	2.55	2.19	3.03	3.93	3.60	3.20	2.66	2.23	3.12	
Mean	Stretch	3.85	3.63	3.07	2.83	2.17	3.11	3.93	3.62	3.34	3.00	2.13	3.20	
	P.O.	3.85	3.69	3.37	2.98	2.48	3.27	3.93	3.76	3.55	2.92	2.61	3.35	
	Check	3.85	3.51	2.53	2.19	1.83	2.78	3.93	3.42	3.09	2.67	1.74	2.97	
	Mean	3.85	3.61	2.99	2.67	2.16		3.93	3.60	3.33	2.86	2.16		
LSD at 5% level forTemp (T)			NS						NS					
Film (F)			0.14						0.17					
T x F			NS						NS					
Storage period (S)			0.18						0.22					
T x S			NS						NS					
F x S			0.31						NS					
T x F x S			NS						NS					

P.O. = polyolefin film

The interactions among storage temperature, wrapping film and storage period, were not statistically significant in both seasons, with one exceptional, i.e., the interaction between wrapping film and storage period. Wrapping in polyolefin film caused generally highest values of non-reducing sugars at any storage period. Such effect was significant in the first season only.

2.5. Total soluble solids (TSS) percent

Data presented in Table (9) showed that TSS % was higher in kernels held at 0°C compared to those stored at 5°C during storage, irrespective of wrapping film or storage period. Wrapping with cleaning stretch film or polyolefin film decreased kernel's TSS % compared to check treatment. But the difference was not significant in the second season. Concerning the storage period, TSS % was gradually decreased by prolonging the storage period. The lowest values were recorded at 20+1 days from storage, regardless of wrapping film or storage temperature. Similar results were reported by Lee *et al.* (1987b) and Risse and McDonald (1990). Regarding the interactions, the lowest TSS % was recorded in kernels wrapped with either cleaning stretch film or polyolefin film after 20+1 days storage at 5°C, in both seasons.

2.6. Dry matter percent

Data in Table (10) showed that no significant difference was found in dry matter percent in kernels kept at 0 and 5°C. On the other hand, kernels of check treatment contained the highest dry matter percent followed, by polyolefin film then cleaning stretch film. This was true, regardless of storage temperature or period. In addition, the dry matter % increased with increasing the storage period up to 15+1 days in both studied seasons. The combination between the wrapping film and storage period was significant in both seasons.

The obtained results indicated that kernels of unwrapped ears had the highest value of dry matter after 20+1 days from storage followed by those wrapped in polyolefin film then cleaning stretch film.

It could be concluded from the previously mentioned results that the total sugars and sucrose were not significantly affected by storage temperature. This might be due to the high initial sugar content in the sweet corn kernels and the loss in sugar content was insignificantly observed. The unwrapped ears (check treatment) were the highest in total sugar values comparing to wrapping films. This result might be due to the high and rapid moisture loss in the kernels of check treatment compared to wrapped ones. These results agree with those of Showalter (1967), Hardenburg (1971), Deak *et al.* (1987), Risse and McDonald (1990), Othieno *et al.* (1995), Aharoni *et al.* (1996), Makino and Hirata (1997) and Aharoni *et al.* (1997). On the Contrary, polyolefin film and cleaning stretch film maintained higher sucrose percent compared to check treatment, this may be due to that wrapping film reduced the loss of water and reduced the gas exchangeable creating a modified atmosphere which decrease the rate of respiration and hence the loss of sucrose during storage. Similar results were reported by Hardenburg (1971), Deak *et al.* (1987), Risse and McDonald (1990) and Aharoni *et al.* (1996).

Table (9): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on TSS % of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003						2003/2004						
		days						days						
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean	
0	Stretch	13.30	12.00	11.50	11.25	10.75	11.76	13.35	11.75	12.75	10.75	11.00	11.92	
	P.O.	13.30	11.75	12.50	10.00	9.87	11.48	13.35	13.00	12.00	10.00	10.25	11.72	
	Check	13.30	11.75	11.87	12.50	11.62	12.21	13.35	11.75	11.50	11.75	11.00	11.87	
	Mean	13.30	11.83	11.96	11.25	10.75	11.82	13.35	12.17	12.08	10.83	10.75	11.84	
5	Stretch	13.30	12.00	12.25	10.50	9.25	11.46	13.35	11.87	12.00	10.50	9.25	11.39	
	P.O.	13.30	11.75	11.25	10.75	9.00	11.21	13.35	12.00	12.12	10.75	9.00	11.44	
	Check	13.30	12.25	11.50	10.75	10.75	11.71	13.35	12.87	12.00	10.75	10.25	11.84	
	Mean	13.30	12.00	11.67	10.67	9.67	11.46	13.35	12.25	12.04	10.67	9.50	11.56	
Mean	Stretch	13.30	12.00	11.87	10.87	10.00	11.61	13.35	11.81	12.37	10.62	10.12	11.66	
	P.O.	13.30	11.75	11.87	10.37	9.43	11.35	13.35	12.50	12.06	10.37	9.62	11.58	
	Check	13.30	12.00	11.69	11.62	11.19	11.96	13.35	12.31	11.75	11.25	10.62	11.86	
	Mean	13.3	11.92	11.81	10.96	10.21		13.35	12.21	12.06	10.75	10.12		
LSD at 5% level for Temp (T)			0.25						0.24					
Film (F)			0.30						NS					
T x F			0.56						NS					
Storage period (S)			0.39						0.38					
T x S			NS						0.54					
F x S			0.68						0.66					
T x F x S			0.96						0.93					

P.O. = polyolefin film

Table (10): Effect of storage temperature (at RH %= 95-98%), wrapping film and storage period on dry matter % of Endeavor F1 sweet corn hybrid.

Storage Temp. °C	Wrapping film	2002/2003 days						2003/2004 days					
		0	5+1	10+1	15+1	20+1	Mean	0	5+1	10+1	15+1	20+1	Mean
0	Stretch	22.72	23.02	23.48	22.59	21.36	22.63	23.79	22.75	21.95	21.71	21.53	22.39
	P.O.	22.72	24.45	24.42	25.18	26.25	24.60	23.79	23.20	23.68	25.29	25.61	24.31
	Check	22.72	24.21	25.19	26.18	26.01	24.86	23.79	26.43	26.25	28.36	26.10	26.19
	Mean	22.72	23.89	24.36	24.65	24.54	24.03	23.79	24.13	23.96	25.12	24.42	24.30
5	Stretch	22.72	22.09	22.30	21.80	19.40	21.66	23.79	23.62	23.10	23.05	20.37	22.79
	P.O.	22.72	23.14	23.61	24.07	24.27	23.56	23.79	23.82	23.73	23.42	24.41	23.84
	Check	22.72	24.92	25.42	26.93	29.21	25.84	23.79	24.68	25.80	27.79	30.96	26.61
	Mean	22.72	23.38	23.78	24.27	24.29	23.69	23.79	24.04	24.21	24.75	25.25	24.41
Mean	Stretch	22.72	22.55	22.89	22.20	20.38	22.15	23.79	23.79	22.53	22.38	20.95	22.57
	P.O.	22.72	23.69	24.01	24.63	25.26	24.08	23.79	23.51	23.71	24.35	25.01	24.08
	Check	22.72	24.57	25.31	26.56	27.61	25.35	23.79	25.56	26.03	28.07	28.53	26.39
	Mean	22.72	23.64	24.07	24.46	24.42		23.79	24.09	24.09	24.93	24.83	

LSD at 5% level for Temp (T)	NS	NS
Film (F)	0.77	0.48
T x F	1.09	NS
Storage period (S)	0.99	0.62
T x S	NS	NS
F x S	1.73	1.07
T x F x S	NS	1.51

P.O. = polyolefin film

Concerning the storage period, total and non reducing sugars were decreased by lengthening the storage period. These results are in agreement with those of Winter *et al* (1955), Cherry (1974), Carey *et al.* (1982), Evenson and Boyer (1986), Lee *et al.* (1987b) and Olsen *et al.* (1990). This might be attributed to the consumption of sugars in respiration and/or the conversion of sugars to starch. TSS % was higher in kernel stored at 0°C compared to those held at 5°C. This result agrees with Deak *et al.* (1987). Kernels of unwrapped ears (check treatment) contained higher dry matter percent than those of wrapped ones. This may be due to rapid loss of water from check treatment comparing to the wrapped ears. Extending the storage period increase TSS and dry matter percent, which may be due to the loss of water of kernels, consequently increased the concentration of these parameters and this agree with Cherry (1974), Garwood *et al.* (1976), Evenson and Bayer (1986), Risse and McDonald (1990) and Aharoni *et al.* (1996).

It could be concluded that weight loss percent, denting, decay and the CO₂ percent increased by increasing the storage temperature (5°C) and this might be attributed to that the high temperature accelerates the biochemical processes such as respiration rate which increased the content of CO₂ inside package. The high temperature (5°C) also increases the loss of water, which cause denting and activates the pathogens, which increase the deterioration and decay, therefore, the optimum storage temperature for sweet corn is (0°C) . It could be also concluded that wrapping films reduced the weight loss percent, denting and maintained quality through generating a modified atmosphere around ears and elevated CO₂ percent and reduced free oxygen, which reduce the rate of respiration and maintain quality by delay loss of sucrose content and maintain appearance of husks. In addition, wrapping film reduces the gas exchange and preserves a saturated modified atmosphere of water vapour, which reduces the moisture loss and keeps out the freshness.

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تأثير درجة حرارة التخزين، نوع الغلاف و طول مدة التخزين على مواصفات كيزان الذرة السكرية أثناء التخزين

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- 1- قسم البساتين - كلية الزراعة - جامعة عين شمس - شبرا الخيمة - القاهرة - مصر.
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أجريت هذه الدراسة في قسم تداول الخضار بمعهد بحوث البساتين وقسم البساتين بكلية الزراعة جامعة عين شمس خلال أعوام ٢٠٠٢، ٢٠٠٣، ٢٠٠٤ بهدف المحافظة على جودة كيزان الذرة السكرية للهجين انديفور (وهو من الأصناف المبشرة تصديرية) ويرغب في المصدرون نظرا لارتفاع نسبة السكر به) ذلك لقياس مقدرة تخزينية مع الحفاظ على الجودة لأطول فترة ممكنة بعد الحصاد وذلك بعد تحديد الموعد المثالي للقطف وهو ٢٥ يوم من خروج الحريرة نظرا لأنها تقطف في الطور البني (غير مكتملة النمو) حيث معدل تنفسها وتدهورها يكون سريع جدا، واستخدم في هذه التجربة نوعين من المغلفات هي البولي اولفين والغلاف المطاطي (الأسترتش) وروعي في اختيارها ان تكون متخصصة بتغليف المواد الغذائية طبقا للمواصفات القياسية المتبعة في تعبئة المواد الغذائية (90/128/EEC) ومقارنتها بغير المغلف والتخزين على درجات حرارة مختلفة (صفر و ٥°م). واوضحت أهم النتائج المتحصل عليها ان التخزين على درجة ٥°م أدى إلى زيادة الفقد في الوزن والتسنين والتلف، وقلل من جودة المظهر مقارنة بالتخزين على صفر°م. وكانت نسبة غاز ثاني أكسيد الكربون داخل العبوة أعلى عند التخزين على درجة ٥°م مقارنة بالصفر°م وكذلك مع التغليف بالبولي اولفين. كما وجد ان استخدام المغلفات قلل بشكل عام من الفقد في الوزن، فالتغليف بالبولي اولفين أدى إلى تقليل الفقد في الوزن بلية المعاملة بالغلاف المطاط (الأسترتش) مقارنة بغير المغلف. التغليف بالبولي اولفين أدى إلى تقليل التسنين ولكن أدى إلى زيادة التدهور المرضي مقارنة بالتغليف بالغلاف المطاط. أفضل جودة للمظهر كانت عند استخدام التغليف بالغلاف المطاط تلاها البولي اولفين. أعلى نسبة سكريات كلية كانت مع الكيزان غير المغلفة مقارنة بالمغلفة. التغليف بالبولي اولفين حافظ على مستوى السكروز (سكريات غير مختزلة) بلية المعاملة بالغلاف المطاط مقارنة بغير المغلف. أعلى نسبة من السكريات غير المختزلة كانت مع التخزين على صفر°م مقارنة بـ ٥°م. بينما لم يوجد تأثير معنوي بين صفر°م، ٥°م على السكريات الكلية وعلى العكس من ذلك فإن المواد الصلبة الذائبة كانت أعلى على صفر°م مقارنة بـ ٥°م. بزيادة مدة التخزين وجدت زيادة معنوية في الفقد الوزن والتلف والتسنين والتغير في لون أسطح القطع في حين أدت زيادة مدة التخزين إلى تناقص قيم السكريات الكلية وغير المختزلة والمواد الصلبة الذائبة وكذلك التدهور في المظهر. وعلى هذا يمكن ان نوصي بأنه تحت ظروف هذه التجربة يمكن تخزين الذرة السكرية صنف انديفور (هجين) تحت درجة حرارة صفر°م ورتوبة ٩٥-٩٨% ذلك للحفاظ على خواص الجودة مع الأخذ في الاعتبار أهمية معاملة التغليف (كمعاملة اضافية للتبريد) حيث قللت من الفقد في الوزن والتسنين والتدهور والمحافظة على الجودة المظهرية والمحافظة على السكروز (السكريات الغير مختزلة) علاوة على الدور الذي قامت به المغلفات كمعاملة اخرى اضافية للتخزين المبرد كنوع من انواع الجو الهوائي المعدل (MAP) لتقليل التدهور بالكيزان.