



## **SHELF LIFE EXTENSION TEST FOR BROCCOLI**

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**OBJECTIVE:**

Determine if the use of CA FILMS technology can be leveraged towards shelf life extension of broccoli to 6 weeks. To meet this objective proper refrigerated temperature of 37° F shall be used, and broccoli shall be evaluated on a daily basis to determine the oxygen and carbon-dioxide concentrations.

**TEST ITEMS:**

Manufacturer: Chandra Associates,  
Milford, MA 01757

Custom built, plastic bags designed specifically to extend the shelf life of broccoli.

**TEST ITEM: BROCCOLI BEHAVIOUR**

Broccoli is one of the most perishable commodities shipped to the Fresh Fruits and Vegetables industry. One primary reason for the highly perishable nature of broccoli is its high respiration rate. The faster the respiration rate of the broccoli, the more heat the broccoli generates and the shorter the post harvest and market life. An astonishing aspect of post harvest life of broccoli is that it can generate up to 35,000 BTU of heat per ton of broccoli per day at 5°C (41°F). By comparison, the respiratory heat from broccoli at 5°C (41°F) is up to five (5) times greater than the heat generated by crisp head lettuce and up to 70 times greater than many other vegetables or fruit.

**TEST DESCRIPTION:**

### Test Setup Description

The test setup consisted of a refrigerator refrigerated at 37° F (with longer defrost cycles, to reduce excessive fluctuations in temperatures) to simulate ship board refrigerated temperatures, Chandra Associates patented 18 pound membrane technology bags and a Quantek Model 902D, battery-operated, portable oxygen/carbon dioxide analyzer used for the measurement of O<sub>2</sub> and CO<sub>2</sub> in gas-flushed (CAP/MAP) food packages. Such a unit is powered by an internal gel battery (optional), with typically 8 hours of operation before recharging is required.

### Broccoli Initial Inspection

#### *Maturity Indices*

Check the head diameter and check the compactness; ensure that all florets (beads) are closed

\*Good quality broccoli should have dark or bright green closed florets, and the head should be compact (firm to hand pressure), with a cleanly cut stalk of the required length.

#### *Optimum Temperature and Relative Humidity*

Low temperature is extremely important to achieve adequate shelf-life in broccoli. A temperature of 0°C (32°F) with >95% RH is required to optimize broccoli storage life (21-28 days). Heads stored at 5°C (41°F) can have a storage life of 14 days; storage life at 10°C (50°F) is about 5 days. Broccoli is usually rapidly cooled by liquid-icing the field-packed waxed cartons. Hydro cooling and forced-air cooling also can be used, but temperature management during distribution is more critical than with iced broccoli.

#### *Rates of Respiration*

Broccoli heads have relatively high respiration rates:

| Temperature               | 0°C (32°F) | 5°C (41°F) | 10°C (50°F) | 15°C (59°F) | 20°C (68°F) |
|---------------------------|------------|------------|-------------|-------------|-------------|
| ml CO <sub>2</sub> /kg·hr | 10-11      | 16-18      | 38-43       | 80-90       | 140-160     |

The respiration rates of florets are slightly more than twice the rates of the intact heads.

To calculate heat of production multiply ml CO<sub>2</sub>/kg·hr by 440 to get Btu/ton-day or by 122 to get kcal/metric ton-day.

#### *Responses to Controlled Atmospheres (CA)*

Broccoli can be benefited by 1-2% O<sub>2</sub> with 5-10% CO<sub>2</sub> atmospheres at a temperature range of 0-5°C (32-41°F). Although under controlled conditions such low O<sub>2</sub> levels extend shelf-life, temperature fluctuations during commercial handling make this risky as broccoli can easily produce offensive sulfur-containing volatiles

#### *Physical Injury*

Rough handling at harvest can damage the florets and increase decay.

#### Instrumentation:

#### Test Procedures

#### Equipment Protocol

1. Plug the AC adapter in for AC units. Press the POWER switch to start unit. The meter reading at this point will not be stable. Let the unit warm up. The O<sub>2</sub> channel requires no

warm-up time, but the CO<sub>2</sub> channel needs 2-3 minutes for the infrared sensor to stabilize.

2. Press the PUMP switch. The pump will come on for approximately 4 to 6 seconds and pull room air into the analyzer. Note that the O<sub>2</sub> meter reading will decrease slightly when the pump is on. This is normal due to the slight vacuum created in the sensor when the pump is running. The CO<sub>2</sub> meter should read 0.1 to 0.2 % when checking room air. Wait approximately 10-12 seconds for the reading to stabilize. Room air should give a reading of 20.7 to 21.1 % oxygen, and 0 to 0.2% CO<sub>2</sub>.

3. Broccoli shall be heat sealed into CA FILMS.'s 18-pound bags and shall be placed in the refrigerator at 37° F. The oxygen and carbon dioxide concentrations shall be checked on a weekly basis. To sample 18 pounds membrane technology plastic bags with broccoli, first attach the sample probe (new units have this factory installed) to the fitting on the front panel of the analyzer. The fitting should be finger tightened only, but it should be tight to prevent leaks when sampling. Insert a particulate filter on the end of the probe, and then insert a needle onto the end of the filter. Pierce the food pack with the syringe needle, preferably through a foam rubber seal (supplied) Ensure that the plastic bags are heat sealed to prevent leakage. Depress the PUMP switch and wait for the reading to stabilize (10-12 seconds). Leave the needle in the food pack until the reading is stable. This is your reading. If sampling packs with high levels of CO<sub>2</sub>, the reading may take longer to stabilize. It is mandatory to use septa when taking atmosphere readings. After taking the reading seal over the septum with Scotch tape

### **Experimental Protocol:**

1. Heat seal the bags
2. Record bag weight and O<sub>2</sub> /CO<sub>2</sub> headspace atmosphere for all bags each week until the end of shelf life.
3. Make visual and sensory observations each week until the end of shelf life.
4. The guidelines for scoring are as follows: please record range of scores from 1 to

5.

5. A score of 1 is the best score or closest to fresh. A score of 5 is the worst score.

**Visual observations can be recorded on attached chart**

**Overall color**            1 = best (fresh looking)            5 = worst (poor, rotten looking)  
**Dehydration**            1 = fresh, no wilting            5 = wilted or dry  
**Damage/Decay**            1 = no decay            5 = severe (mushy, slimy)  
**Condensation**            1 = no water in bag            5 = large amount of water

|        | Overall Color |   |   |   | Dehydration |   |   |   | Damage/Decay |   |   |   | Condensation |   |   |   |
|--------|---------------|---|---|---|-------------|---|---|---|--------------|---|---|---|--------------|---|---|---|
| Week 0 | 1             | 1 | 1 | 1 | 1           | 1 | 1 | 1 | 1            | 1 | 1 | 1 | 1            | 1 | 1 | 1 |
| Week 2 | 1             | 1 | 1 | 2 | 1           | 1 | 1 | 2 | 1            | 1 | 1 | 2 | 3            | 3 | 3 | 1 |
| Week 4 | 1             | 1 |   | 3 | 1           | 1 |   | 3 | 1            | 1 |   | 3 | 1            | 1 |   | 4 |
| Week 6 |               | 2 |   | 4 |             | 2 |   | 4 |              | 2 |   | 5 |              | 2 |   | 5 |

|  |                    |
|--|--------------------|
|  | Bag A w membrane   |
|  | Bag B w membrane   |
|  | Bag C w membrane   |
|  | Control in Air (A) |

Please note the date when the visual shelf life has expired. Please note that end of trial is defined as appearance of 20% total bag decay. Marketable shelf life will be shorter than that but less statistically useful.

**At the end of trial, conduct sensory evaluations:**

1. Secure bags of fresh product to use as fresh control.
2. Open all bags in succession and record off-odor as compared to fresh control.
3. Empty contents of each bag onto table and record % browning, % yellowing, floret, cut end discoloration, dehydration, damage, decay and other observations.

**Blind Test Protocol:**

Conduct blind test at the end of week 2, week 4 and week 6 of shelf life.

1. Place some of contents of each bag group into a tray for “blind” color and taste tests.
2. Record color once all trays have been set up.
3. Taste each commodity separately at one sitting. (It does not need to be eaten.) Rinse palate with water after each sample. Fresh Broccoli Florets can be used as control and comparison. Record observations in column “Off-flavor”.
4. Rate each tray on the marketability of the product column “Marketability (Y/N)”.
5. Record a score for each tray on individual preference of taste and overall quality of product. Record preference score in column titled “Personal Preference”.

Scoring Guidelines

*Visual observations can be recorded in attached chart*

- |                            |                          |                                   |
|----------------------------|--------------------------|-----------------------------------|
| <b>Color</b>               | 1 = best (fresh looking) | 5 = worst (poor, rotten looking)  |
| <b>Damage/Decay</b>        | 1 = no decay             | 5 = severe (mushy, slimy texture) |
| <b>Dehydration</b>         | 1 = fresh, no wilting    | 5 = severe (wilted or dry)        |
| <b>Off-odor</b>            | 1 = none                 | 5 = severe                        |
| <b>Off-flavor</b>          | 1 = none                 | 5 = inedible                      |
| <b>Personal Preference</b> | 1 = preferred choice     | 5 = least choice                  |

|        | Overall Color |   |   |   | Damage/Decay |   |   |   | Dehydration |   |   |   | Off-odor |   |   |   | Off-flavor |   |   |   |
|--------|---------------|---|---|---|--------------|---|---|---|-------------|---|---|---|----------|---|---|---|------------|---|---|---|
| Week 0 | 1             | 1 | 1 | 1 | 1            | 1 | 1 | 1 | 1           | 1 | 1 | 1 | 1        | 1 | 1 | 1 | 1          | 1 | 1 | 1 |
| Week 2 | 1             | 1 | 1 | 2 | 1            | 1 | 1 | 1 | 1           | 1 | 1 | 2 | 1        | 1 | 1 | 2 | 1          | 1 | 1 | 1 |
| Week 4 |               | 1 |   | 2 |              | 1 |   | 3 |             | 1 |   | 3 |          | 1 |   | 3 |            | 1 |   | 4 |
| Week 6 |               | 2 |   | 4 |              | 2 |   | 5 |             | 2 |   | 4 |          | 1 |   | 5 |            | 2 |   | 5 |

|  |                    |
|--|--------------------|
|  | Bag A w membrane   |
|  | Bag B w membrane   |
|  | Bag C w membrane   |
|  | Control in air (A) |

Evaluations of oxygen and carbon-dioxide concentrations shall be performed on a weekly basis.



Figure 1: Week 0



Figure 2: Week 2



Figure 3: Week 3

Figure 4: Week 4



Figure 5: Week 5





Figure 6: Week 6



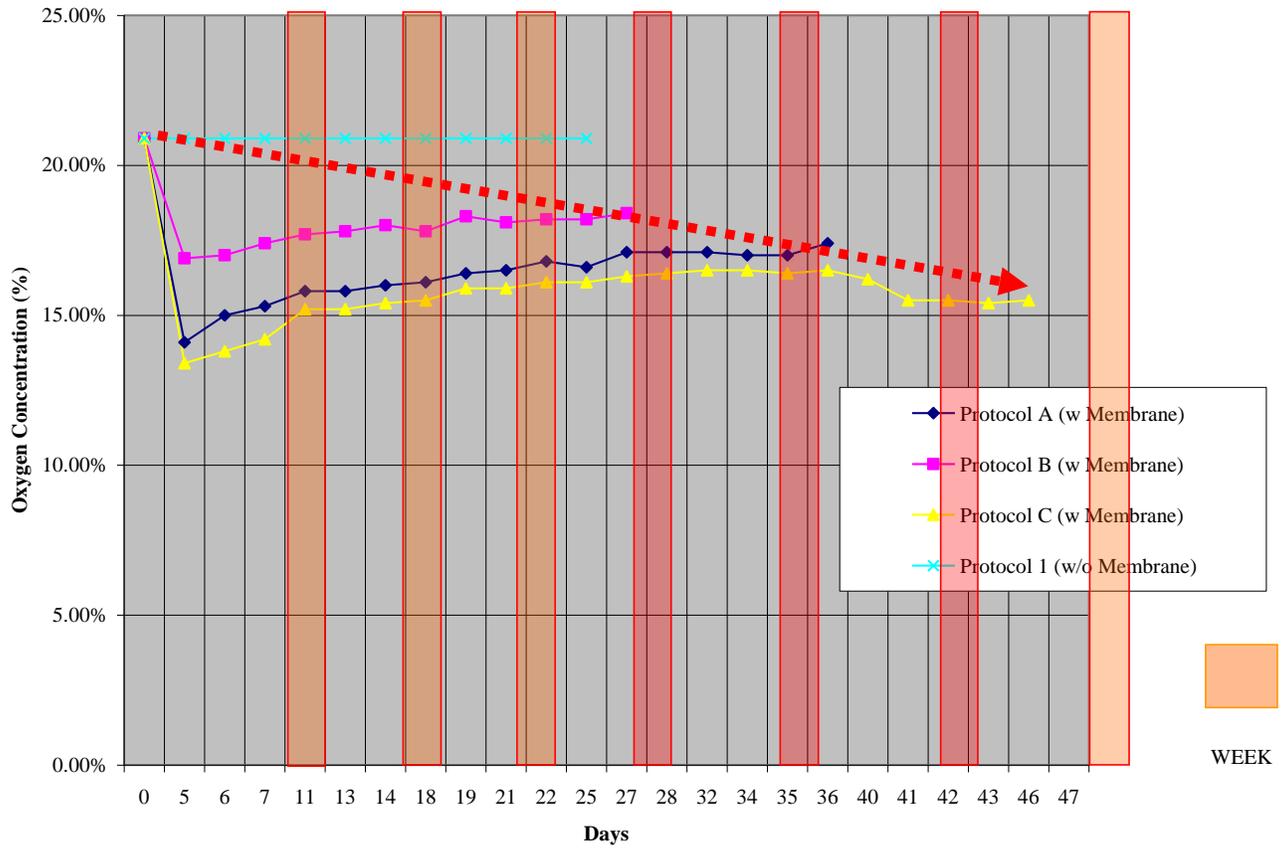
**Figure 7: Commercial off the shelf broccoli vs. 46 days old broccoli**



**RESULTS:**

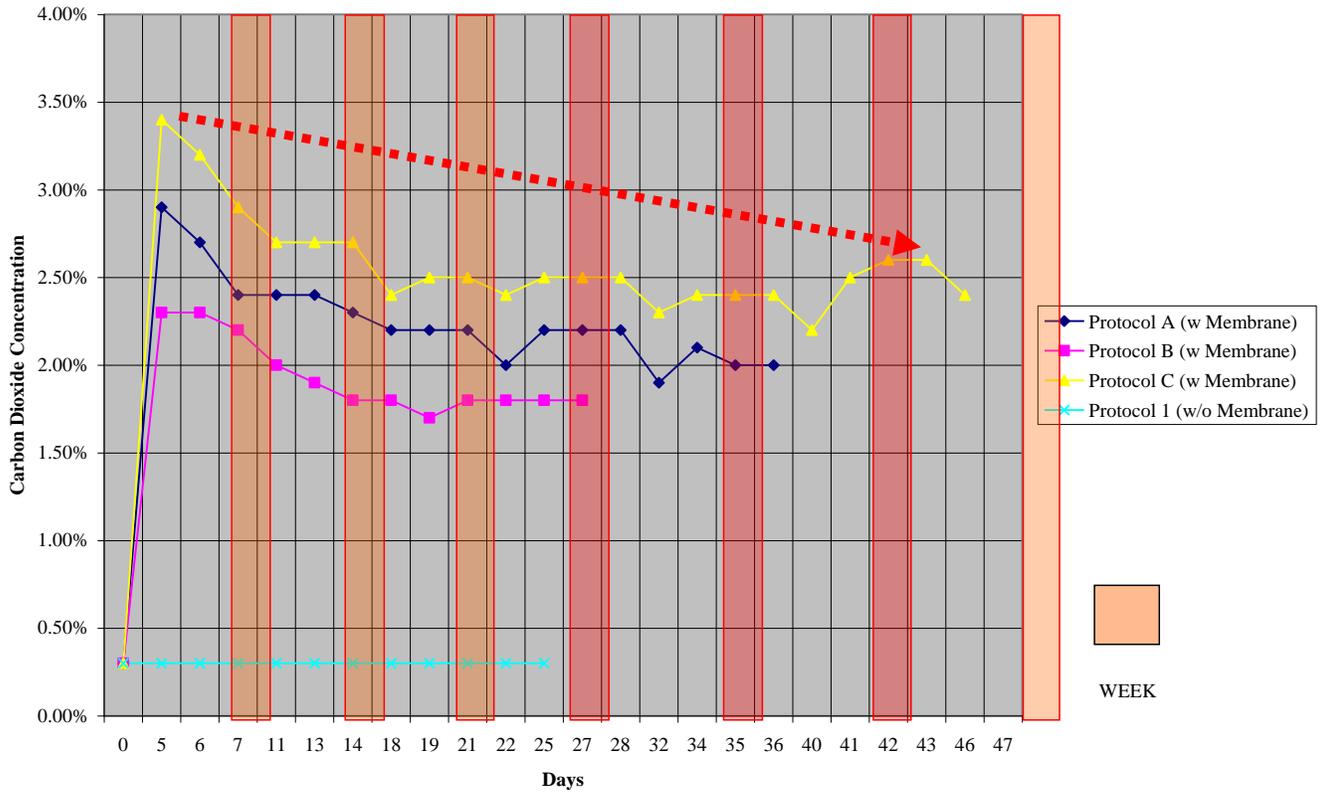
Graph 1: Showing Oxygen Concentrations (For Protocols A, B & C) Vs Weeks

Oxygen Concentration Vs. Days

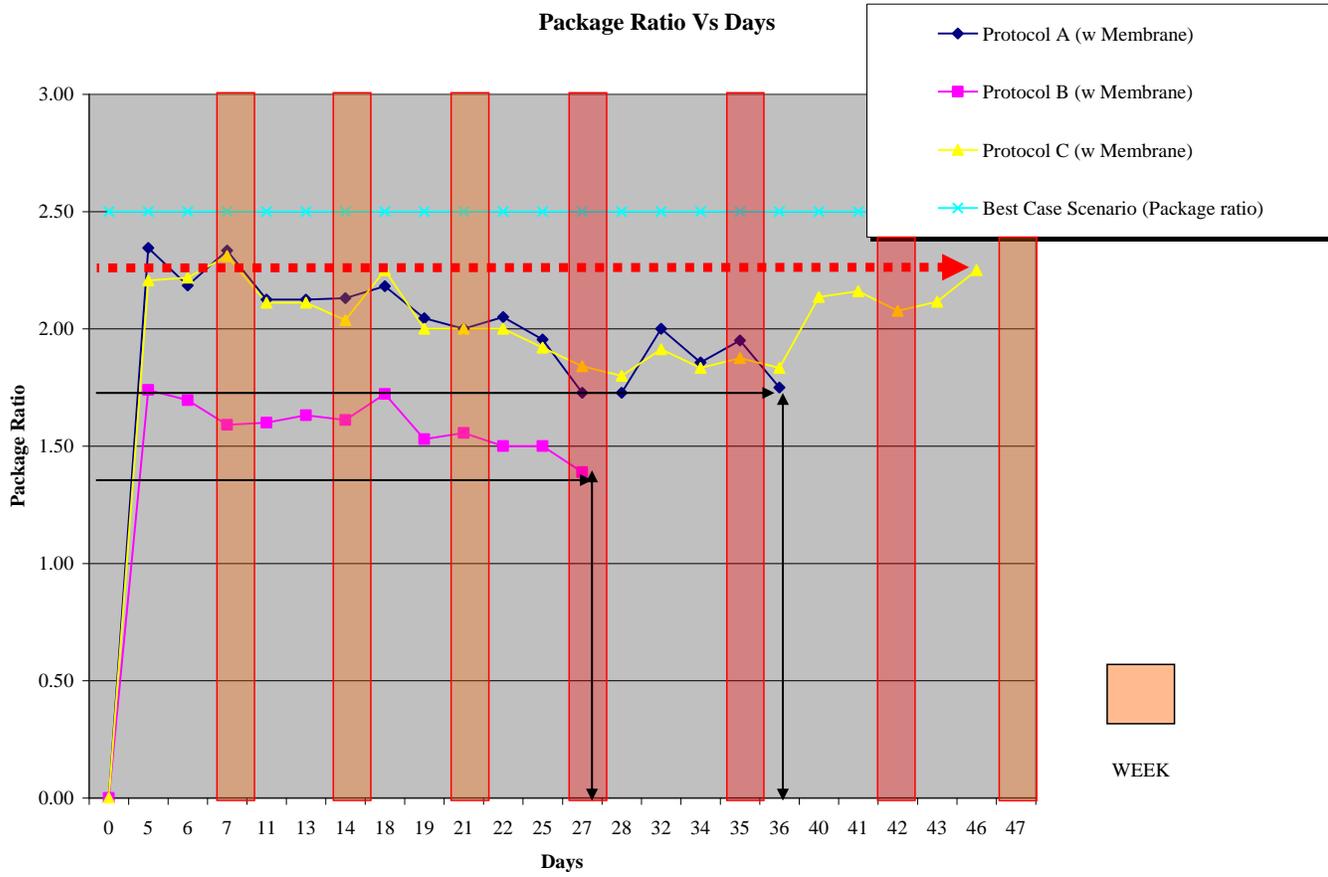


Graph 2: Showing Carbon Dioxide Concentrations (For Protocols A, B & C) Vs Weeks

Carbon Dioxide Concentration Vs Days



Graph 3: Package Ratio (For Protocols A, B & C) Vs Weeks



Notes:

#### Week 4

After end of week 4, control in air was tested vs. the Protocol B. Results have been pretty amazing.

For the control in air, there was a 50% loss in broccoli. Out of a total of 40 heads, 20 heads had gone bad. The lost broccoli, had wilted, yellowed and was soft and rubbery. (7.1 lbs has gone bad, and 7.1 lbs was still good). (**50% loss**)

Protocol B weighed 20.2 pounds, and out of a 43 heads, all heads were good. The broccoli still looked fresh and had no bad odor to it. (**0 % Loss**). It was noted that the butt ends of the broccoli heads removed from the Control in Air Protocol #2 were dried, dehydrated and cavitated. Clearly, water loss detracted from the visual quality of this broccoli. In contrast, the butt ends of the broccoli heads offloaded from the container Protocol B were visually fresh and not dehydrated or cavitated. (*Note: Significantly, scientists have demonstrated that the post-harvest life of broccoli can be doubled with elevated carbon dioxide if water loss and wilting can be minimized*)

#### Week 5

After end of week 5, control in air was tested vs. the Protocol A. Results have been pretty amazing just like week 4.

For the control in air, there was a 90% loss in broccoli. Out of a total of 40 heads, 36 heads had gone bad. The lost broccoli, had wilted, yellowed and was soft and rubbery. Florets had begun to break and there was considerable amount of yellowing on the top. Some broccoli stems (4 out of 40) were still hard and there was considerable loss of moisture. (12.8 lbs has gone bad, and 2.1 lbs was still good). (**90% loss**) It was noted that the butt ends of the broccoli heads removed from the Control in Air Protocol #2 were

dried, dehydrated and cavitated. Clearly, water loss detracted from the visual quality of this broccoli. In contrast, the butt ends of the broccoli heads offloaded from the container Protocol B were visually fresh and not dehydrated or cavitated

Protocol C weighed 20 pounds, and out of a 43 heads, all heads were good. The broccoli still looked fresh and had no bad odor to it. Some moisture was lost. **(1.3 % Loss)**.

#### Week 6

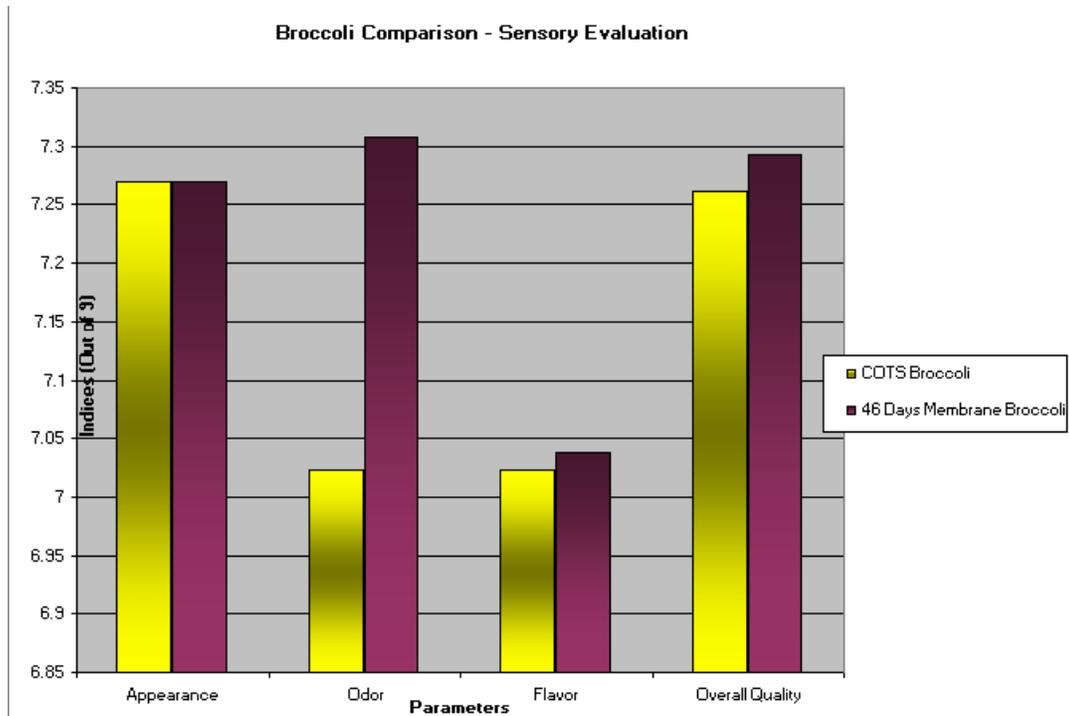
At the end of Week 6 results from Control in Air Protocol 1(45 days old) broccoli was compared with Protocol C broccoli. Broccoli from Control in air protocol had a 100% loss. Out of a total of 20.1 lbs, the entire broccoli had a 100% loss. Broccoli showed yellowing, mole development, dehydration and was soft and rubbery. Broccoli from Protocol C (45 days old, with membranes) was still fresh and did not loose moisture, There was no visible yellowing, and out of 20.1 lbs, 16 lbs was still good. (20.3% Loss).

#### Sensory Evaluation

A sensory evaluation was conducted after the completion of 45 day broccoli test, and broccoli from off the shelf at a local store was compared with 45 days old with membrane technology.

The Graph shows the evaluation and it tends to show that the evaluators preferred 45 days old broccoli vs. the commercial off the shelf broccoli.

Graph 4: Sensory Evaluation of 46 days old broccoli vs. COTS broccoli



**CONCLUSIONS AND RECOMMENDATIONS:**

Chandra Associates has successfully demonstrated that the shelf life of broccoli can be extended up to 45 days without loss in freshness, texture, quality, appearance and flavor. Chandra Associates CA FILMS patented membrane technology has been directly responsible for this extension.