C.1. Pectin

Pectin is composed of polymers of galacturonic acid. During senescence polygalacturonic acid can be degraded by enzymes that fragment large pectin polymers. In order to monitor pectin breakdown the uronic acid content was monitored during storage. A high level of uronic acid is an indication that pectin polymers are being broken down into smaller fragments. This fragmentation of high molecular weight polygalacturonic polymers leads to fruit softening.

Significant interaction between treatments and weeks was observed ($p<0.05$), therefore an error term was used to calculate the significance of treatment and week effects. Uncoated control peppers had a significantly ($p<0.05$) higher overall uronic acid content (mg uronic acid/ mg acetone insoluble residues (AIR)) than the coated treatment groups (Table 5.4). Analysis of individual weeks indicated that during weeks two and five control groups were significantly ($p<0.05$) higher in uronic acid content (Figure 5.5). The higher uronic acid content of the control group indicated that pectin polymers have been degraded to a higher degree. The differences between control and coated peppers revealed that the coatings did have some effect on limiting pectin breakdown.

Pectin breakdown is attributed to three major enzymes: polygalacturonase, pectin lyase and pectin methylesterase. Both pectin methylesterase and polygalacturonase are found in plant tissue, while pectate lyase is found in microorganisms. The lack of pectin breakdown in coated peppers is probably due to several factors. First, control groups lost more water weight, and were therefore decaying at a more rapid rate. The increased senescence most likely sped up metabolic process, which in turn may have increased the activity levels of the endogenous pectin degrading enzymes. The increased metabolic response, however, was not supported by respiration data. The increased weight loss may also have made the pepper susceptible to microbial pectin degradation by the enzyme pectate lyase, however, the presence of microbes is not certain. In addition, the textural changes which were thought to be a result of pectin breakdown should have resulted in differences in puncture force that was not evident as will be discussed in the following section.

Table 5.4: Average log of uronic acid content of coated and uncoated green bell peppers stored for five weeks.

Treatment	**Log Uronic Acid (g)/Acid Insoluble Residue (g)***
Control	0.59^{a}
Locust Bean Gum	0.46^{b}
Maltodextrin	0.47^{b}
Xanthan Gum	0.55^{a}

*Values with different superscripts were significantly different ($p<0.05$).

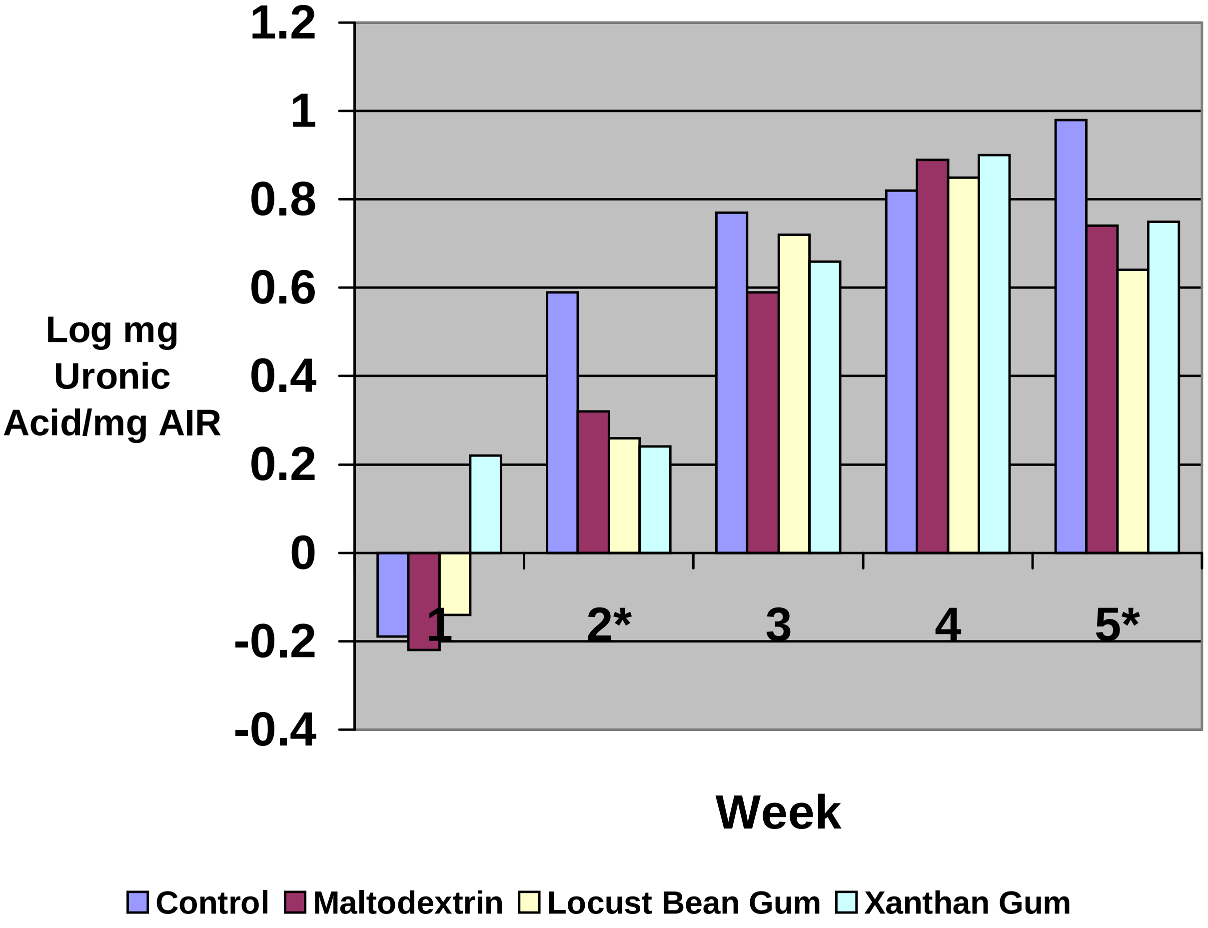

Figure 5.5: Log of uronic acid content changes in coated and uncoated green peppers stored for five weeks.

* Uncoated control peppers contained significantly higher levels of uronic acids ($p<0.05$)

Weekly pectin changes were found to have both significant linear and quadratic trends ($p<0.01$ for both trends) (Figure 5.6 and 5.7, respectively). Both trends were positive in nature, which is expected due to the progressive breakdown of pectin that normally occurs as peppers senescence.

C.2. Puncture Test

Significant interaction between treatments and weeks was observed ($p<0.05$), therefore an error term was used to calculate the significance of treatment and week effects. Coated peppers did not differ significantly ($p>0.05$) from uncoated peppers in the force required to puncture the pepper wall ($p>0.05$) (Table 5.5). Puncture force for all treatments combined did show linear ($p<0.01$) and cubic ($p<0.01$) trends during the five-week study (Figure 5.8). Both the xanthan gum treatment and the control groups showed a linear trend over the five week study ($p<0.05$, for both trends) (Figure 5.9), while the maltodextrin coating and the control both showed a cubic relationship ($p<0.01$, $p<0.05$, respectively) (Figure 5.10). No significant ($p>0.05$) relationships were indicated between weeks and the remaining treatments.

Storage time was the primary factor influencing puncture force. The peppers in all treatment groups appeared to require increased force for puncture over time, as demonstrated in the linear relationship graph (Figure 5.8). This increase in force may be attributed to the increased rubbery nature of the softening pepper tissue. Subjective observations showed that the fruits did soften over time, however, softened samples were rubbery and tended to bend under the force of the probe, and therefore, required extended pressure for fruit wall rupture. In contrast, fresh samples were crisp and tended to snap when a certain level of force was exceeded. The significance of a cubic relationship between storage time and puncture force may indicate that there is a point at which the rubbery nature of the pepper also degrades and becomes easier to puncture. This shift to decreased puncture force was indicated in the fifth week of the study (Figure 5.8). However, it is also possible that the cubic relationship was merely a result of too few sampling times during the duration of the study. Additional sampling may have resulted in eliminating the cubic curve tendency.

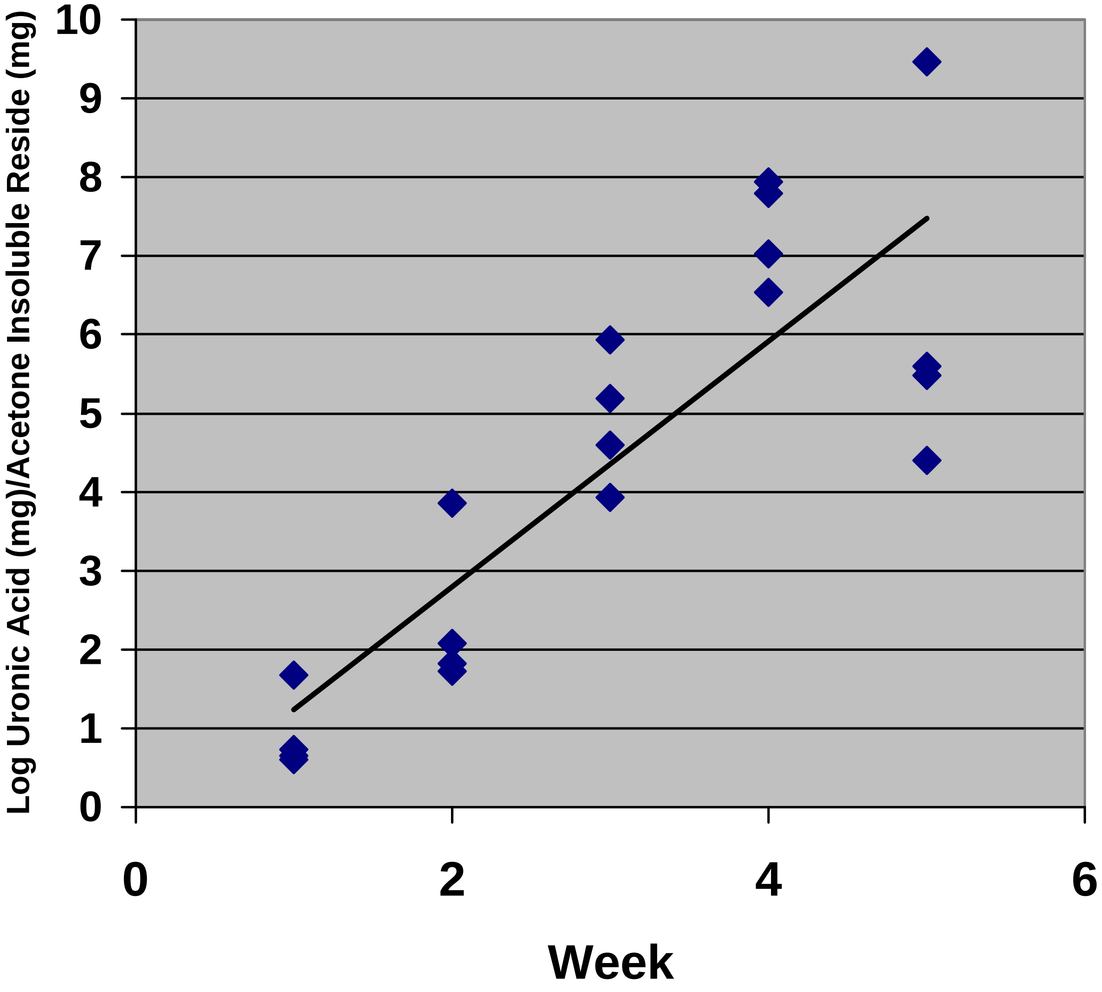

Figure 5.6: Linear relationship ($p<0.01$) between log of uronic acid content of coated and uncoated green bell peppers and week. Data were pooled over treatments. Each point represents a treatment mean. No significant differences between treatments were observed ($p>0.05$).

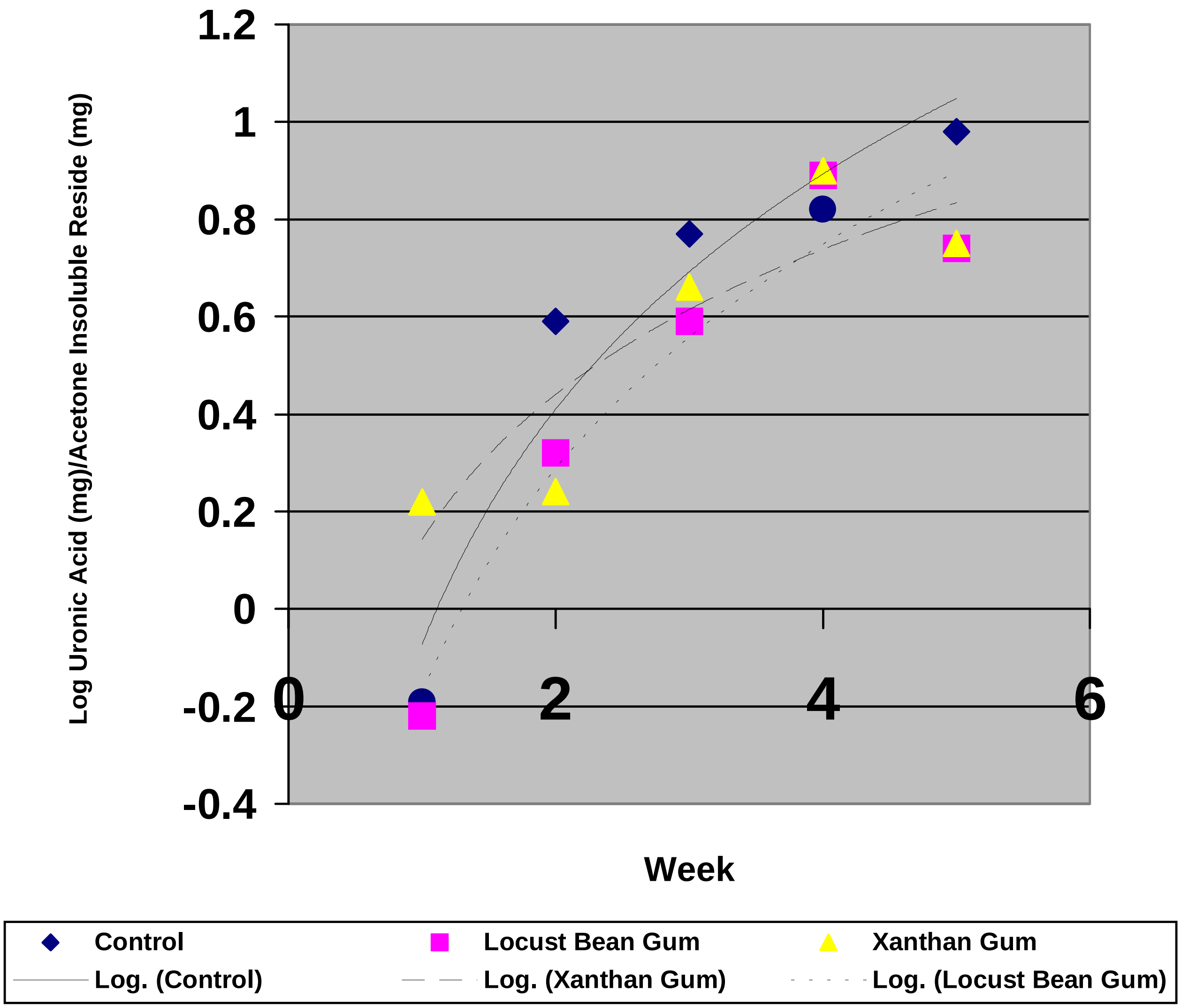

Figure 5.7: Quadratic relationship ($p<0.01$) between log of uronic acid content of control, locust bean gum and xanthan gum green bell peppers groups and week. Each point represents a treatment mean. Coated groups differed significantly ($p<0.05$) from uncoated control peppers on weeks 2 and 5.

Table 5.5: Force (load kg) required to puncture green pepper samples stored for five weeks.

Treatment [a]	Week				
	1	2	3	4	5
Control	3.04	2.59	3.16	3.56	3.30
Xanthan	2.84	2.59	2.80	3.61	3.16
Maltodextrin	3.02	2.51	2.77	3.34	2.64
Locust Bean Gum	2.82	2.87	2.75	3.36	3.15
Coated Groups Average	2.89	2.66	2.77	3.45	2.98

[a] Coated treatment groups did not differ significantly ($p>0.05$) from uncoated controls.

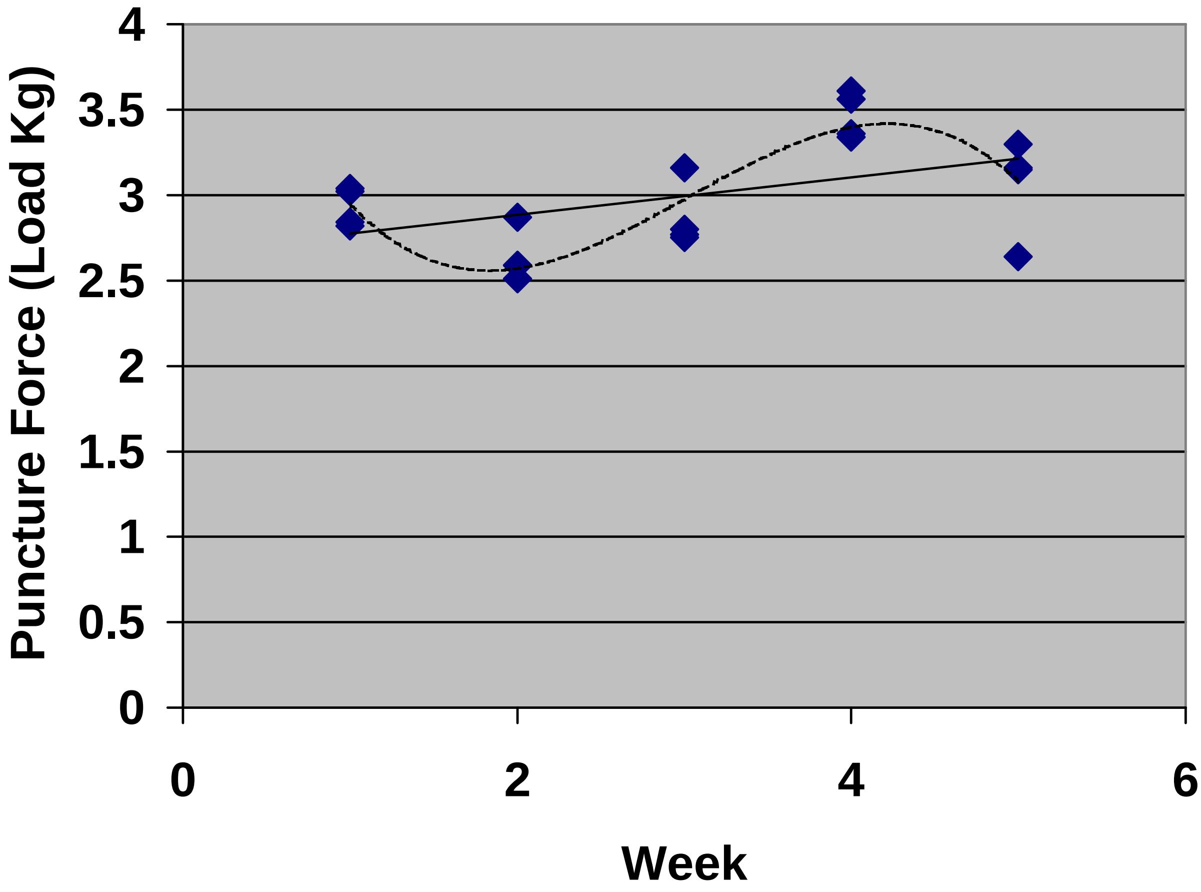

Figure 5.8: Linear relationship ($p<0.01$) and cubic relationship ($p<0.01$) between mean puncture force of coated and uncoated green peppers and storage week. Data were pooled over treatments. Each point represents the mean of a treatment. No significant ($p>0.05$) differences between treatments were observed.

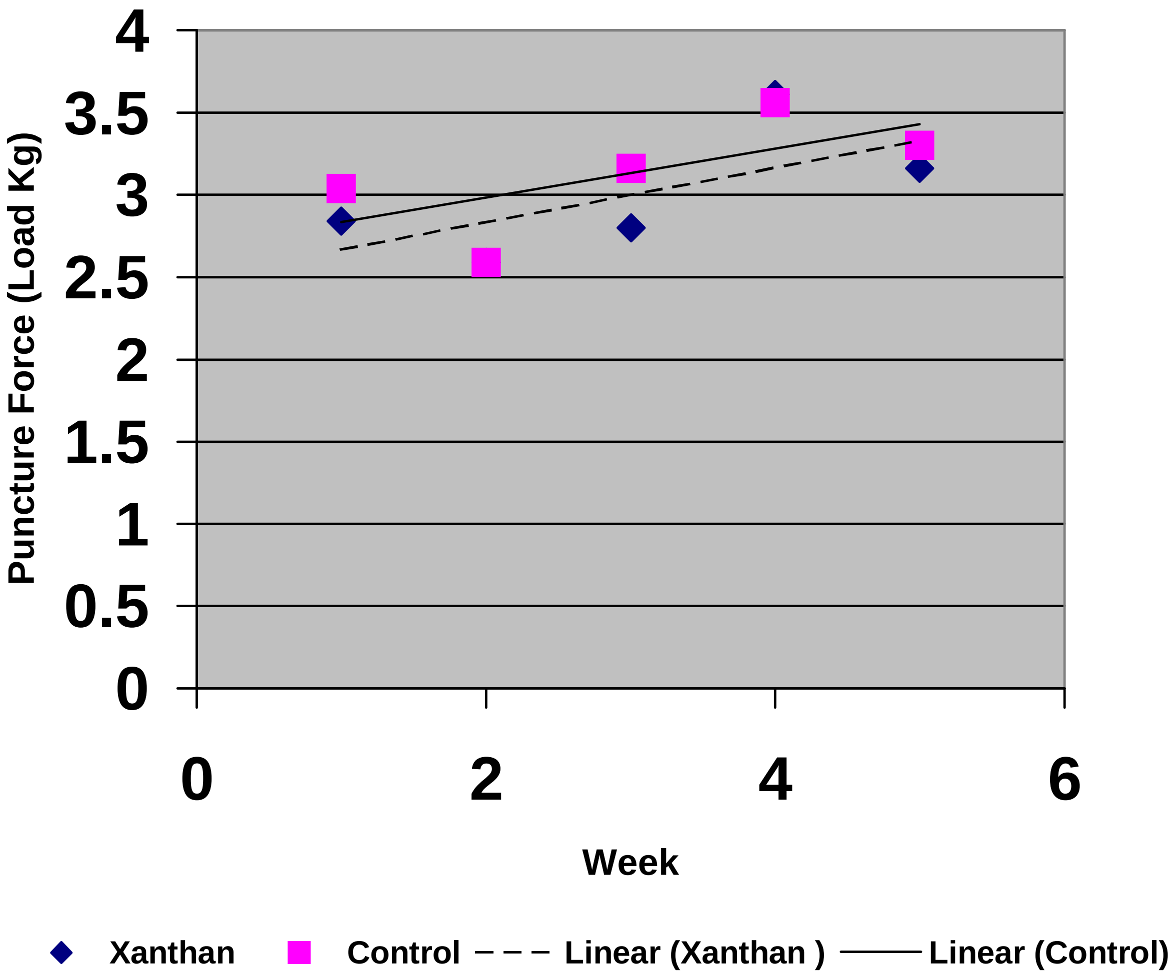

Figure 5.9: Linear relationship between average puncture force of xanthan gum and control treatments of green peppers and storage week ($p<0.05$, $p<0.05$). Each point represents the treatment mean for the designated week.

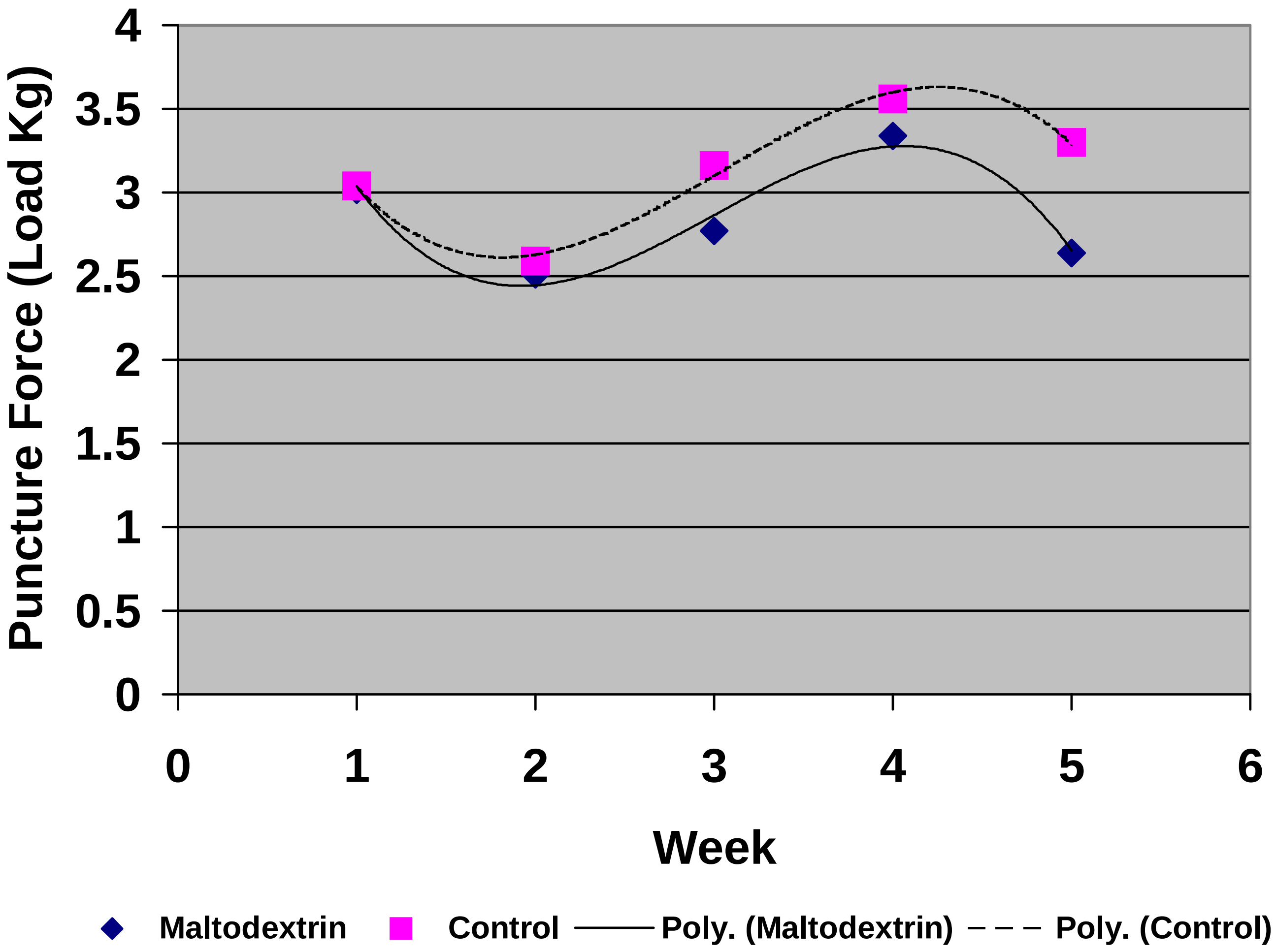

Figure 5.10: Cubic relationship between average puncture force of maltodextrin and control treatment peppers and storage week ($p<0.01$, $p<0.05$ respectively). Each point represents the treatment mean for the designated week.

The linear and cubic trends displayed by analyzing all data points for all treatments are supported by significant linear trends derived from the xanthan gum and control groups. The maltodextrin and control groups showed significant cubic trends. The only group to show no significant pattern of change over time was the locust bean treatment. Despite the presence of linear and cubic relationships in specific coatings, there is no explanation for the trends that has practical significance due to the fact that the puncture force fluctuated so little over the five week study. The lack of clear textural differences may be due to the testing method used. Although the Instron puncture test has been used reliably on other produce including onions (Maw et al., 1996) this method may not adequately resolve textural differences in green peppers due to the bending of the fruit's tissue as it changes with age.

A more appropriate test may involve using a slicing probe and recording the force applied until the pepper sample is fully cut. With this method the force applied could be plotted against time. The resulting curve could be used to determine overall force applied instead of maximum force applied at the moment of complete puncture. The area under the curve could be calculated to give a more comprehensive value. Other studies have also used a shear test to determine textural differences (Berrang et al., 1990). In this type of test the Instron is fitted with a Warner Bratzler blunt blade apparatus which then cuts the vegetable at a predetermined speed. The force required to cut as well as the surface area cut are recorded.

D. Color

Color changes in bell peppers are attributed to the breakdown of chlorophyll either by enzymes or by photodegradation. Chlorophyll pigments are normally protected from photodegradation by intercellular membranes, known as thylakoid membranes. However, these membranes deteriorate during senescence, making the pigment molecules prone to destruction. Coatings are thought to prevent photodegradation by delaying senescence and thereby preserving the protective thylakoid membrane.

Color changes were measured using two objective tests. Color was initially measured using Hunter Colorimeter L* a* and b* values. These values were used to calculate chroma and hue angle values. Hue angle measurements aid in color description: 0° is purple color; 90° is yellow color; 180° is blue-green color; and 270° is blue color. Chroma values describe color intensity; vivid colors have high chroma values, while dull colors have low chroma values. Color changes were also measured by quantifying the level of chlorophyll pigment present in the skin of the peppers.

D.1. Hue Angle

Average hue angles for each treatment are presented in Table 5.6. Significant interaction between treatments and weeks was observed ($p<0.05$), therefore an error term was used to calculate the significance of treatment and week effects. Hue angle values for the control peppers did not differ significantly from coated peppers values ($p>0.05$) on any given week of the study. In addition, hue angles did not change significantly ($p>0.05$) from week to week during the study (Table 5.7). The lack of color differences between experimental weeks indicates pepper color was stable throughout the study, despite the applied treatment. Since the color level, as determined by chlorophyll content and hue angle, was stable throughout the study, green color deterioration was determined not to be a major problem in prolonged storage of green peppers. Coatings did not increase the green color beyond what was already present, therefore, the difference in color values between treatments was irrelevant.

Despite the lack of objective data, some of the peppers were observed to be changing on the surface from a green to a yellow color. The lack of corresponding data may be due to the lack of complete color changes across the whole pepper, which may have not been picked up during sampling, or may have been insignificant when mixed with the green portions of the fruit.

D.2. Chromaticity

Significant interaction between treatments and weeks was observed ($p<0.05$), therefore an error term was used to calculate the significance of treatment and week effects. Average weekly chromaticity values for both coated and uncoated peppers combined are listed in Table 5.8. No significant differences ($p>0.05$) in chroma value were seen during the storage period. The lack

Table 5.6 Average hue angle for coated and uncoated green bell peppers stored for five weeks.

Treatment *	**Average Hue Angle**
Control	114.8
Locust Bean Gum	114.1
Maltodextrin	115.1
Xanthan Gum	114.5

* Treatments did not differ ($p>0.05$) in hue angle values.

Table 5.7: Average weekly hue angle for coated and uncoated green bell peppers stored for five weeks.

Week [a]	**Average Hue Angle**
1	115.0
2	115.6
3	115.8
4	112.4
5	113.9

[a] Weeks did not differ significantly ($p>0.05$) in hue angle values.

Table 5.8 Average weekly chroma value for coated and uncoated green bell peppers stored for five weeks. Data were pooled over treatments.

Week *	**Average Chroma Angle**
1	38.0
2	36.0
3	36.6
4	38.5
5	39.4

[*] Weeks did not differ significantly (p>0.05) in Chroma values.

of change in vividness of color in the control group indicated that the color intensity did not diminish during storage. The results indicated that color brightness was a stable trait, which may infer that its maintenance is not of concern post harvest.

Average chromaticity values for each treatment are presented in Table 5.9. In general, treatments differed significantly in their chroma values ($p<0.05$), however there were no significant differences ($p>0.05$) between uncoated control peppers and coated peppers. Multiple comparison testing showed that the maltodextrin coated peppers were duller in color than the locust bean gum coated peppers. The lack of difference between control peppers and the treated peppers indicated that the vividness of the fruits was not enhanced or preserved by the application of coatings. Differences between maltodextrin and locust bean gum coated groups may be attributed to several factors. First, the maltodextrin coating had a lower lipid content than the locust bean gum coating. The lower lipid level may have caused an increase in senescence of the fruit due to moisture loss. This increased senescence may have included thylakoid membrane breakdown and eventual chlorophyll destruction. However, because maltodextrin and locust bean gum coatings differed in chroma values overall, and not only during the latter weeks of the study, the difference in vivid color was most likely related to the optical properties of the coating itself. The two coatings did provide different surface characteristics to the peppers, which probably resulted in different light reflectance properties, and hence, the overall difference in color intensity.

Chroma values for completely green pepper are reported to average 30.4, while those that are yellow/green in color averaged 45.5 (Lancaster et al., 1997). Therefore, the averages in chroma values for this study seem to indicate a green pepper but with some yellow color present. This portion of yellow may contribute to the "duller" green color indicated by the lower chroma values. The maltodextrin coated group had a chroma value that was slightly less indicating a possibly greener color. The higher color of the locust bean gum coated group may indicate a yellowish tinge. However, despite these differences, the true numerical differences in chroma values are small, and probably not practically significant.

Table 5.9 Average chroma value for coated and uncoated green bell peppers stored for five weeks.

Treatment	**Average Chroma Value***
Control	37.7 ^{a,b}
Locust Bean Gum	38.3 ^{a}
Maltodextrin	35.7 ^{b}
Xanthan Gum	37.7 ^{a,b}

*Treatments values with the same superscript did not differ significantly ($p>0.05$).