D.3. Chlorophyll

Chlorophyll is degraded by light as well as enzymes. Color changes occur in green peppers during ripening. According to Lancaster et al. (1997) peppers that are green in color will have a chlorophyll content of 0.170 mg/g, while yellow green peppers have less chlorophyll (0.082 mg/g). Yellow peppers have no chlorophyll present. Edible coatings are expected to preserve green color by reducing metabolic processes that enhance degradation. The average weekly chlorophyll content of all experimental groups are presented in Table 5.10. Average chlorophyll content of each treatment group are listed in Table 5.3. Based on the values published by Lancaster et al., 1997), the peppers in this study contained an intermediate amount of chlorophyll.

Average chlorophyll content for all groups showed a significant quadratic trend ($p<0.05$) from week to week during the study (Figure 5.11). No significant interaction effects were observed ($p>0.05$). In this trend chlorophyll content dropped in the first three weeks, and increased in the last two weeks. A slightly significant positive linear trend ($p<0.060$) was also observed from week to week. Despite these trends of increased chlorophyll content in the latter weeks, peppers appeared to become more yellow as the study progressed, which suggests chlorophyll degradation. Possible explanations for the discrepancy between observed color changes and objective measurements may be due to sampling problems. Ideally chlorophyll content was measured on samples randomly taken from pepper skin surfaces. However, errors in content may have occurred if the samples were not randomly selected, greener sections were selected over more yellow tissue, or if selection was not made in a manner that was representative of the actual color changes. Sampling peppers at different stages of maturity may also affect results. Peppers were all harvested at the same time. However, there is no way to know which fruits were more mature. Mature peppers would have begun to lose greater amounts of chlorophyll while more immature fruits would have higher contents. The lack of control over pepper maturity may have led to an inaccurate portrayal of chlorophyll changes over time.

Table 5.10: Weekly chlorophyll content of coated and uncoated green bell peppers. Data were pooled over treatments.

Week	Chlorophyll Content (mg/g)*
1	0.125
2	0.095
3	0.115
4	0.121
5	0.136

*Green peppers contain ~ 0.170 mg/g, yellow-green peppers contain 0.082 mg/g

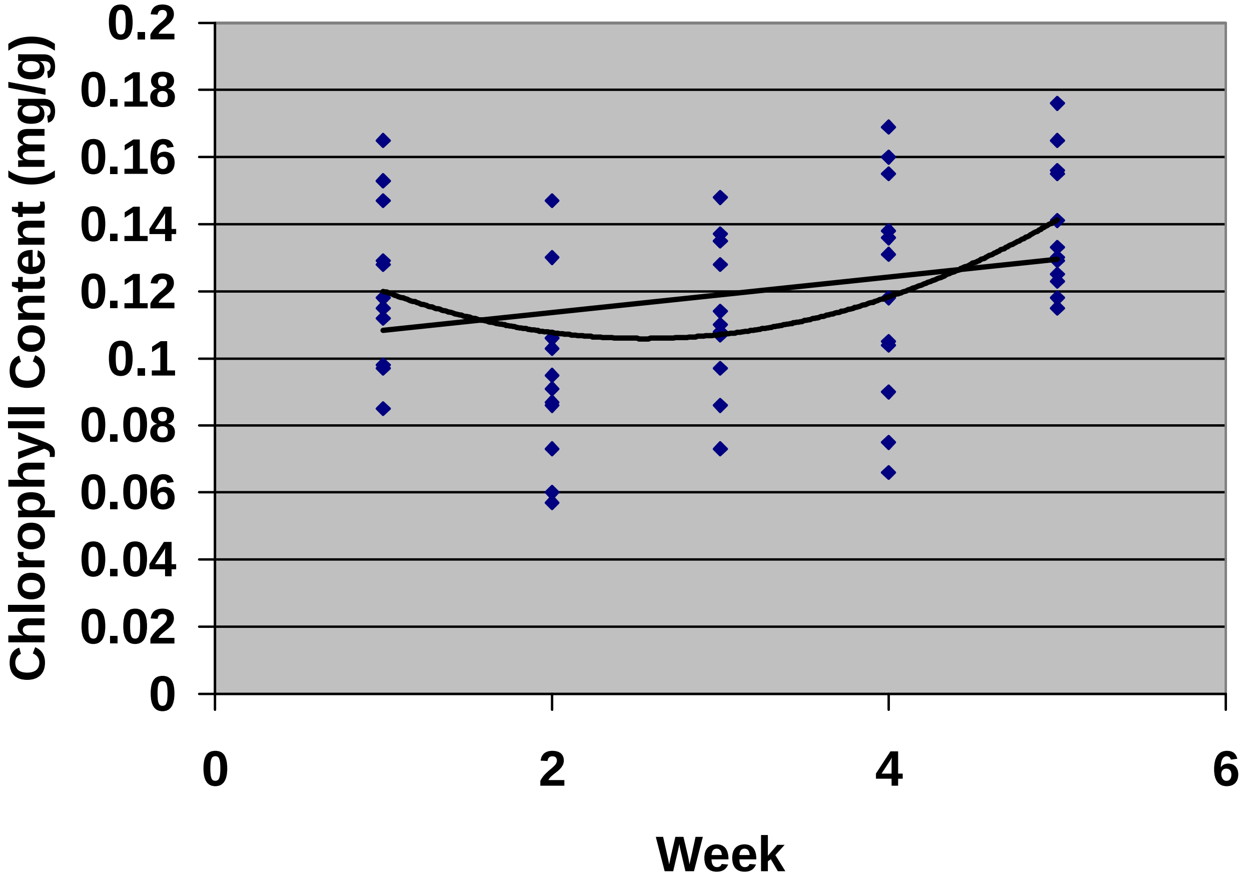

Figure 5.11: Linear (p=0.06) and quadratic (p<0.01) relationships between chlorophyll content of coated and uncoated green bell peppers and storage week. Data were pooled over treatments. Each marker represents a sample mean from each treatment. No significant differences between treatments were observed (p>0.05).

Uncoated control peppers did not differ significantly ($p>0.05$) in chlorophyll content from coated groups on any given week of the study (Table 5.3). These results reaffirm hue angle and chroma results that the green pigment was not appreciably lost during storage, and that coating application had no effect on chlorophyll degradation. Other studies have also shown that edible coatings (including coatings made from lipids, carbohydrates and proteins) have had no effect on color preservation of green peppers (Lerdthanangkul and Krochta, 1996).

Analysis of changes in individual treatments over the five-week period showed there was a significant positive linear ($p<0.05$) relationship between chlorophyll content of the maltodextrin coated peppers and week of the study (Figure 5.12). No other coatings showed significant ($p>0.05$) relationships with the week of storage. Again, chlorophyll content was expected to decrease during storage. Results showed higher chlorophyll amounts at the beginning and end of the study, with content dropping in the second week. This eradicate behavior may have been attributed to sampling problems or lack of regulation of pepper maturity.

E. Vitamin C Analysis

E.1. Ascorbic Acid

Peppers in this study had lower levels of ascorbic acid than predicted by research (Moser and Bendich, 1991). Normally fresh peppers contain between 125-200 mg ascorbic acid/100 grams of fruit, however fresh peppers in this study contained slightly less (102.5 mg/100 grams for fresh samples). This slight difference may be attributed to the variety of pepper, or the growing conditions.

Results of ascorbic acid (AA) changes showed that uncoated peppers did not differ significantly ($p>0.05$) from coated peppers during any week of the study ($p>0.05$) (Table 5.11). A significant quadratic trend over weeks in ascorbic acid content for all treatments was seen ($p<0.01$) (Figure 5.13). No interaction effects were seen ($p>0.05$). Specific trends of individual coatings included quadratic trends for both locust bean coated peppers ($p<0.05$) and xanthan gum coated peppers

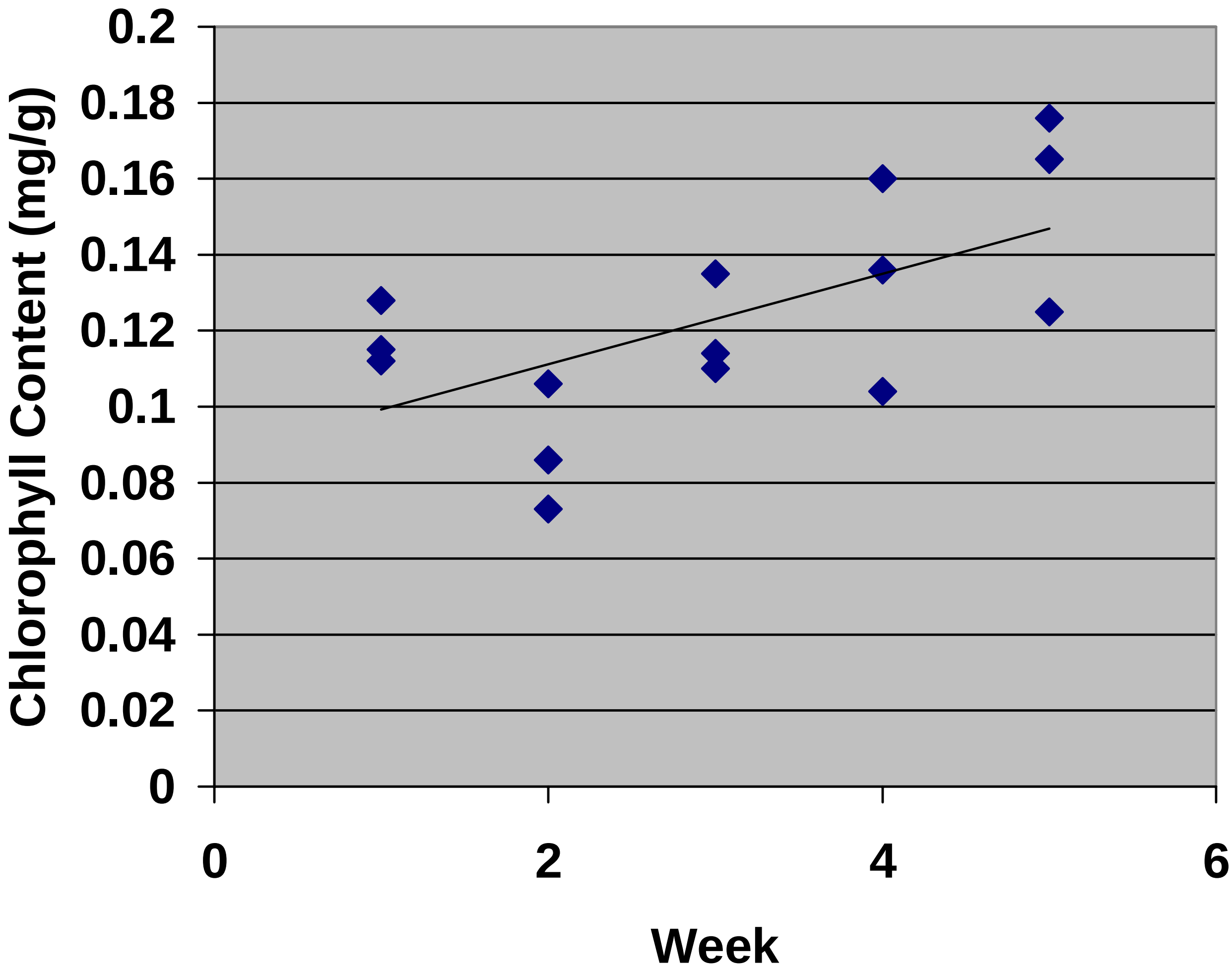

Figure 5.12: Linear relationship between chlorophyll content of maltodextrin coated green bell peppers and storage week ($p<0.05$). Each marker represents a one sample tested during the designated week.

Table 5.11: Ascorbic acid content (mg/100g) of green pepper fruits stored for five weeks.

Treatment [a]	Week				
	1	2	3	4	5
Control	112.37	95.29	81.82	100.33	93.12
Xanthan Gum	105.65	96.36	60.05	105.16	102.96
Maltodextrin	95.0	83.13	66.11	105.92	91.35
Locust Bean Gum	96.95	95.47	77.35	89.25	107.97
Coated Groups Average	98.87	91.65	67.84	100.11	100.76

[a] Uncoated control peppers did not differ significantly ($p>0.05$) in ascorbic acid content from coated groups ($p>0.05$).

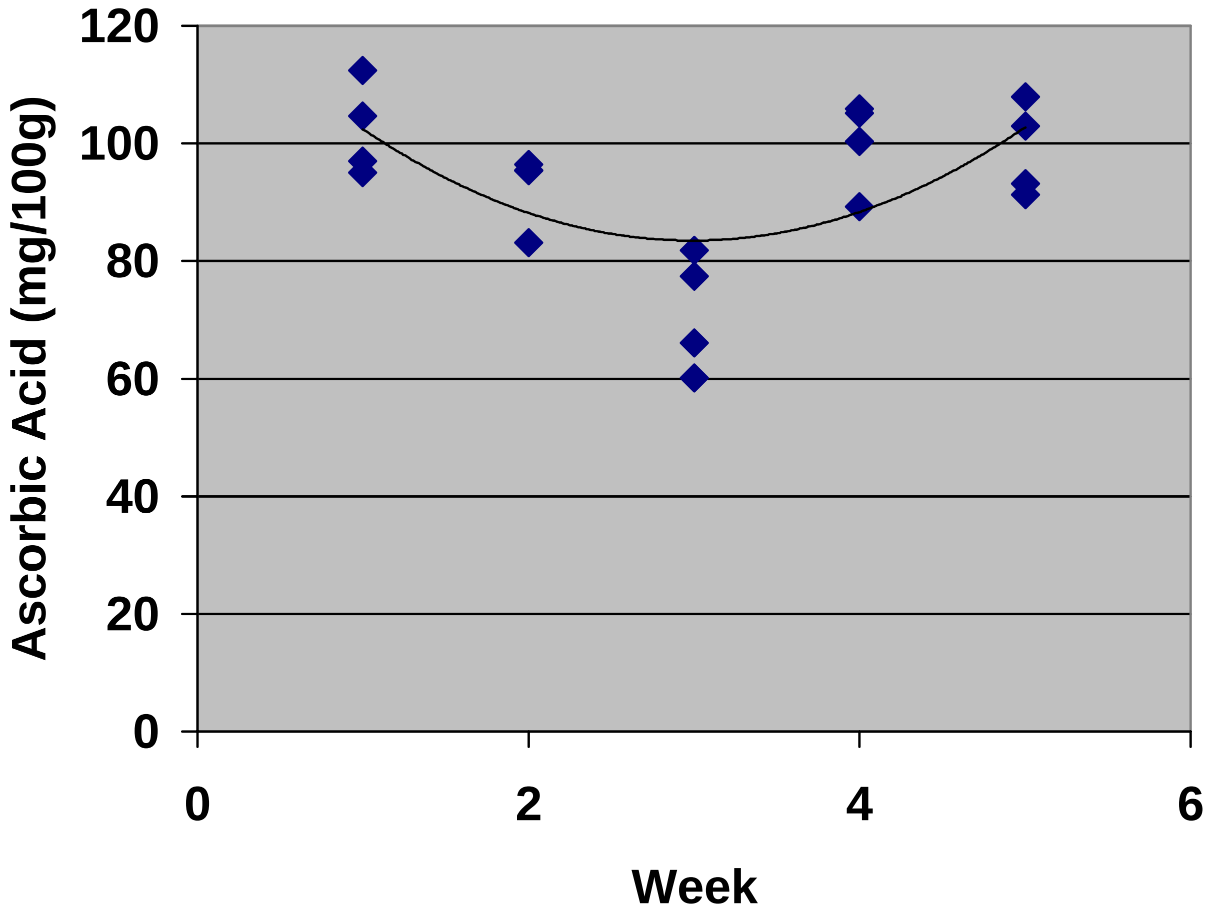

Figure 5.13: Quadratic ($p<0.01$) relationship between ascorbic acid (AA) content of coated and uncoated green peppers and storage week. Data were pooled over treatments. Each point represents a treatment mean for the designated week. No significant differences between treatments were observed ($p>0.05$)

(p<0.01) (Figure 5.14). When AA data was analyzed without the third week, results indicated that there were no significant interaction, week, or treatment effects (p>0.05).

Similar trends between uncoated and coated peppers are an indication that coatings did not enhance preservation of ascorbic acid. The coatings were predicted to function by blocking out oxygen, as well as reducing overall metabolic processes which in turn would reduce vitamin C degradation. Respiration data also showed no differences between coated and uncoated groups, which also indicated that the coatings did not offer any ability to reduce senescence related to metabolic changes. In contrast, research (Barth, et al., 1993) on broccoli stored in plastic materials (which mimic modified atmospheric storage) did show an initial drop in AA content of approximately 15%. After this initial drop in AA losses were minimal throughout the rest of storage compared to unprotected samples.

The significant quadratic relationship between ascorbic acid and storage week is strongly related to the large drop in values observed during the third week. Again, no overt laboratory error was recognized, so there is not a clear reason for elimination of these data. Possible explanations for a quadratic relationship between ascorbic acid content and storage week may be attributed to increased ascorbic acid synthesis or fluctuations between the AA and dehydroascorbic acid (DHA) vitamin forms. However, the lack of significant trends upon omission of the third week indicates that the quadratic fit may not be valid.

E.2 Dehydroascorbic Acid

The use of analysis of variance to test differences between treatments and weeks requires an underlying assumption of homogeneity of variance. The dehydroascorbic acid (DHA) data violated this assumption even after several data transformations were attempted. Therefore, elimination of the third week of DHA data was required due to the inability to stabilize the variance with that week included. Significant differences between DHA content of uncoated and coated peppers were seen (p=0.06) (Figure 5.15). DHA content was higher in uncoated peppers for weeks one (p<0.05) and four (p=0.05). DHA content did not differ significantly (p>0.05)

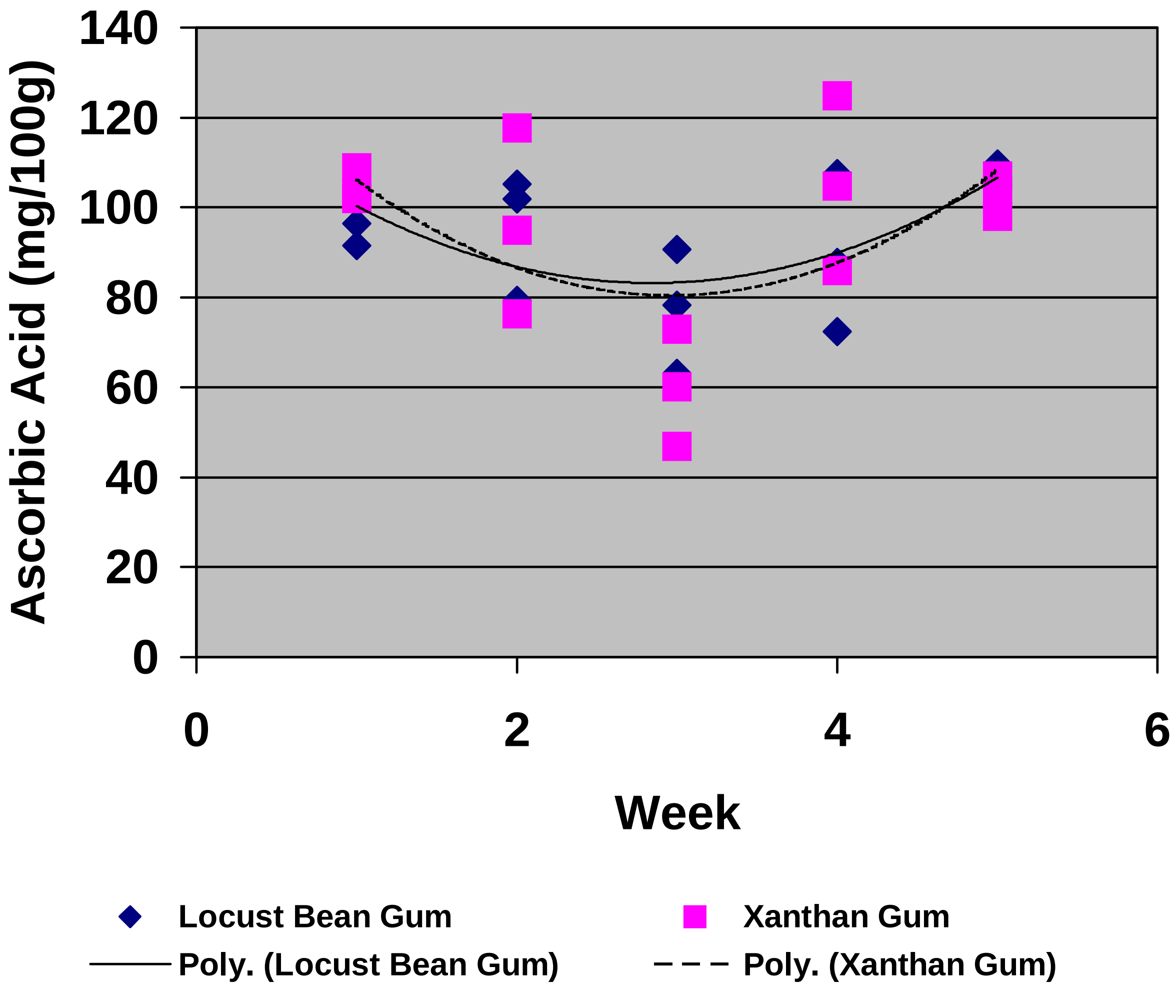

Figure 5.14: Quadratic relationship between ascorbic acid (AA) content of locust bean gum ($p<0.05$) and xanthan gum ($p<0.01$) coated peppers and storage week. Each point represents a sample treatment mean from the treatment designated.

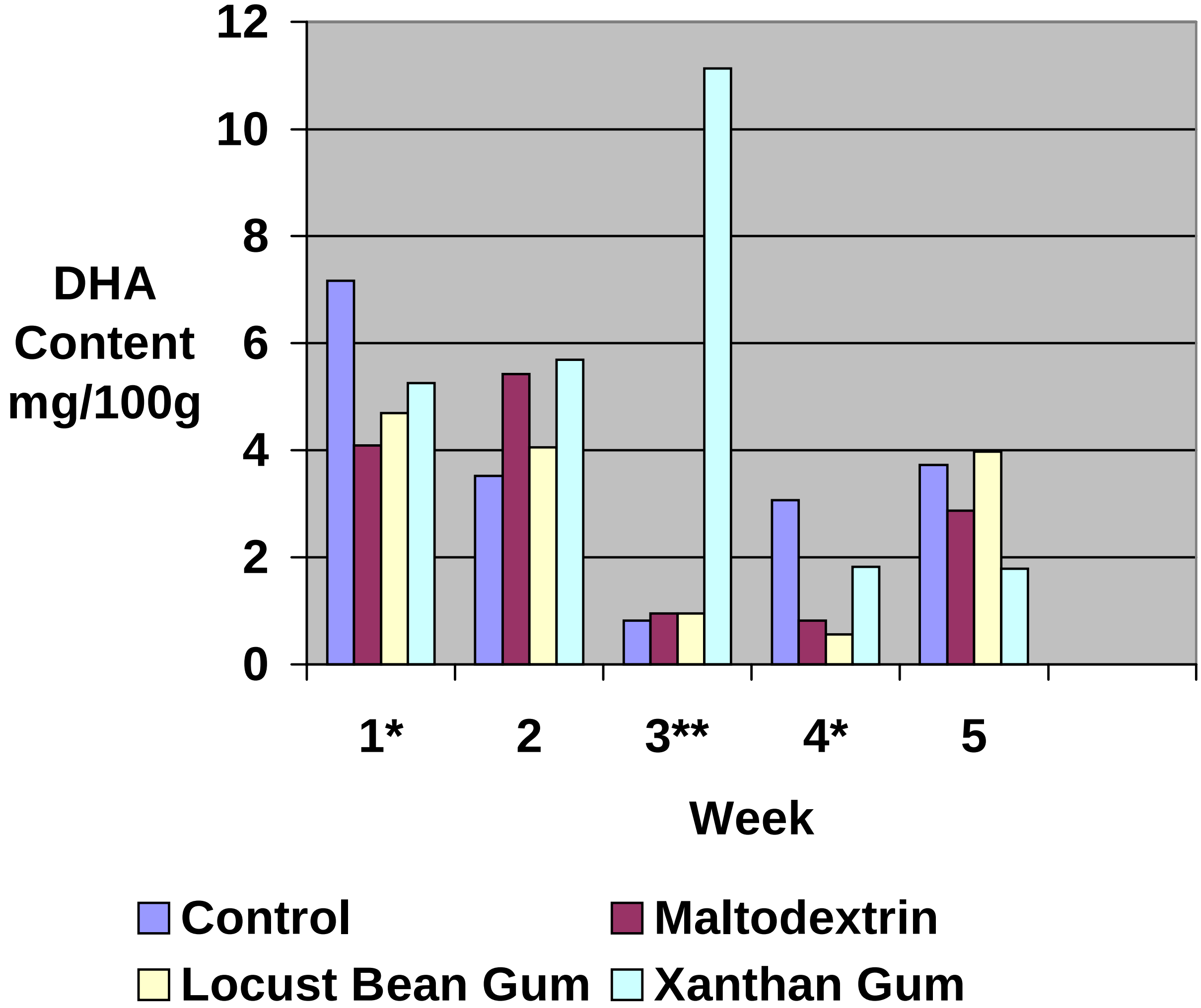

Figure 5.15: Changes in dehydroascorbic acid (DHA) content in coated and uncoated green bell peppers stored for five weeks.
*control groups were significantly higher in DHA than coated treatment groups ($p \le 0.05$)
**week three was eliminated from statistical analysis

between treatments in weeks two and five (Table 5.12). No significant interaction effects were seen ($p>0.05$).

Although the AA levels of coated peppers were not significantly higher than uncoated peppers, higher DHA content in uncoated peppers may indicate that the edible coatings were effective in preventing the change from AA to DHA. The preservation of the vitamin in the AA form is beneficial because the vitamin is prevented from shifting into the DHA form, and the subsequent irreversible change from DHA to diketogulonic acid (DKG) is avoided. Preventing the vitamin from shifting to the DKG form, which has no vitamin activity, helps maintain nutritional quality.

Significant differences in weekly DHA content were seen ($p<0.01$) (Table 5.13), with significant linear and quadratic relationships in evidence ($p<0.05$ for both trends) (Figure 5.16). Control, xanthan gum, and maltodextrin treatments all showed significant linear contrasts ($p<0.01$ for all trends) (Figures 5.17, 5.18, and 5.19, respectively). A quadratic relationship between DHA content and weeks was seen for the control treatment ($p<0.05$) and the locust bean gum treatment ($p<0.05$) (Figures 5.20 and 5.21, respectively). Linear trends were negative indicating a loss of DHA during storage. DHA was hypothesized to increase during storage due to the continued breakdown of AA. However, no loss of AA during storage was determined. The decrease in DHA content may be due to its irreversible conversion to DKG as the fruits aged. DHA is also a known precursor for oxalic acid; production of this compound could also account for diminishing levels of DHA.

E.3. Correlation of Ascorbic Acid and Dehydroascorbic Acid Content

The AA and DHA content for weeks 1, 2, 4, and 5 were subjected to correlation analysis. Theoretically, as AA decreases there is a corresponding increase in DHA levels. There was no significant relationship between AA and DHA when values were averaged over the weeks ($p>0.05$, $r=0.2943$) and no significant relationship when treatment and week values were ignored ($p>0.05$, $r=0.2943$). The only significant relationship ($p<0.05$, $r=0.59092$) between AA and DHA was seen during week one in which there was a positive relationship between the AA and DHA content.

Table 5.12: Dehydroascorbic acid (DHA) content (mg/100g) of green pepper fruits stored for five weeks.

Treatment	Week				
	1[a]	2[b]	3[c]	4[a]	5[b]
Control	7.16	3.52	0.82	3.07	3.72
Xanthan Gum	5.25	5.59	11.14	1.83	1.79
Maltodextrin	4.09	5.42	0.95	0.82	2.87
Locust Bean Gum	4.69	4.06	9.50	0.56	3.97
Coated Groups Average	4.68	5.02	7.20	1.07	2.88

[a] Uncoated control peppers differ significantly ($p<0.05$).from coated groups.
[b] Uncoated control peppers did not differ significantly ($p>0.05$) from coated groups.
[c] Week three was excluded from analysis due to the inability to stabilize the variance when this week was included.

Table 5.13: Weekly changes in dehydroascorbic acid (DHA) content changes of green bell peppers averaged for all treatment groups. Data were pooled over treatments.

Week	**Dehydroascorbic Acid Content (mg/100g)[a]**
1	5.30
2	4.65
3[b]	5.60
4	1.57
5	3.90

[a] significant weekly differences were found ($p<0.05$).
[b] week three was eliminated in analysis.

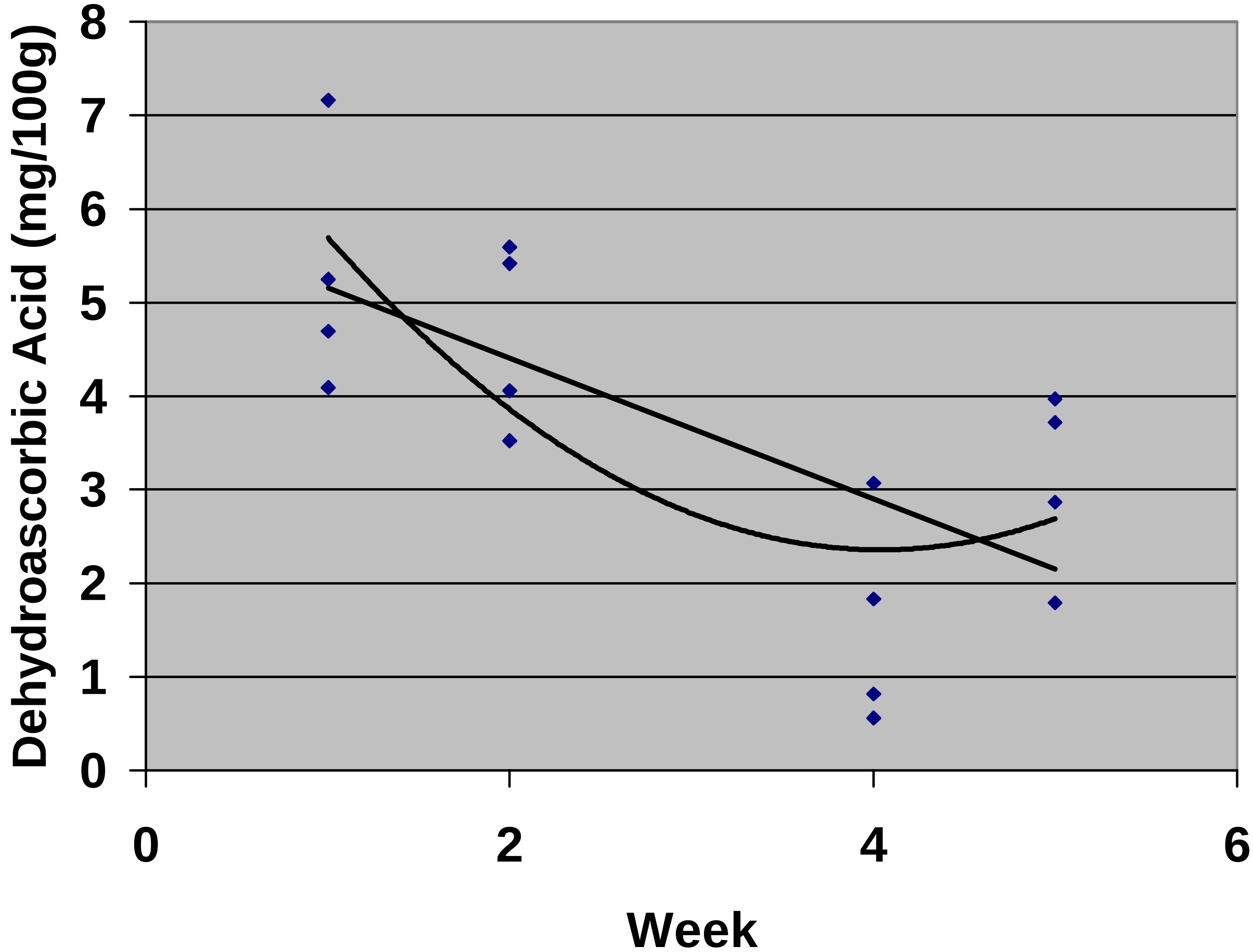

Figure 5.16: Weekly linear ($p<0.05$) and quadratic ($p<0.05$) trends in dehydroascorbic acid (DHA) content of coated and uncoated green bell peppers stored for 5 weeks. Data were pooled over all treatments. Each point represents the mean of a sample taken during the designated week.

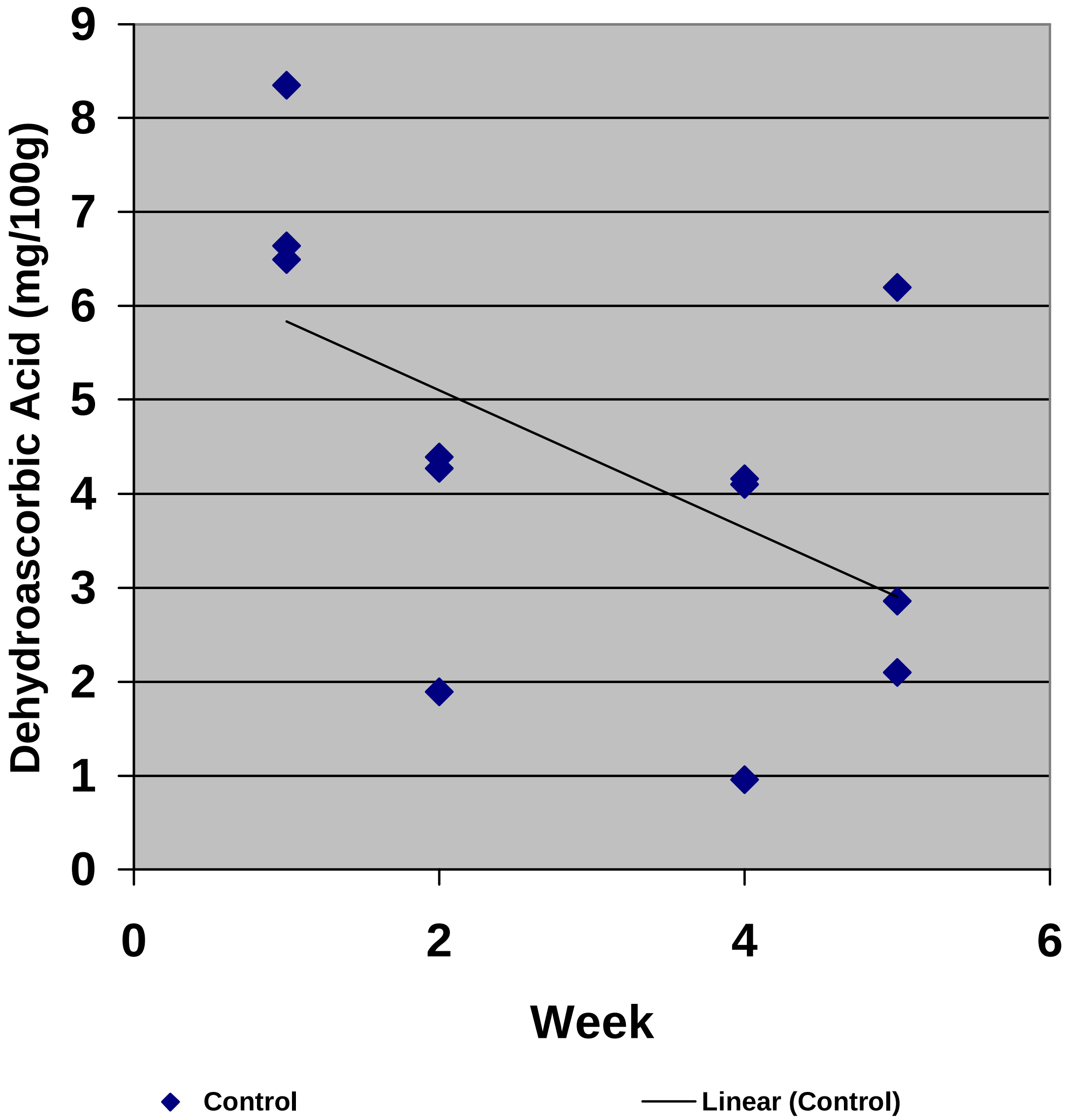

Figure 5.17: Linear relationship of dehydroascorbic acid (DHA) content in control (uncoated) green bell peppers ($p<0.01$) for weeks 1, 2, 4, and 5. Each point represents one sample mean for taken on the designated week.

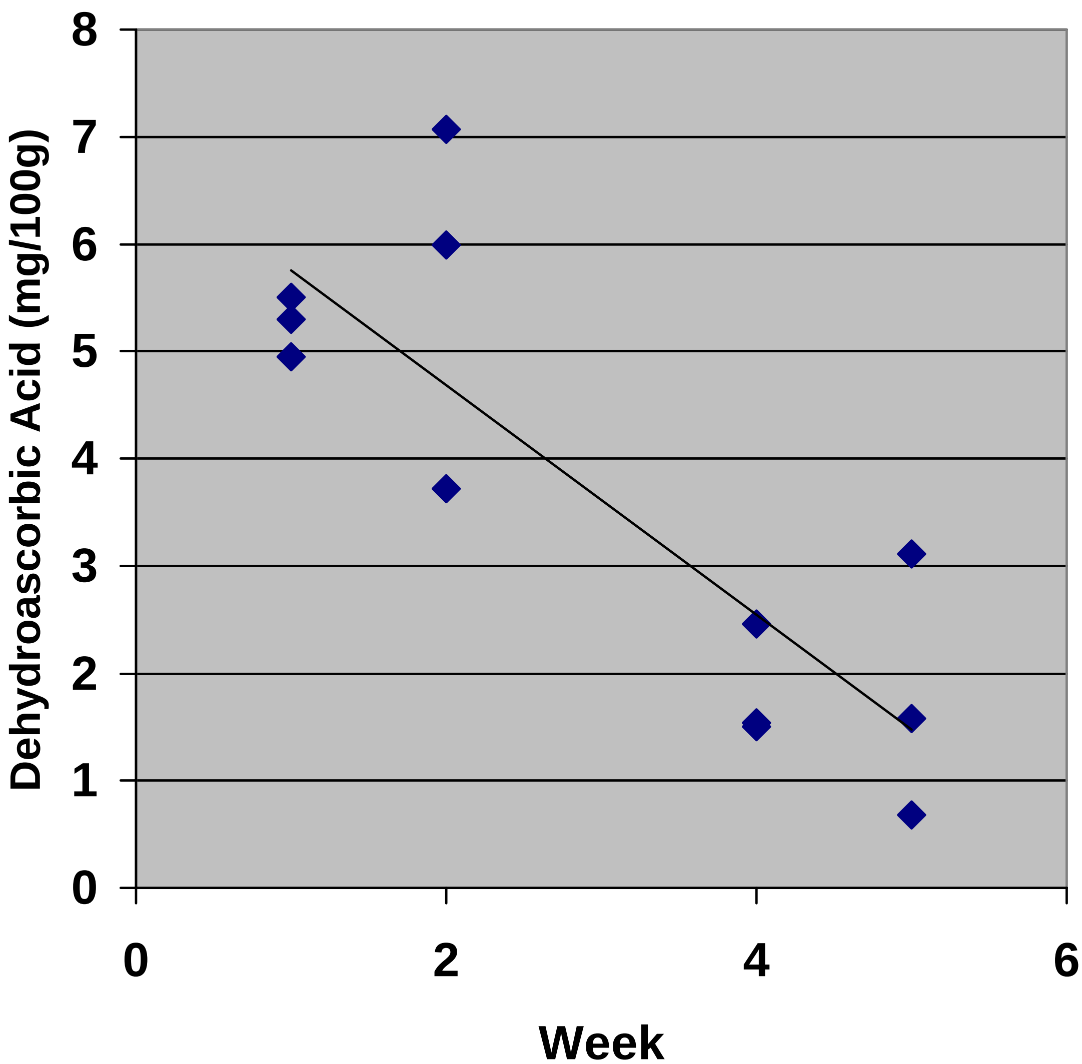

Figure 5.18: Linear relationship of dehydroascorbic acid (DHA) content in xanthan gum coated green bell peppers ($p<0.01$) for weeks 1, 2, 4, and 5. Each point represents one sample mean taken on the designated week.

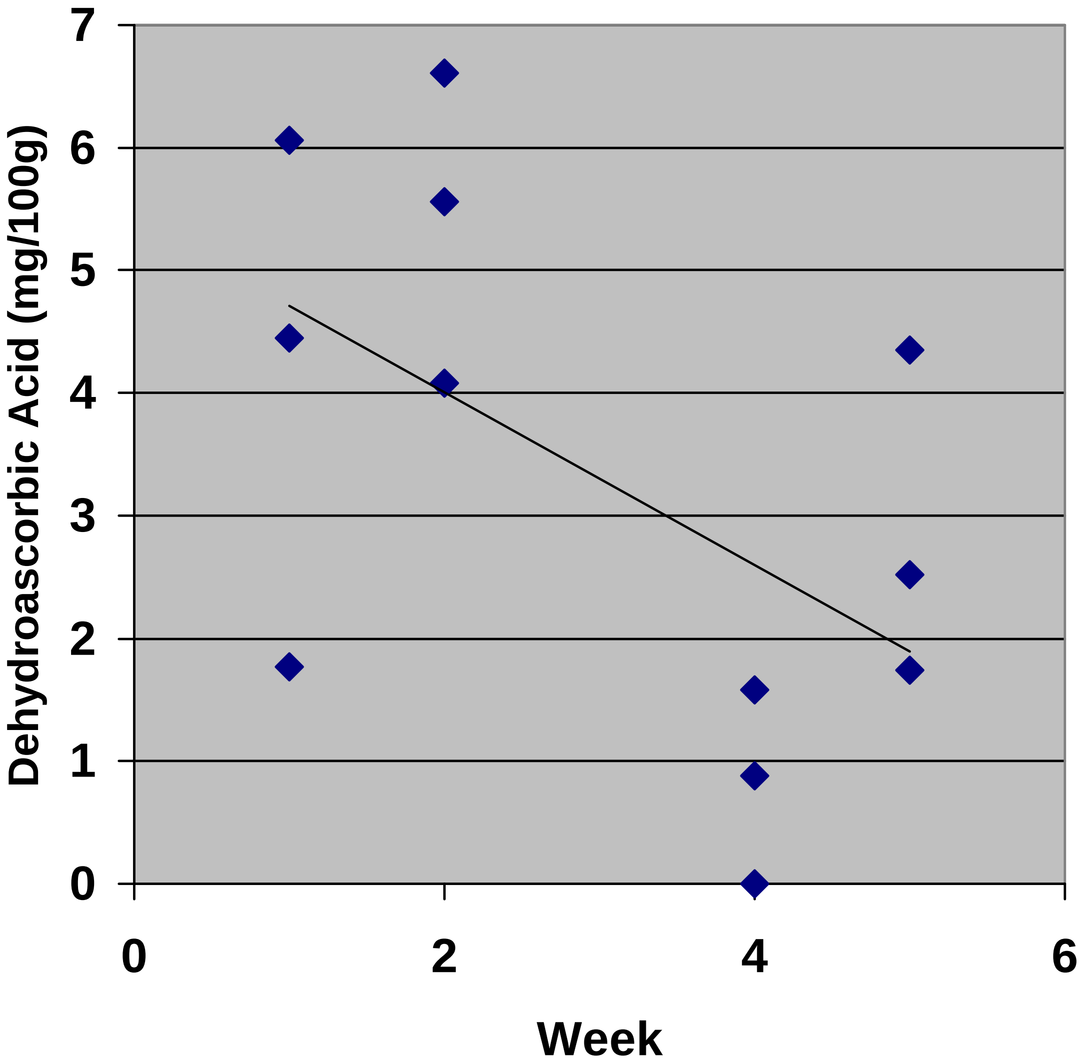

Figure 5.19: Linear relationship of dehydroascorbic acid (DHA) content in maltodextrin coated green bell peppers ($p<0.01$) for weeks 1, 2, 4, and 5. Each point represents one sample mean taken on the designated week.

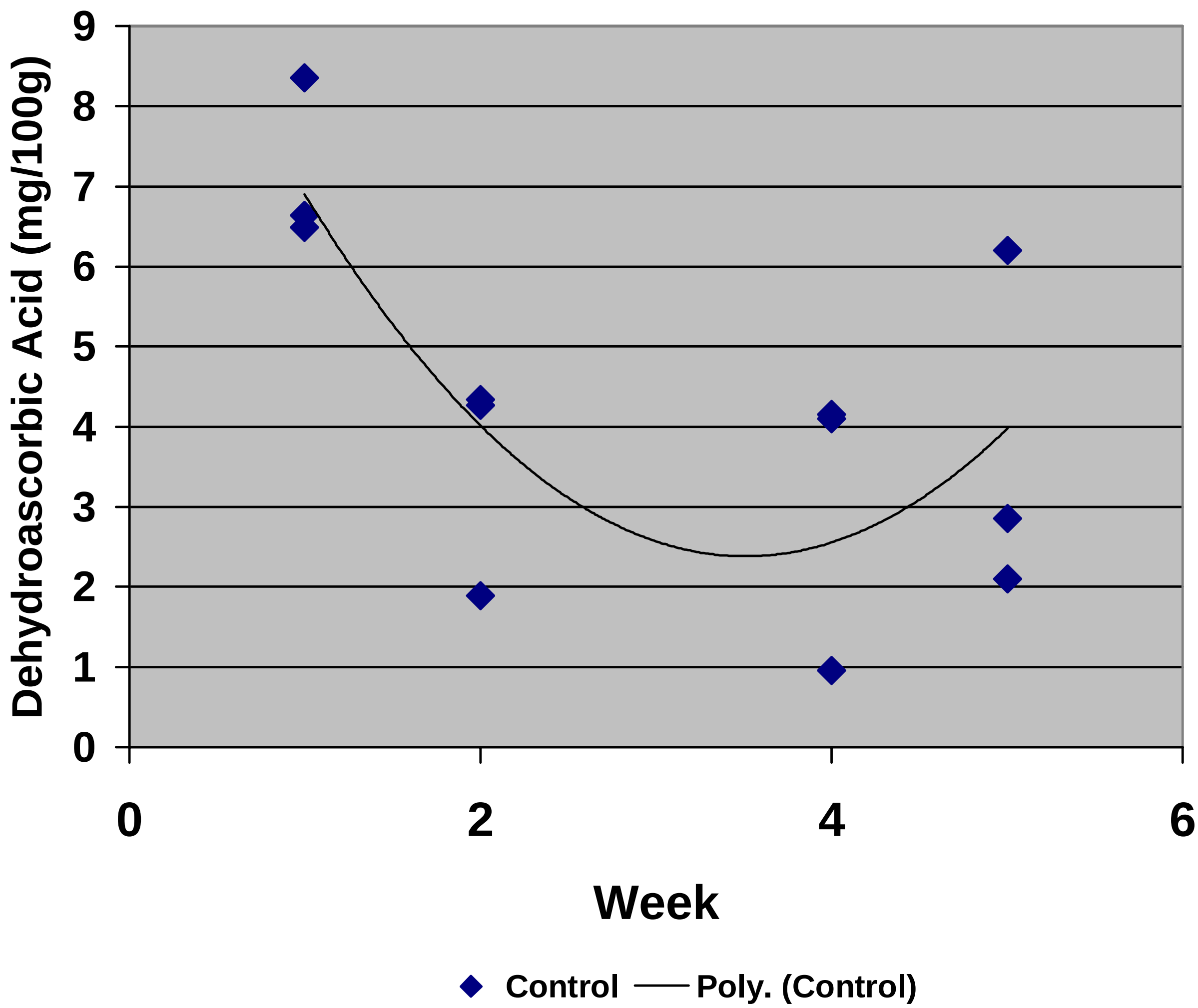

Figure 5.20: Quadratic relationship between experimental weeks 1, 2, 4, and 5 and dehydroascorbic acid (DHA) content of control green bell peppers ($p<0.05$). Each point represents one sample mean taken on the designated week.

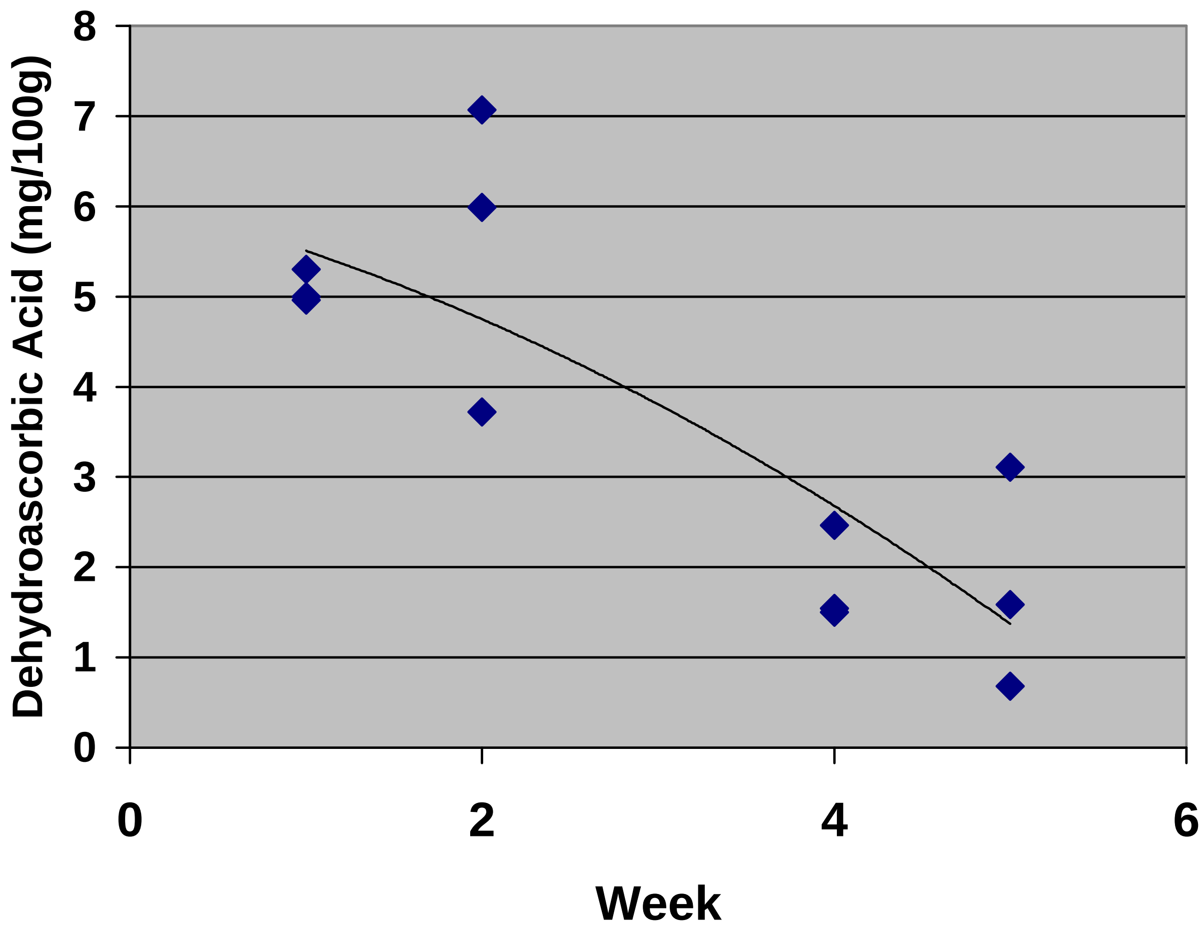

Figure 5.21: Quadratic relationship between experimental weeks 1, 2, 4 and 5 and dehydroascorbic acid (DHA) content of locust bean gum coated peppers ($p<0.05$). Each point represents one sample mean taken on the designated week.

Overall, the lack of correlation between AA and DHA may have indicated that decreases in AA content were not directly related to increases in DHA. The fact that DHA is able to change into both AA and DKG may account for the lack of direct correlation between AA and DHA content. In addition, possible continued synthesis of AA may also alter the relationship. If AA content is synthesized, the corresponding amount of DHA may also continue to increase due to the greater availability of AA to be broken down.