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**TECHNICAL REPORT  
NATICK/TR-98/023**

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# **NUTRIENT ENHANCEMENT OF FRUIT AND EFFECTS OF STORAGE CONDITIONS**

by  
**Joseph Cohen  
and  
Jeff Tucker**

**May 1998**

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## PREFACE

This report describes a test conducted over a 12 month period with two osmotically dried commercial fruit products (pitted cherries, mango-flavored apple cubes) that had been nutrient enhanced with the addition of either folic acid or zinc (Zn) and magnesium (Mg). The products were prepared by the CherryCentral Co., Traverse City, MI. The data for this report were collected by investigators from the US Army Soldier Systems Command (SSCOM), Natick Research, Development and EngineeringCenter (NRDEC) from 1 June 1997 to 1 May 1998.

The products were stored at 40, 70 and 100 °F (4, 21 and 38 °C). They were tested for percent moisture, water activity ( $A_w$ ) and Hunter reflectance color (L, a and b) at storage times of one, three, six, nine and twelve months as well as initially with no storage. The folic acid content was measured at each withdrawal. Zn and Mg were measured at the initial time and after one month of storage.

In addition, sensory testing for overall acceptability, color, flavor and texture was conducted by the Natick untrained consumer panel for both the unstored products and the products that had been stored for one month at 120 °F (49 °C). The Natick trained technical panel also evaluated the products for appearance, odor, flavor, texture and overall acceptability, after one month storage at 120 °F. Finally the products were subjected to a field test for acceptability by untrained soldiers.

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# **NUTRIENT ENHANCEMENT OF FRUIT AND EFFECTS OF STORAGE CONDITIONS**

## **INTRODUCTION**

The military services have a need for low and intermediate moisture foods of good nutrition and high sensory acceptability with a reduced cost of processing. Such foods will deliver a high density of nutrients, calories, etc. Osmotic dehydration is such a low cost operation that has many advantages. The infusion of additional nutrients, such as vitamins and minerals, into the food during the osmotic drying will further enhance the dried rations. The products would be processed at lowered temperatures, thus enhancing the sensory acceptability. Because of the lowered processing temperatures there would be less nutrient loss.

Cohen and Yang previously studied (1995) the most important parameters that affect the drying process. They also demonstrated the feasibility of infusing nutrients into the food. They determined that osmotic drying and nutrient infusion would be a viable process for the military to use in the preparation of high quality foods.

Cohen, Yang and Atwood studied (1997) the storage stability of six commercial osmotically dried fruit products that had been purchased from the CherryCentral Co. They determined that these products would have high acceptability. However, the commercial package was not acceptable as it allowed the transmission of vapor. The products tended to dry out with time, and other changes occurred.

The purpose of this study was to determine the acceptability of osmotically dried, nutrient enhanced fruit (whole pitted cherries and mango-flavored apple cubes) at various storage conditions, including a vapor resistant package.

## **PRODUCTS AND METHODS**

### **A. Fruit Products**

The products and their ingredients are listed by code letter in Table 1.

The nutrients (folic acid, magnesium (Mg) and zinc (Zn)) were chosen for infusion after consultation with the Natick Nutritional Group and with the persons involved in preparing the military rations. It is difficult to meet the requirements for these nutrients in current military rations.

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**TABLE 1 - FRUIT PRODUCTS AND INGREDIENTS**

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<b>Code</b>	<b>Product with Description</b>
<b>CV</b>	<b>Cherries with added folic acid</b> Whole, pitted cherries, approximately 0.5 - 0.75 in (1.2 - 1.8 cm). Ingredients - cherries, sugar, sunflower oil, folic acid
<b>CM</b>	<b>Cherries with added magnesium and zinc</b> Same as C-V but added magnesium and zinc and no folic acid
<b>AV</b>	<b>Mango flavored apple cubes with added folic acid</b> Cubed, peeled apples, approximately 0.25 in (0.6 cm) Ingredients - apples, high fructose corn syrup, ascorbic and citric acid, (to maintain color), salt, natural flavors, color added, sunflower oil
<b>AM</b>	<b>Mango flavored apple cubes with added magnesium and zinc</b> Same as A-V but added magnesium and zinc and no folic acid

---

#### **B. Method of Manufacture**

All the products were prepared from fresh fruit by initially drying by osmosis in a concentrated (42 Brix) sucrose/fructose solution in a temperature-controlled kettle at 13 °C (55 °F) for 24 hours. The fruit was then drained and placed in a convection dryer at 79 °C (175 °F) for 4 hours. A small amount of sunflower oil was added as a processing aid to keep the products free flowing.

All the products were packaged in clear laminated film supplied by the American National Can Co. to the following specifications.

MVTR (moisture vapor transmission rate) - 0.3 g/100 sq in /24 h at 100 °F and 90% relative humidity. Oxygen transmission - 0.6 cc/100 sq in /24 h and 0% relative humidity.

#### **C. Storage**

The products were all stored at 40, 70 and 100 °F (4, 21 and 38 °C) as well as a smaller quantity at 120 °F (49 °C) accelerated storage. It is generally accepted that one month of storage at 120 °F is equivalent to three years at 80 °F (ambient temperature).

## **D. Testing**

### **1. Sensory Measurements**

#### **a. Consumer Panel**

Testing was done at Natick by the regular untrained consumer panel consisting of 36 - 37 participants. All four products were tested at the same time. The panelists evaluated the flavor, texture and color, as well as the overall acceptability, using a 9-point hedonic scale ranging from 1-dislike extremely to 9-like extremely, with 5-neither like nor dislike. They were also asked to comment on the the products. The testing was done with unstored fruit and repeated with fruit that had been stored for one month at 120 °F.

#### **b. Technical Panel**

Testing was done at Natick by the regular, trained technical panel consisting of 15 panelists. All four products were tested at the same time. The panelists evaluated the appearance, odor, flavor, texture and overall acceptability using the same 9-point hedonic scale as the consumer panel.

#### **c. Field Test**

This testing was done at Twentynine Palms Marine Base in California. Approximately 50 soldiers tested the four products as part of a study being done to determine the acceptability of Meal-Ready-To-Eat (MRE) components. The fruits were rated only for overall acceptability.

## **E. Physical Measurements**

### **1. Percent Moisture**

The percent moisture was determined with a Computrac Max-50™ radiant heating moisture analyzer with the temperature set at 150 °C (302 °F). A single measurement was made.

### **2. Water Activity**

Water activity was measured using an Aqua Lab Model CX-2™ instrument. All readings were done in duplicate.

### **3. Reflectance Color**

A Pacific Systems Spectrogard Reflectometer, Model 96™, was used for these measurements. Measurements were made through a 2.2 cm (7/8 in) viewing window. Quadruplicate readings were made for each sample. Hunter "L", "a" and "b" measurements were made. A greater "L" indicates a lighter color, a greater negative "a" indicates more red, less green, and a greater "b" indicates more yellow, less blue.

## RESULTS AND DISCUSSION

### A. Sensory

#### 1. Consumer Panel

The results of both tests (at zero storage time and 1 month at 120 ° F are presented in Table 2.

**TABLE 2 - SENSORY EVALUATION OF NUTRIENT INFUSED FRUIT  
(CONSUMER PANEL)**

	Characteristic							
	Overall	Flavor		Color		Texture		
		Storage Time						
	Init.	1 Mo.	Init.	1 Mo.	Init.	1 Mo.	Init.	1 Mo.
Cherries - CV	6.6	6.1	6.5	5.9	6.9	6.4	7.1	6.2
SD	1.7	1.8	1.7	1.9	1.3	1.8	1.2	1.9
Cherries - CM	6.8	6.1	6.4	6.1	7.1	6.5	7.3	6.4
SD	1.6	2.0	1.9	2.0	1.2	1.7	1.2	1.7
Cherries - CO*	6.9	5.6	6.8	6.4	6.8	6.2	7.2	6.5
SD	1.8	1.7	1.9	1.7	1.6	2.0	1.3	1.6
Mango Apples - AV	6.3	6.2	6.6	6.3	6.4	6.1	5.9	6.1
SD	1.7	1.7	1.7	1.7	1.3	1.6	1.6	1.7
Mango Apples - AM	5.7	5.8	5.9	5.8	6.5	6.1	5.2	6.1
SD	1.9	1.7	1.8	1.9	1.2	1.5	1.2	1.5
Mango Apples - AO*	5.7	6.2	5.8	4.6	6.3	5.2	5.3	4.6
SD	1.9	1.6	1.7	1.8	1.6	1.8	2.2	1.8

\* For comparison the scores are compared here with fruit identically prepared but without nutrient addition and tested earlier. Cohen, Yang, et al, (1997).

There was no difference between the treatments or the storage time. All the scores are quite acceptable (a rating greater than 5.0).

#### 2. Technical Panel

These results are presented in Table 3.

**TABLE 3 - SENSORY EVALUATION OF NUTRIENT INFUSED FRUIT  
(TECHNICAL PANEL)**

	Characteristic										
	Overall	Odor				Flavor		Texture		Appear.	
		Storage Time									
	Init.	1 Mo.	Init.	1 Mo.	Init.	1 Mo.	Init.	1 Mo.	Init.	1 Mo.	
Cherries - CV	7.1	6.6	6.6	6.6	6.9	6.6	6.9	7.0	6.9	6.8	
SD	0.7	0.9	0.9	0.9	1.2	1.4	1.0	1.0	0.9	1.2	
Cherries - CM	7.2	6.5	7.0	6.7	6.8	6.5	7.2	6.7	7.0	6.5	
SD	0.9	1.0	0.8	1.0	1.1	1.2	0.8	1.0	0.9	1.2	
Apples - AV	6.7	5.9	6.5	6.3	6.9	6.0	6.7	6.4	6.8	6.0	
SD	1.0	0.9	1.4	1.2	0.9	0.9	1.2	1.1	1.1	1.0	

The mineral infused apples were not tested.

There was no difference between the treatments or the storage time. All the scores were quite acceptable (rating well above 5.0).

### 3. Military Field Test

These results are presented in Table 4.

**TABLE 4 - SENSORY EVALUATION OF NUTRIENT INFUSED FRUIT  
(FIELD TEST)**

<u>PRODUCT</u>	<u>NO. OF PANELISTS</u>	<u>SCORE</u>	<u>ST. DEV.</u>
AV	14	7.4	1.5
AM	5	7.0	1.6
CV	29	7.3	2.4
CM	17	7.4	1.9

All the products were highly rated. There was no significant difference between either the two apple products or the two cherry products.

### B. Physical Analyses

The data for the physical analyses are in Tables A-1 to A-10 which are in Appendix A. The data is also plotted in Figures B-1 - B-28 which are in Appendix B.

Because there was some uncertainty in the results due to sampling and the important information is in the overall trends, the data was "smoothed" by taking the median of three consecutive values. This smoothed data is shown in the Figures. Both the actual data and the smoothed data (in parentheses) are presented in the Tables.

The smoothed data for all the physical analyses were also subjected to Analysis of Variance data analysis. This information is presented in Table 10 in Appendix C.

Because there is virtually no significance in the data, it was thought to be more informative to look at the Figures and to report results based on that.

#### 1. Percent Moisture

These results are shown in Tables A-1 and A-2 and illustrated in Figures B-1 to B-4. As indicated there is a large decrease in the moisture content with increased storage time. The apples' moisture drops to almost zero after 3 months of storage at 70 and 100 °F. The cherries' drop in moisture is less abrupt than with the apples, but it still occurs. This difference is because the apples have a much greater surface than the cherries. At 40 °F, the moisture is held better than at the higher temperatures. The barrier material retains the moisture better than the transparent commercial pouch.

## **2. Water Activity**

These results are shown in Table A-3 to A-4 and illustrated in Figures B-5 to B-8. The water activity changes are similar to the change in the moisture content, as expected. With apples, the water activity dropped considerably after 6 months. With cherries, the water activity has held up well through 12 months except at 100 °F storage in the commercial pouch. With both the apples and cherries there is a decrease in water activity with increased storage temperature and storage time with the commercial pouch. This same decrease does not occur with the barrier pouch.

## **3. Reflectance Color**

### **a. Hunter "L"**

A decreased value indicates a darkening of the products. There is a distinct decrease in these values with increased storage time for the apples at the storage temperature of 100 °F in both pouches. The vitamin-fortified apples have only slightly darkened with time at the lower temperatures. The mineral-fortified apples have also held up well at the lower storage temperatures, except for those stored at 70 °F in the commercial pouch. The data are shown in Table A-5 to A-6 and illustrated in Figures B-9 - B-12.

### **b. Hunter "a"**

A greater negative value indicates more red, less green in the sample. The apple values at 40 and 70 °F storage all slightly decreased with time indicating a reddening. At 100 °F storage, the values increased indicating a loss of the red pigment. With the cherries there was an initial increase in red through 3 months of storage and then the values tended to level off. The data are shown in Table A-7 to A-8 and illustrated in Figures B-13 to B-16.

### **c. Hunter "b"**

A greater value indicates more yellow, less blue in the sample. There is an apparent decrease in the "b" value with time with both products at all temperature conditions, indicating loss of yellow coloration. This is particularly noticeable at 100 °F storage. It is also more noticeable with the apples. The data is shown in Table 9 and illustrated in Figures 13 - 20.

Since the color changes do not appear to be affected strongly by the pouch material, the changes are related to the storage temperature, rather than the loss of moisture.

### C. Nutrient Analyses

All the products were analyzed initially and after one month of storage for folic acid and Mg and Zn. These analyses were done under contract using the standard AOAC method which utilizes bacterial growth. These data are presented in Table 5. The data is illustrated in Figures B-21 -to B-26. All the data are transformed to 100% dryness.

As expected, the mineral content did not appreciably change with temperature. Consequently, no further mineral analyses were done.

The folic acid content did decrease with temperature after an initial increase. There was no difference between the two pouch materials. Since the AOAC method used is a bacterial (Streptococcus faecalis) growth method we thought the initial increase to be an artifact of the method and subsequent analyses were done employing high pressure liquid chromatography (HPLC). This consisted of a reverse phase phenyl column using UV detection at 280 nm with an 11:89 (acetonitrile/0.33 M phosphate buffer adjusted to pH 2.3) mobile phase. Folic acid eluted in approximately 10 minutes at a flow rate of 1 ml/min. This data is presented in Table 6.

With apples, the folic acid content did not change before nine months of storage, at which time it did decrease. It also did not change between 40 and 70 °F storage, but did decrease at 100 °F storage. There was no difference due to the packing material. With cherries, the folic acid content did increase between three and six months of storage. There was a decrease of folic acid with the temperature of storage. There was no significant difference between the two types of packages.

The large difference between the initial and later analyses possibly may be attributed to the method used. (Military requirements for future procurements will probably require that the AOAC method be used.)

TABLE 5 - NUTRIENT ANALYSIS FOR INITIAL AND ONE MONTH STORAGE

<u>Product</u>	<u>Package</u>	<u>Storage Time</u> <u>Months</u>	<u>Storage Temp.</u> <u>Degrees F</u>	<u>Concentration</u>
A. Folic Acid				
Apples	NA	0	NA	1,084 *
Apples	transparent	1	40	1,582
Apples	transparent	1	70	1,420
Apples	transparent	1	100	1,126
Apples	transparent	1	120	526
Apples	barrier	1	40	1,406
Apples	barrier	1	70	1,451
Apples	barrier	1	100	1,163
Apples	barrier	1	120	346
Cherries	NA	0	NA	872
Cherries	transparent	1	40	1,047
Cherries	transparent	1	70	746
Cherries	transparent	1	100	316
Cherries	transparent	1	120	203
Cherries	barrier	1	40	1,105
Cherries	barrier	1	70	913
Cherries	barrier	1	100	325
Cherries	barrier	1	120	197
* µg/100g				
B. Magnesium (Mg)				
Apples	NA	0	NA	601 **
Apples	transparent	1	40	622
Apples	transparent	1	70	616
Apples	transparent	1	100	620
Apples	transparent	1	120	603
Apples	barrier	1	40	643
Apples	barrier	1	70	634
Apples	barrier	1	100	614
Apples	barrier	1	120	602
Cherries	NA	0	NA	596
Cherries	transparent	1	40	614
Cherries	transparent	1	70	575
Cherries	transparent	1	100	573
Cherries	transparent	1	120	619
Cherries	barrier	1	40	582
Cherries	barrier	1	70	577
Cherries	barrier	1	100	567
Cherries	barrier	1	120	610

\*\* mg/100g

**TABLE 5 - NUTRIENT ANALYSIS FOR INITIAL AND ONE MONTH STORAGE**  
(Continued)

C. Zinc (Zn)

Apples	NA	0	NA	22**
Apples	transparent	1	40	23
Apples	transparent	1	70	23
Apples	transparent	1	100	25
Apples	transparent	1	120	21
Apples	barrier	1	40	23
Apples	barrier	1	70	24
Apples	barrier	1	100	23
Apples	barrier	1	120	21
Cherries	NA	0	NA	75
Cherries	transparent	1	40	77
Cherries	transparent	1	70	73
Cherries	transparent	1	100	73
Cherries	transparent	1	120	78
Cherries	barrier	1	40	75
Cherries	barrier	1	70	73
Cherries	barrier	1	100	72
Cherries	barrier	1	120	81

\*\* mg/100g

---

The data for the folic acid analyses after storage times of 3, 6, 9 and 12 months is shown in Table 10. It is also shown in Figures 27 to 28. The smoothed data is shown in parentheses.

**TABLE 6 - FOLIC ACID ANALYSIS FOR THREE TO TWELVE MONTHS STORAGE**

<u>Product</u>	<u>Storage Time,</u> <u>months</u>	<u>Storage Temp.,</u> <u>degrees. F</u>	<u>Conc. (µg/100g) with pouch</u>	
			<u>transparent</u>	<u>barrier</u>
Apples	3	40	14,000 (15,400)	13,000 (14,200)
Apples	3	70	14,700 (14,700)	15,000 (16,700)
Apples	3	100	13,000 (13,100)	12,000 (13,200)
Apples	6	40	15,500 (15,400)	16,100 (14,200)
Apples	6	70	15,000 (14,700)	14,700 (14,700)
Apples	6	100	12,400 (12,400)	10,400 (10,400)
Apples	9	40	11,800 (12,300)	11,600 (13,200)
Apples	9	70	10,000 (10,200)	10,300 (10,300)
Apples	9	100	8,000 (8,400)	7,000 (7,200)
Apples	12	40	12,300 (11,800)	13,200 (11,600)
Apples	12	70	10,200 (10,000)	10,300 (10,300)
Apples	12	100	8,400 (8,000)	7,200 (7,000)
Cherries	3	40	19,000 (19,000)	21,500 (21,500)
Cherries	3	70	18,500 (18,500)	19,900 (19,900)
Cherries	3	100	18,900 (18,900)	17,100 (17,100)
Cherries	6	40	11,800 (12,700)	16,000 (16,000)
Cherries	6	70	11,100 (11,100)	11,900 (11,900)
Cherries	6	100	8,000 (9,300)	8,500 (8,500)
Cherries	9	40	12,700 (12,700)	15,900 (15,900)
Cherries	9	70	10,100 (10,100)	11,400 (11,400)
Cherries	9	100	9,300 (9,300)	7,100 (7,100)
Cherries	12	40	15,600 (12,700)	16,800 (15,900)
Cherries	12	70	16,700 (9,300)	16,100 (7,100)
Cherries	12	100	14,400 (14,400)	16,200 (11,400)

**CONCLUSIONS**

Two nutrient enhanced fruit products have been prepared. They have shown to be highly acceptable by technical and consumer panels and by soldiers in a field test.

The commercial package is not acceptable for long term storage, particularly at elevated temperatures, but the military foil barrier package is. The quality parameters, water activity, moisture content and reflectance color change on storage.

The mineral content is stable. The folic acid content does change on storage, particularly with storage temperature.

## RECOMMENDATIONS

The fruit products, cherries and mango flavored apple cubes, with added nutrients should be incorporated with the MRE rations.

Additional products might be studied for acceptability i.e. blueberries, strawberries, different flavored apple cubes.

Future studies can determine the effectiveness of the addition of other nutrients, i.e. vitamin B12, calcium (Ca).

This document reports research undertaken at the U.S. Army Soldier Systems Command, Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-98/023 in the series of reports approved for publication.

## REFERENCES

- Cohen, Joseph and Yang, Tom. C.S. Sept. 1995. Osmotic Dehydration and Its Applications in Nutrient Infusion of Various Foods. Technical Report, US Army, Natick Research, Development and Engineering Center, TR-95/034
- Cohen, Joseph, Yang, Tom, C.S. and Atwood, Bonita. Apr. 1997. Storage Stability of Six Osmotically Dried, Commercial Fruit Products. Technical Report, US Army, Natick Research, Development and Engineering Center, TR-97/01

**APPENDIX A - DATA FOR PHYSICAL ANALYSES**

TABLE A-1 - PERCENT MOISTURE OF NUTRIENT INFUSED APPLE CUBES

<u>INFUSANT</u>	<u>PACKAGE</u>	<u>STORAGE</u> <u>TEMP. °F</u>	<u>STORAGE TIME, MONTHS</u>					
			<u>0</u>	<u>1</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>12</u>
minerals	transparent	40	(6.0) 6.0	(6.8) 6.8	(6.8) 8.9	(6.4) 4.2	(4.4) 6.4	(4.4) 4.4
minerals	transparent	70	(6.0) 6.0	(7.4) 7.4	(7.4) 7.9	(0.3) 0.3	(0.2) 0.2	(0.2) 0.2
minerals	transparent	100	(6.0) 6.0	(6.0) 6.0	(0.3) 0.3	(0.2) 0.2	(0.2) 0.1	(0.2) 0.2
minerals	barrier	40	(6.0) 6.0	(7.7) 8.2	(7.7) 7.7	(4.7) 3.7	(4.7) 3.7	(4.7) 4.7
minerals	barrier	70	(6.0) 6.0	(6.8) 6.8	(6.8) 7.4	(0.4) 0.2	(0.4) 0.4	(0.4) 5.7
minerals	barrier	100	(6.0) 6.0	(6.0) 7.1	(5.2) 5.2	(0.5) 0.4	(0.5) 0.5	(0.5) 4.6
vitamins	transparent	40	(7.0) 7.0	(7.0) 8.6	(7.0) 7.0	(7.0) 0.3	(7.7) 7.7	(8.2) 8.2
vitamins	transparent	70	(7.0) 7.0	(7.0) 6.9	(6.9) 8.2	(0.2) 0.2	(0.2) 0.2	(0.2) 0.3
vitamins	transparent	100	(7.0) 7.0	(5.0) 5.0	(0.3) 0.3	(0.2) 0.2	(0.2) 0.1	(0.2) 0.2
vitamins	barrier	40	(7.0) 7.0	(7.2) 10.1	(7.2) 7.2	(6.1) 5.0	(6.1) 6.1	(6.1) 6.9
vitamins	barrier	70	(7.0) 7.0	(8.5) 9.4	(8.5) 8.5	(5.0) 5.0	(0.1) 0.1	(0.1) 0.1
vitamins	barrier	100	(7.0) 7.0	(7.6) 7.6	(7.6) 8.0	(0.3) 0.3	(0.3) 0.3	(0.2) 0.2

**Table A-2 - PERCENT MOISTURE OF NUTRIENT INFUSED CHERRIES**

INFUSANT	PACKAGE	STORAGE TEMP. °F	STORAGE TIME, MONTHS					
			0	1	3	6	9	12
minerals	transparent	40	(21.8)	(25.1)	(25.1)	(18.0)	(18.0)	(18.0)
			21.8	25.1	29.7	15.7	18.0	19.0
minerals	transparent	70	(21.8)	(21.8)	(21.8)	(20.9)	(18.0)	(18.0)
			21.8	21.8	23.1	10.7	20.9	18.0
minerals	transparent	100	(21.8)	(23.3)	(23.3)	(0.3)	(0.1)	(0.1)
			21.8	23.8	23.3	0.3	0.1	0.1
minerals	barrier	40	(21.8)	(22.7)	(22.7)	(17.5)	(17.5)	(17.5)
			21.8	22.7	26.5	13.7	17.5	18.6
minerals	barrier	70	(21.8)	(23.8)	(23.8)	(21.9)	(16.3)	(15.2)
			21.8	23.8	27.8	16.3	21.9	15.2
minerals	barrier	100	(21.8)	(21.8)	(20.6)	(17.4)	(17.4)	(17.4)
			21.8	20.6	23.5	15.4	17.4	19.9
vitamins	transparent	40	(22.0)	(21.4)	(21.1)	(15.6)	(15.0)	(15.0)
			22.0	21.1	21.4	5.3	15.6	15.0
vitamins	transparent	70	(22.0)	(19.5)	(18.7)	(18.0)	(15.8)	(14.4)
			22.0	19.5	18.0	18.7	14.4	15.8
vitamins	transparent	100	(22.0)	(19.3)	(15.3)	(0.4)	(0.2)	(0.2)
			22.0	15.3	19.3	0.4	0.2	0.2
vitamins	barrier	40	(22.0)	(21.2)	(20.9)	(14.9)	(14.9)	(14.9)
			22.0	20.9	21.2	8.4	14.9	16.1
vitamins	barrier	70	(22.0)	(22.0)	(19.50)	(15.9)	(15.0)	(12.9)
			22.0	24.1	19.5	15.0	15.9	12.9
vitamins	barrier	100	(22.0)	(18.9)	(18.0)	(17.6)	(15.6)	12.1)
			22.0	18.9	17.6	18.0	12.1	15.6

**Table A-3 - WATER ACTIVITY OF NUTRIENT INFUSED APPLE CUBES**

<u>INFUSANT</u>	<u>PACKAGE</u>	<u>STORAGE</u> <u>TEMP. °F</u>	<u>STORAGE TIME, MONTHS</u>					
			<u>0</u>	<u>1</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>12</u>
minerals	transparent	40	(0.33) 0.33	(0.38) 0.38	(0.43) 0.43	(0.43) 0.44	(0.44) 0.34	(0.44) 0.45
minerals	transparent	70	(0.33) 0.33	(0.38) 0.39	(0.38) 0.38	(0.38) 0.46	(0.46) 0.31	(0.46) 0.48
minerals	transparent	100	(0.33) 0.33	(0.36) 0.38	(0.38) 0.36	(0.38) 0.42	(0.42) 0.26	(0.42) 0.43
minerals	barrier	40	(0.33) 0.33	(0.36) 0.36	(0.42) 0.43	(0.42) 0.42	(0.42) (0.31)	(0.42) 0.43
minerals	barrier	70	(0.33) 0.33	(0.37) 0.37	(0.39) 0.39	(0.39) 0.44	(0.44) 0.34	(0.44) 0.51
minerals	barrier	100	(0.33) 0.33	(0.45) 0.45	(0.47) 0.47	(0.47) 0.50	((0.50) 0.44	(0.51) 0.51
vitamins	transparent	40	(0.37) 0.37	(0.40) 0.40	(0.43) 0.43	(0.43) 0.48	(0.48) 0.40	(0.48) 0.52
vitamins	transparent	70	(0.37) 0.37	(0.39) 0.39	(0.42) 0.42	(0.42) 0.48	(0.48) 0.36	(0.48) 0.52
vitamins	transparent	100	(0.37) 0.37	(0.37) 0.39	(0.37) 0.36	(0.37) 0.43	(0.43) 0.29	(0.43) 0.51
vitamins	barrier	40	(0.37) 0.37	(0.39) 0.41	(0.39) 0.39	(0.39) 0.47	(0.47) 0.38	(0.47) 0.47
vitamins	barrier	70	(0.37) 0.37	(0.39) 0.39	(0.41) 0.41	(0.41) 0.47	(0.41) 0.34	(0.47) 0.49
vitamins	barrier	100	(0.37) 0.37	(0.40) 0.44	(0.40) 0.40	(0.40) 0.51	(0.50) 0.35	(0.50) 0.50

Table A-4 - WATER ACTIVITY OF NUTRIENT INFUSED CHERRIES

<u>INFUSANT</u>	<u>PACKAGE</u>	<u>STORAGE</u> <u>TEMP. °F</u>	<u>STORAGE TIME, MONTHS</u>					
			<u>0</u>	<u>1</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>12</u>
minerals	transparent	40	(0.44) 0.44	(0.44) 0.47	(0.45) 0.41	(0.45) 0.49	(0.49) 0.45	(0.49) 0.50
minerals	transparent	70	(0.44) 0.44	(0.45) 0.47	(0.45) 0.45	(0.45) 0.50	(0.49) 0.4	(0.49) 0.49
minerals	transparent	100	(0.44) 0.44	(0.44) 0.47	(0.44) 0.41	(0.41) 0.46	(0.41) 0.30	(0.41) 0.41
minerals	barrier	40	(0.44) 0.44	(0.47) 0.48	(0.47) 0.47	(0.47) 0.50	(0.50) 0.44	(0.50) 0.50
minerals	barrier	70	(0.44) 0.44	(0.47) 0.47	(0.47) 0.47	(0.47) 0.50	(0.50) 0.45	(0.50) 0.51
minerals	barrier	100	(0.44) 0.44	(0.47) 0.49	(0.47) 0.47	(0.47) 0.44	(0.47) 0.47	(0.47) 0.56
vitamins	transparent	40	(0.42) 0.42	(0.46) 0.46	(0.46) 0.46	(0.49) 0.49	(0.50) 0.50	(0.50) 0.50
vitamins	transparent	70	(0.42) 0.42	(0.44) 0.44	((0.44) 0.44	(0.44) 0.49	(0.49) 0.43	(0.49) 0.51
vitamins	transparent	100	(0.42) 0.42	(0.42) 0.42	(0.42) 0.39	(0.41) 0.48	(0.41) 0.27	(0.41) 0.41
vitamins	barrier	40	(0.42) 0.42	(0.45) 0.45	(0.46) 0.46	(0.46) 0.49	(0.48) 0.44	(0.49) 0.49
vitamins	barrier	70	(0.42) 0.42	(0.45) 0.47	(0.45) 0.45	(0.45) 0.50	(0.50) 0.40	(0.50) 0.51
vitamins	barrier	100	(0.42) 0.42	(0.46) 0.48	(0.47) 0.46	(0.47) 0.47	(0.49) 0.49	(0.49) 0.56

Table A-5 - HUNTER "L" REFLECTANCE COLOR OF NUTRIENT INFUSED APPLE CUBES

<u>INFUSANT</u>	<u>PACKAGE</u>	<u>STORAGE</u>	<u>STORAGE TIME, MONTHS</u>					
			<u>TEMP. °F</u>	<u>0</u>	<u>1</u>	<u>3</u>	<u>6</u>	<u>9</u>
minerals	transparent	40	(41.9)	(44.8)	(44.8)	(44.8)	(44.8)	(44.8)
			41.9	49.8	44.8	45.5	44.7	45.8
minerals	transparent	70	(41.9)	(47.6)	(47.6)	(45.3)	(45.0)	(45.0)
			41.9	51.1	47.6	45.3	41.3	45.0
minerals	transparent	100	(41.9)	(47.5)	(47.5)	(45.5)	(40.3)	(37.1)
			41.9	47.9	47.5	45.5	40.3	37.1
minerals	barrier	40	(41.9)	(45.9)	(46.4)	(46.9)	(46.4)	(45.8)
			41.9	45.9	46.9	46.4	47.2	45.8
minerals	barrier	70	(41.9)	(45.3)	(45.3)	(45.3)	(46.3)	(46.3)
			41.9	48.3	45.3	44.8	46.3	47.0
minerals	barrier	100	(41.9)	(41.9)	(37.4)	(37.4)	(34.0)	(31.3)
			41.9	52.2	20.9	37.4	34.0	31.3
vitamins	transparent	40	(42.8)	(42.8)	(42.8)	(42.0)	(41.8)	(40.6)
			42.8	43.7	42.0	43.0	40.6	41.8
vitamins	transparent	70	(42.8)	(42.8)	(41.9)	(41.5)	(41.1)	(36.6)
			42.8	46.5	41.9	41.5	41.1	36.6
vitamins	transparent	100	(42.8)	(42.5)	(35.9)	(33.2)	(30.8)	(30.0)
			42.8	42.5	35.9	33.2	30.8	30.0
vitamins	barrier	40	(42.8)	(42.9)	(42.9)	(42.9)	(42.6)	(42.6)
			42.8	48.6	42.9	41.3	43.5	42.6
vitamins	barrier	70	(42.8)	(43.0)	(43.0)	(40.8)	(40.7)	(36.8)
			42.8	49.8	43.0	40.7	40.8	36.8
vitamins	barrier	100	(42.8)	(42.8)	(34.8)	(30.9)	(26.4)	(23.1)
			42.8	47.7	34.8	30.9	26.4	23.1

**Table A-6 - HUNTER "L" REFLECTANCE COLOR OF NUTRIENT INFUSED CHERRIES**

INFUSANT	PACKAGE	STORAGE TEMP. OF	STORAGE TIME, MONTHS					
			0	1	3	6	9	12
minerals	transparent	40	(21.8)	(21.8)	(20.4)	(19.0)	(17.4)	(16.7 )
			21.8	25.7	20.4	17.4	19.0	16.7
minerals	transparent	70	(21.8)	(21.8)	(21.0)	(19.8)	(19.3)	(18.7)
			21.8	27.7	21.0	19.8	19.3	18.7
minerals	transparent	100	(21.8)	(22.7)	(22.7)	(18.4)	(17.5)	(17.4)
			21.8	26.7	22.7	18.4	17.4	17.5
minerals	barrier	40	(21.8)	(21.8)	(20.9)	(18.9)	(18.9)	(18.1)
			21.8	26.3	20.9	18.9	18.1	19.8
minerals	barrier	70	(21.8)	(21.8)	(20.7)	(19.6)	(19.6)	(18.7)
			21.8	25.7	19.6	20.7	18.7	20.1
minerals	barrier	100	(21.8)	(22.3)	(22.3)	(19.2)	(19.2)	(19.2)
			21.8	27.4	22.3	19.2	18.4	19.2
vitamins	transparent	40	(22.0)	(22.0)	(21.0)	(18.2)	(17.4)	(13.3)
			22.0	26.2	21.0	17.4	18.2	13.3
vitamins	transparent	70	(22.0)	(22.0)	(20.4)	(18.9)	(18.8)	(16.5)
			22.0	25.7	20.4	18.8	18.9	16.5
vitamins	transparent	100	(22.0)	(22.0)	(21.6)	(16.8)	(16.8)	(14.3)
			22.0	28.7	21.6	16.8	14.3	17.1
vitamins	barrier	40	(22.0)	(22.0)	(20.5)	(17.1)	(17.1)	(16.9)
			22.0	25.8	20.5	17.1	16.9	18.9
vitamins	barrier	70	(22.0)	(22.0)	(19.6)	(18.8)	(18.7)	(17.4)
			22.0	25.7	19.6	18.8	17.4	18.7
vitamins	barrier	100	(22.0)	(22.0)	(20.9)	(17.9)	(17.9)	(16.2)
			22.0	27.0	20.9	17.9	16.2	18.3

**Table A-7 - HUNTER "a" REFLECTANCE COLOR OF NUTRIENT INFUSED APPLE CUBES**

INFUSANT	PACKAGE	STORAGE TEMP. °F	STORAGE TIME, MONTHS					
			0	1	3	6	9	12
minerals	transparent	40	(4.8)	(4.8)	(4.8)	(4.1)	(3.9)	(3.7)
			4.8	5.5	4.1	4.8	3.9	3.7
minerals	transparent	70	(4.8)	(4.4)	(3.7)	(3.5)	(3.5)	(3.4)
			4.8	4.4	3.7	3.5	3.4	3.8
minerals	transparent	100	(4.8)	(4.8)	(5.4)	(6.7)	(6.8)	(6.7)
			4.8	4.5	5.4	6.8	6.7	6.9
minerals	barrier	40	(4.8)	(4.8)	(4.7)	(4.7)	(4.7)	(4.7)
			4.8	4.8	3.8	4.7	4.8	4.0
minerals	barrier	70	(4.8)	(4.8)	(3.9)	(3.9)	(3.8)	(3.8)
			4.8	5.0	3.9	3.9	3.8	3.0
minerals	barrier	100	(4.8)	(5.3)	(6.1)	(7.1)	(7.1)	(7.1)
			4.8	5.3	6.1	7.1	7.6	6.7
vitamins	transparent	40	(6.5)	(5.5)	(5.2)	(5.2)	(5.2)	(5.2)
			6.5	5.5	5.1	5.2	5.6	4.9
vitamins	transparent	70	(6.5)	(6.5)	(6.2)	(6.2)	(6.4)	(6.4)
			6.5	6.7	6.0	6.2	6.4	6.5
vitamins	transparent	100	(6.5)	(7.5)	(7.9)	(8.6)	(8.6)	(8.5)
			6.5	7.9	7.5	8.9	8.6	8.5
vitamins	barrier	40	(6.5)	(5.9)	(5.7)	(5.3)	(5.3)	(5.0)
			6.5	5.9	5.1	5.7	5.3	5.0
vitamins	barrier	70	(6.5)	(6.0)	(5.7)	(5.7)	(5.7)	(5.4)
			6.5	6.0	4.9	5.7	6.2	5.4
vitamins	barrier	100	(6.5)	(6.3)	(7.5)	(7.5)	(6.7)	(6.0)
			6.5	6.3	7.5	8.1	6.7	6.0

Table A-8 - HUNTER "a" REFLECTANCE COLOR OF NUTRIENT INFUSED CHERRIES

INFUSANT	PACKAGE	STORAGE TEMP. °F	STORAGE TIME, MONTHS					
			0	1	3	6	9	12
minerals	transparent	40	(3.8)	(2.4)	(2.3)	(2.3)	(2.3)	(2.3)
			3.8	2.4	1.7	2.3	2.6	2.3
minerals	transparent	70	(3.8)	(2.4)	(1.5)	(1.5)	(1.3)	(1.0)
			3.8	2.4	1.5	1.5	1.3	1.0
minerals	transparent	100	(3.8)	(0.9)	(0.2)	(0.1)	(0.0)	(-0.2)
			3.8	0.9	0.2	0.0	0.1	-0.2
minerals	barrier	40	(3.8)	(2.5)	(2.0)	(2.0)	(2.0)	(1.7)
			3.8	2.5	1.7	2.0	2.3	1.7
minerals	barrier	70	(3.8)	(2.7)	(1.5)	(1.4)	(1.3)	(1.0)
			3.8	2.7	1.4	1.5	1.3	1.0
minerals	barrier	100	(3.8)	(1.1)	(0.2)	(0.1)	(-0.1)	(-0.2)
			3.8	1.1	0.2	0.1	-0.1	-0.2
vitamins	transparent	40	(3.1)	(2.2)	(1.9)	(1.9)	(2.3)	(2.3)
			3.1	2.2	1.7	1.9	2.3	2.4
vitamins	transparent	70	(3.1)	(2.9)	(1.3)	(1.3)	(1.3)	(1.1)
			3.1	2.9	1.2	1.3	1.4	1.1
vitamins	transparent	100	(3.1)	(1.1)	(0.1)	(0.1)	(0.1)	(-0.1)
			3.1	1.1	0.1	0.1	0.1	-0.1
vitamins	barrier	40	(3.1)	(2.1)	(1.9)	(1.7)	(1.7)	(1.6)
			3.1	2.1	1.7	1.9	1.7	1.6
vitamins	barrier	70	(3.1)	(2.4)	(1.7)	(1.4)	(1.3)	(1.3)
			3.1	2.4	1.7	1.3	1.4	1.0
vitamins	barrier	100	(3.1)	(1.3)	(0.1)	(0.1)	(0.0)	(-0.2)
			3.1	1.3	0.1	0.1	0.0	-0.2

**Table A-9 - HUNTER "b" REFLECTANCE COLOR OF NUTRIENT INFUSED APPLE CUBES**

INFUSANT	PACKAGE	STORAGE TEMP. °F	STORAGE TIME, MONTHS					
			0	1	3	6	9	12
minerals	transparent	40	(18.6)	(17.9)	(17.9)	(17.3)	(16.8)	(16.2)
			18.6	17.9	17.3	18.3	16.2	16.8
minerals	transparent	70	(18.6)	(17.1)	(16.5)	((16.5)	(16.3)	(14.2)
			18.6	16.5	17.1	16.5	14.2	16.3
minerals	transparent	100	(18.6)	(17.8)	(17.8)	(17.8)	(16.0)	(14.2)
			18.6	15.3	17.8	18.3	16.0	14.2
minerals	barrier	40	(18.6)	(17.6)	(17.6)	(17.6)	(17.1)	(17.1)
			18.6	15.0	17.6	16.8	18.7	17.1
minerals	barrier	70	(18.6)	(17.3)	(16.8)	(16.8)	(16.8)	(16.1)
			18.6	16.6	17.3	16.8	16.9	16.1
minerals	barrier	100	(18.6)	(16.8)	(15.7)	(14.3)	(13.0)	(10.3)
			18.6	15.7	16.8	14.3	13.0	10.3
vitamins	transparent	40	(18.7)	(17.5)	(17.5)	(17.5)	(16.8)	(16.8)
			18.7	15.1	17.5	18.2	16.8	17.1
vitamins	transparent	70	(18.7)	(17.5)	(17.5)	(17.5)	(16.8)	(15.7)
			18.7	16.8	17.5	18.0	16.8	15.7
vitamins	transparent	100	(18.7)	(13.4)	(13.4)	(13.4)	(12.3)	(11.7)
			18.7	12.9	13.4	14.7	12.3	11.7
vitamins	barrier	40	(18.7)	(18.0)	(18.0)	18.0)	(17.2)	(16.9)
			18.7	18.0	17.9	17.2	18.2	16.9
vitamins	barrier	70	(18.7)	(18.7)	(17.1)	(16.8)	(16.0)	(14.6)
			18.7	18.9	17.1	16.8	16.0	14.6
vitamins	barrier	100	(18.7)	(18.2)	(13.5)	(12.1)	(8.9)	(6.6)
			18.7	18.2	13.5	12.1	8.9	6.6

Table A-10 - HUNTER "b" - REFLECTANCE COLOR OF NUTRIENT INFUSED CHERRIES

<u>INFUSANT</u>	<u>PACKAGE</u>	<u>STORAGE</u> <u>TEMP. °F</u>	<u>STORAGE TIME, MONTHS</u>					
			<u>0</u>	<u>1</u>	<u>3</u>	<u>6</u>	<u>9</u>	<u>12</u>
minerals	transparent	40	(0.7) 0.7	(0.3) 0.3	(0.3) 0.3	(0.4) 0.4	(0.4) 0.4	(0.4) 0.8
minerals	transparent	70	(0.7) 0.7	(0.7) 0.8	(0.5) 0.4	(0.4) 0.5	(0.4) 0.4	(0.4) 0.5
minerals	transparent	100	(0.7) 0.7	(0.3) 0.3	(0.3) 0.00	(0.4) 0.6	(0.4) 0.4	(0.4) 0.7
minerals	barrier	40	(0.7 ) 0.7	(0.4) 0.4	(0.3) 0.3	(0.3) 0.3	(0.5) 0.5	(0.5) 0.5
minerals	barrier	70	(0.7) 0.7	(0.7) 0.7	(0.6) 0.2	(0.3) 0.6	(0.5) 0.3	(0.5) 0.5
minerals	barrier	100	(0.7) 0.7	(0.3) 0.3	(0.3) -0.1	(0.5) 0.7	(0.7) 0.5	(0.7) 0.7
vitamins	transparent	40	(0.8) 0.8	(0.3) 0.3	(0.3) 0.3	(0.3) 0.2	(0.3) 0.3	(0.3) 0.6
0.6vitamins	transparent	70	(0.8) 0.8	(0.4) 0.4	(0.3) 0.3	(0.3) 0.2	(0.2) 0.3	(0.2) 0.2
vitamins	transparent	100	(0.8) 0.8	(0.4) 0.4	(-0.1) -0.1	(-0.3) -0.3	(-0.3) -0.4	(-0.3) -0.2
vitamins	barrier	40	(0.8) 0.8	(0.2) 0.2	(0.1) -0.2	(0.1) 0.1	(0.1) 0.2	(0.1) 0.3
vitamins	barrier	70	(0.8) 0.8	(0.5) 0.5	(0.5) 0.5	(0.3) 0.3	(0.3) 0.1	(0.3) 0.4
vitamins	barrier	100	(0.8) 0.8	(0.2) 0.2	(-0.1) -0.2	(-0.2) -0.1	(-0.2) -0.2	(-0.2) -0.2

**APPENDIX B - FIGURES FOR PHYSICAL ANALYSES**

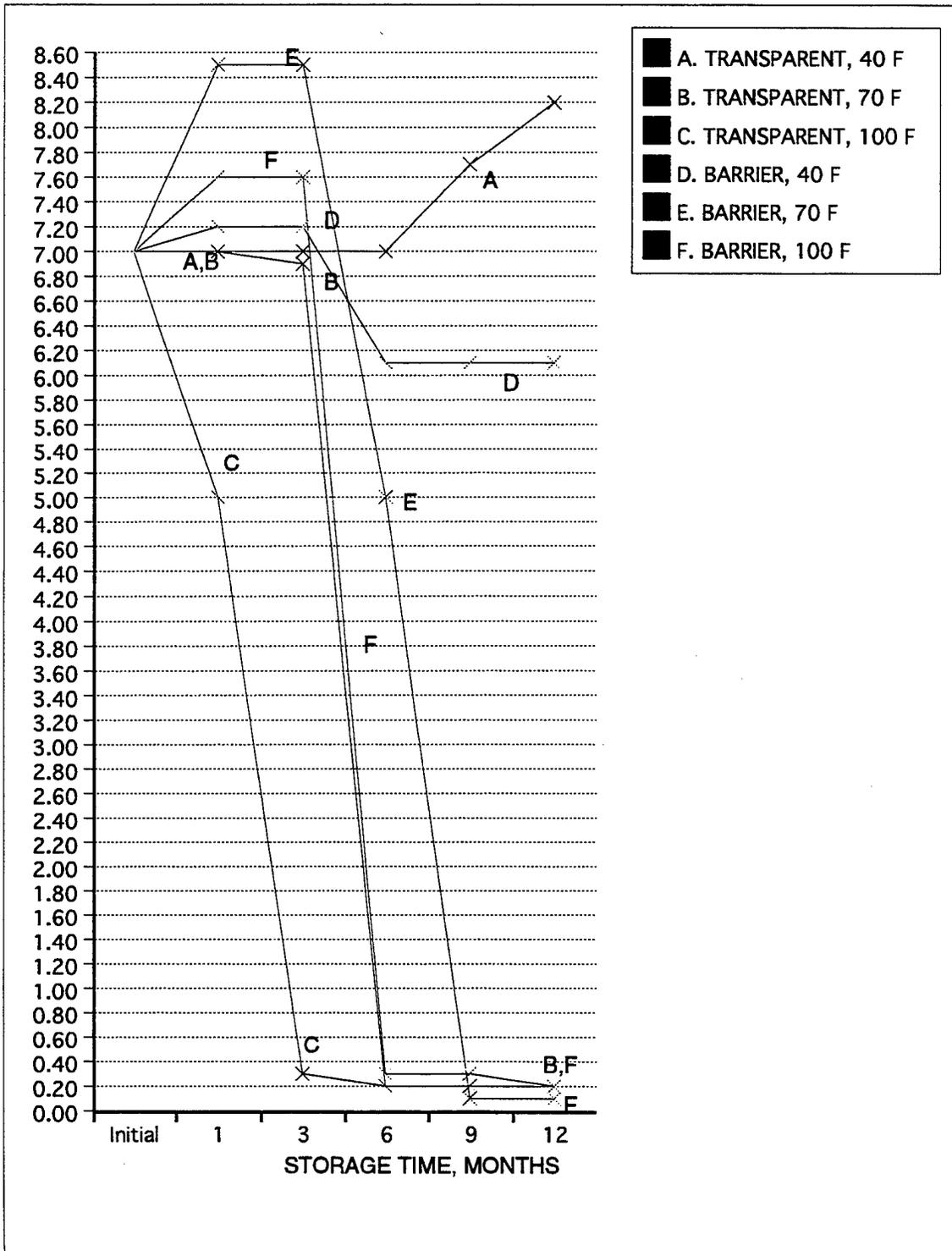


Fig. B-1 - PERCENT MOISTURE - VITAMIN FORTIFIED APPLE CUBES

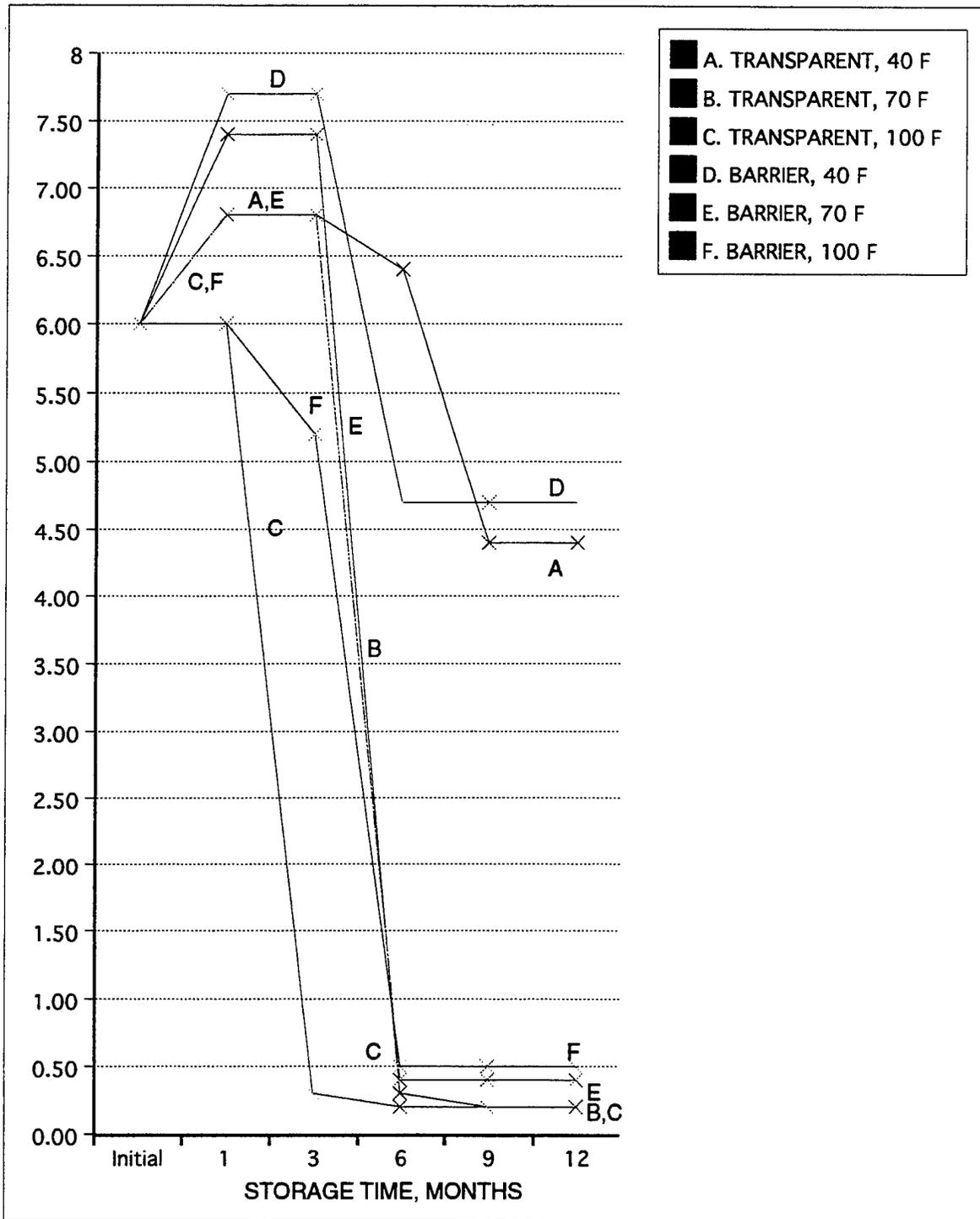


Fig. B-2 - PERCENT MOISTURE - MINERAL FORTIFIED APPLE CUBES

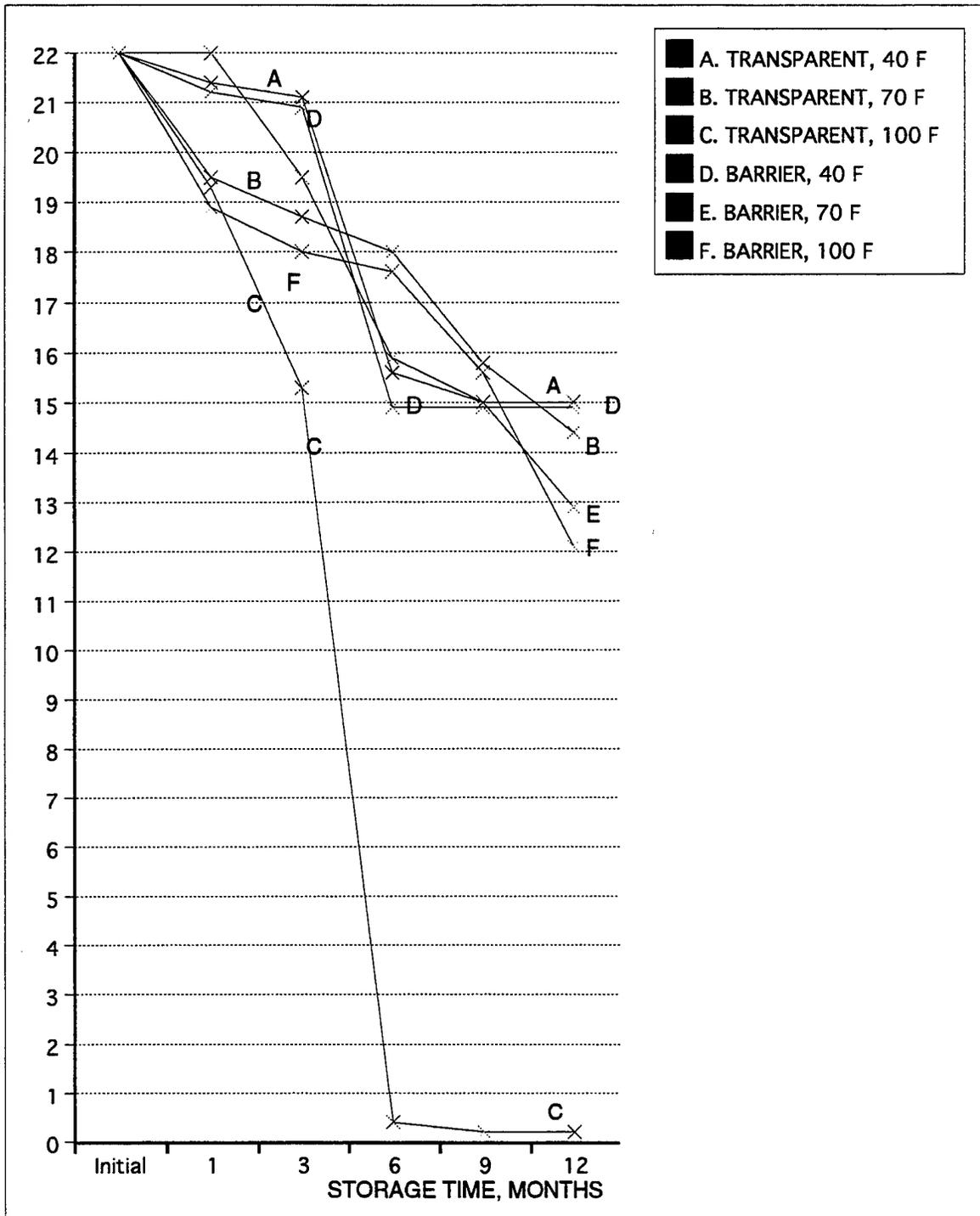


Fig. B-3 - PERCENT MOISTURE - VITAMIN FORTIFIED CHERRIES

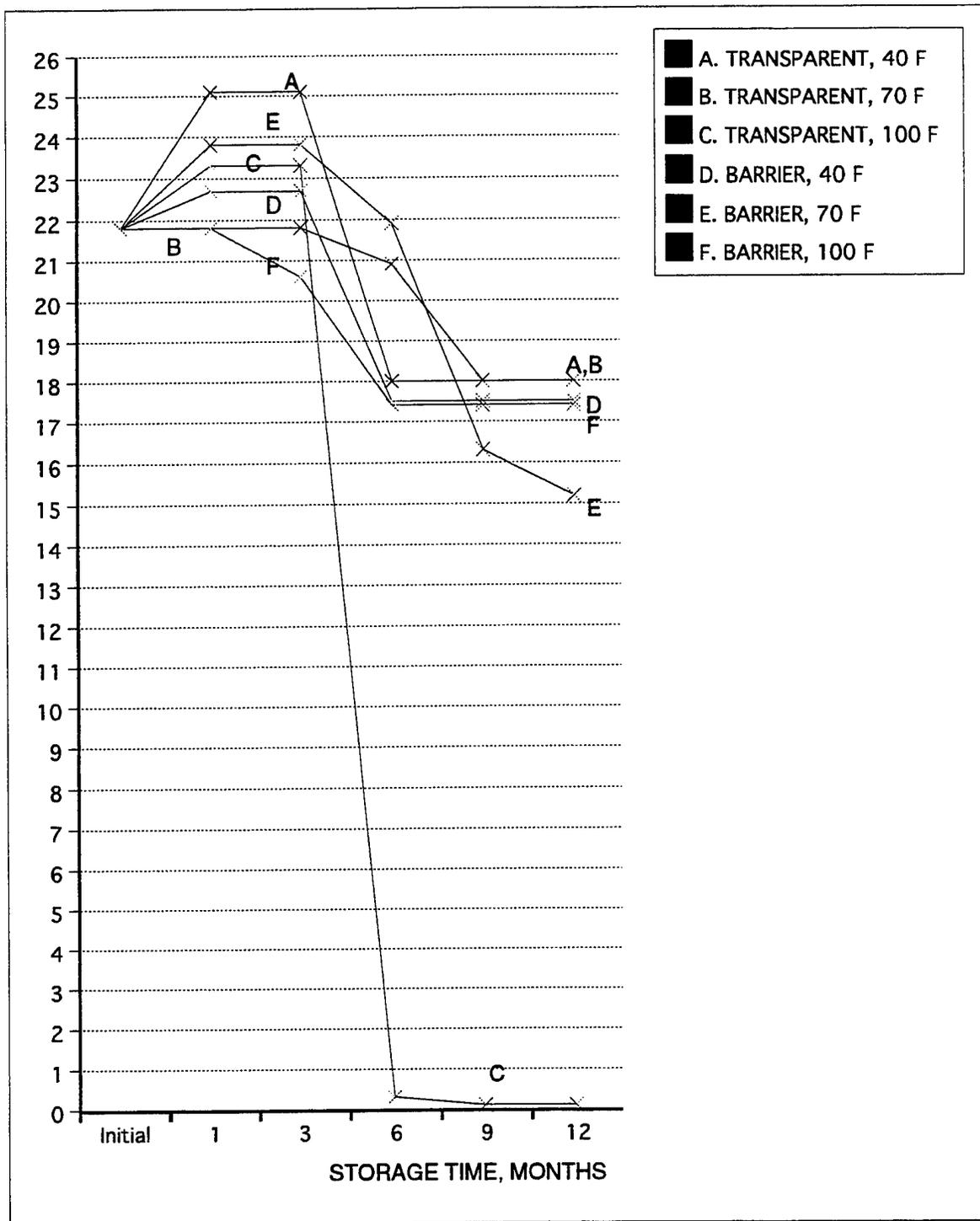


Fig. B-4 - PERCENT MOISTURE, MINERAL FORTIFIED CHERRIES

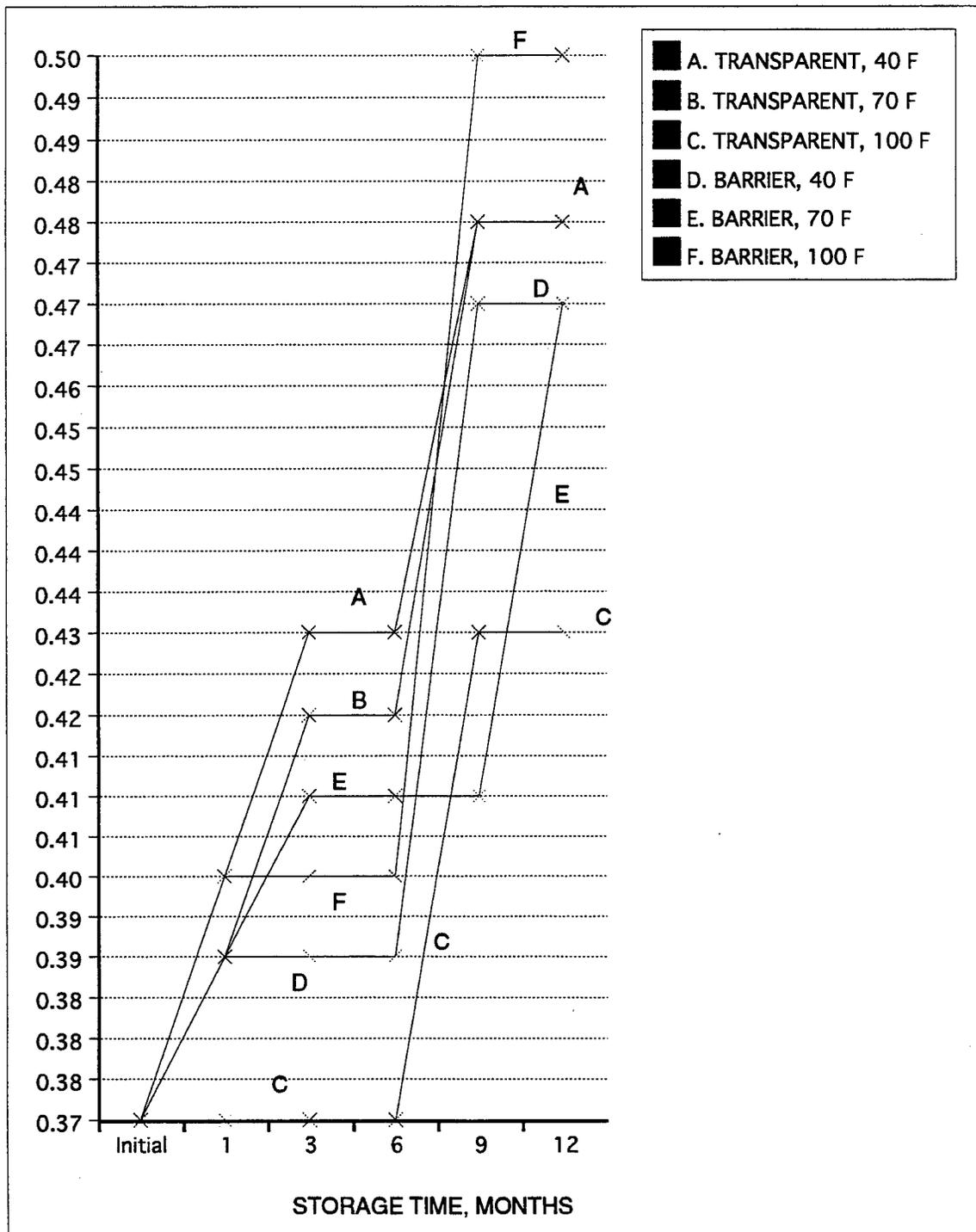


Fig. B-5 - WATER ACTIVITY - VITAMIN FORTIFIED APPLE CUBES

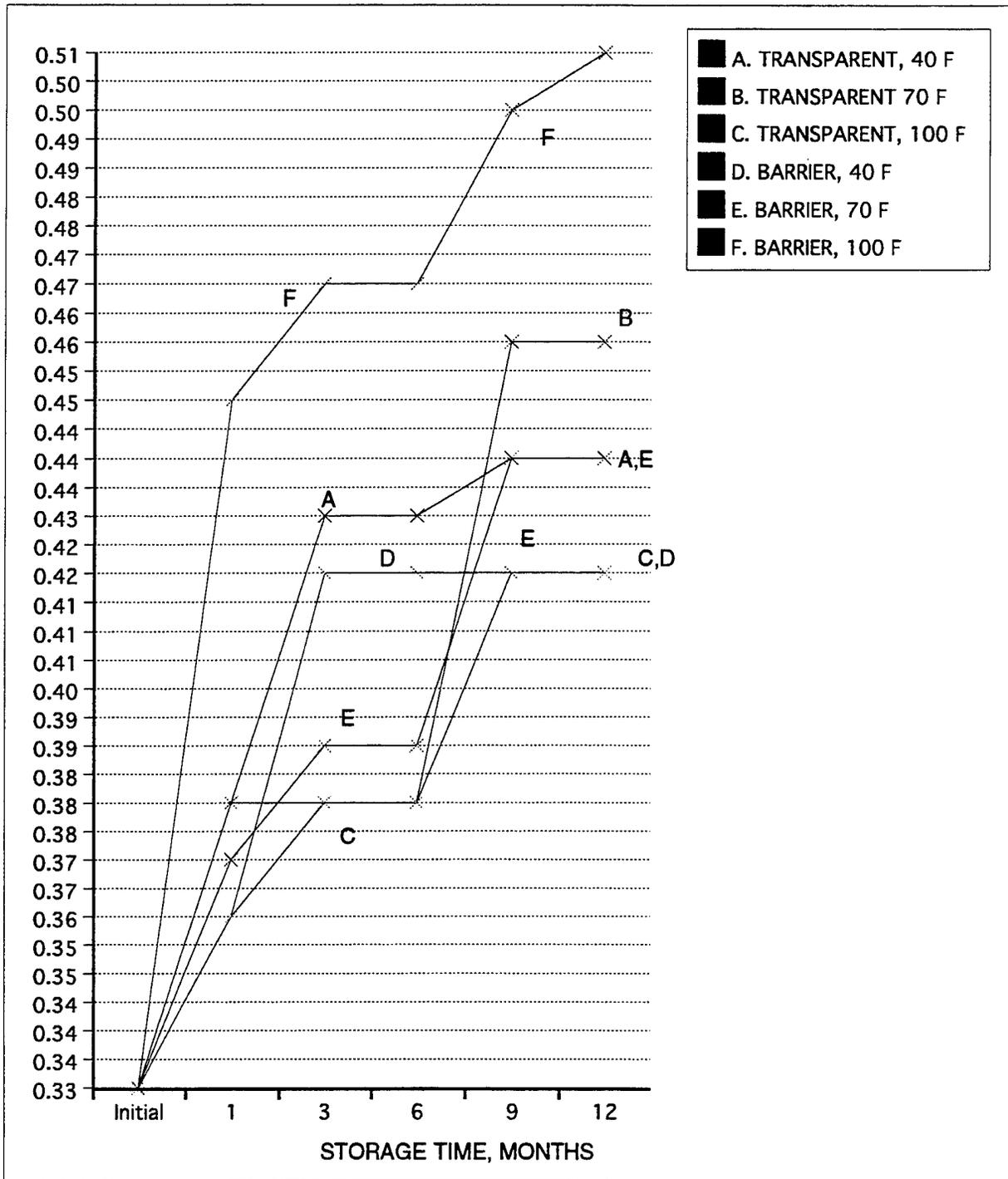


Fig.B- 6 - WATER ACTIVITY - MINERAL FORTIFIED APPLE CUBES

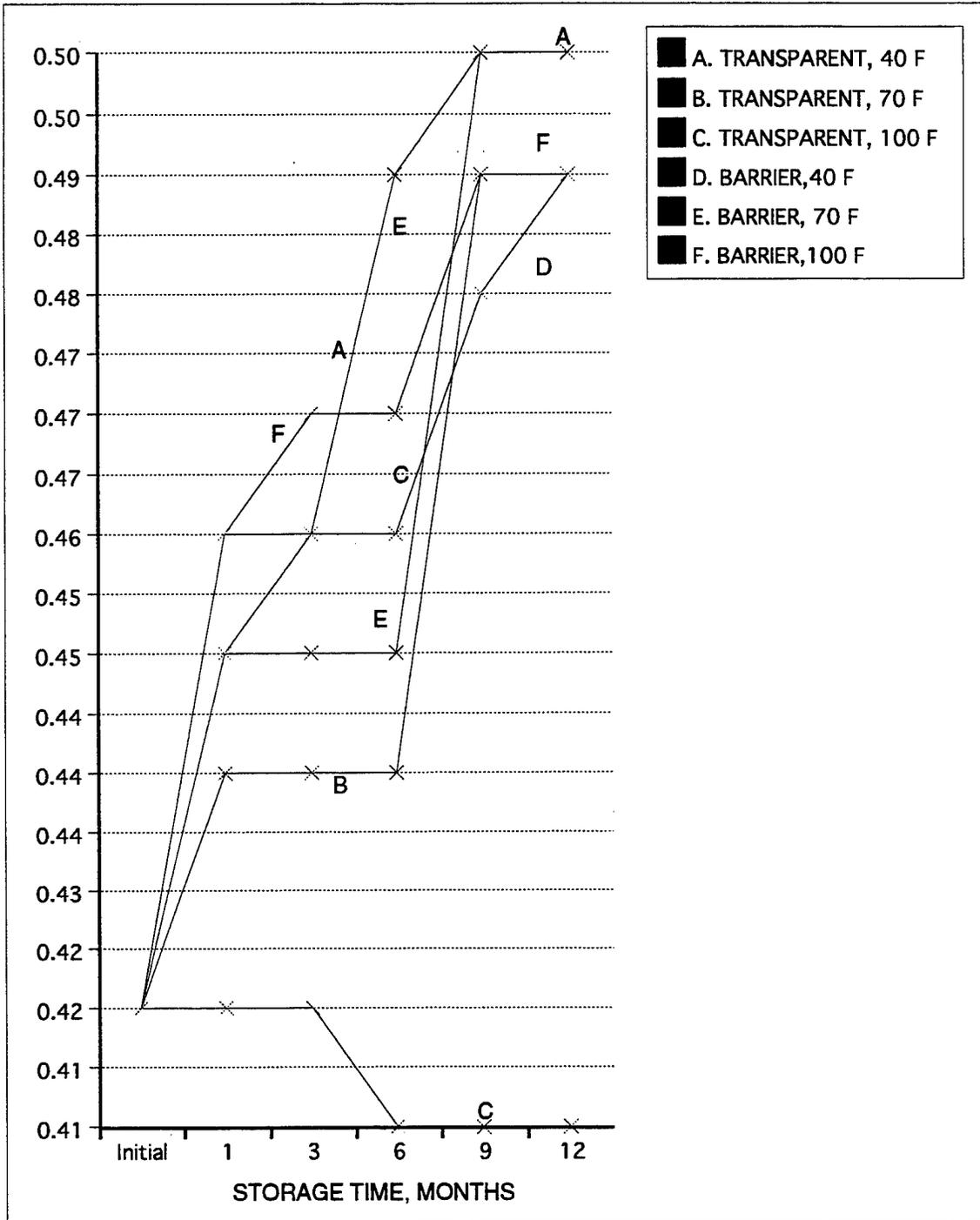


Fig. B-7 - WATER ACTIVITY, VITAMIN FORTIFIED CHERRIES

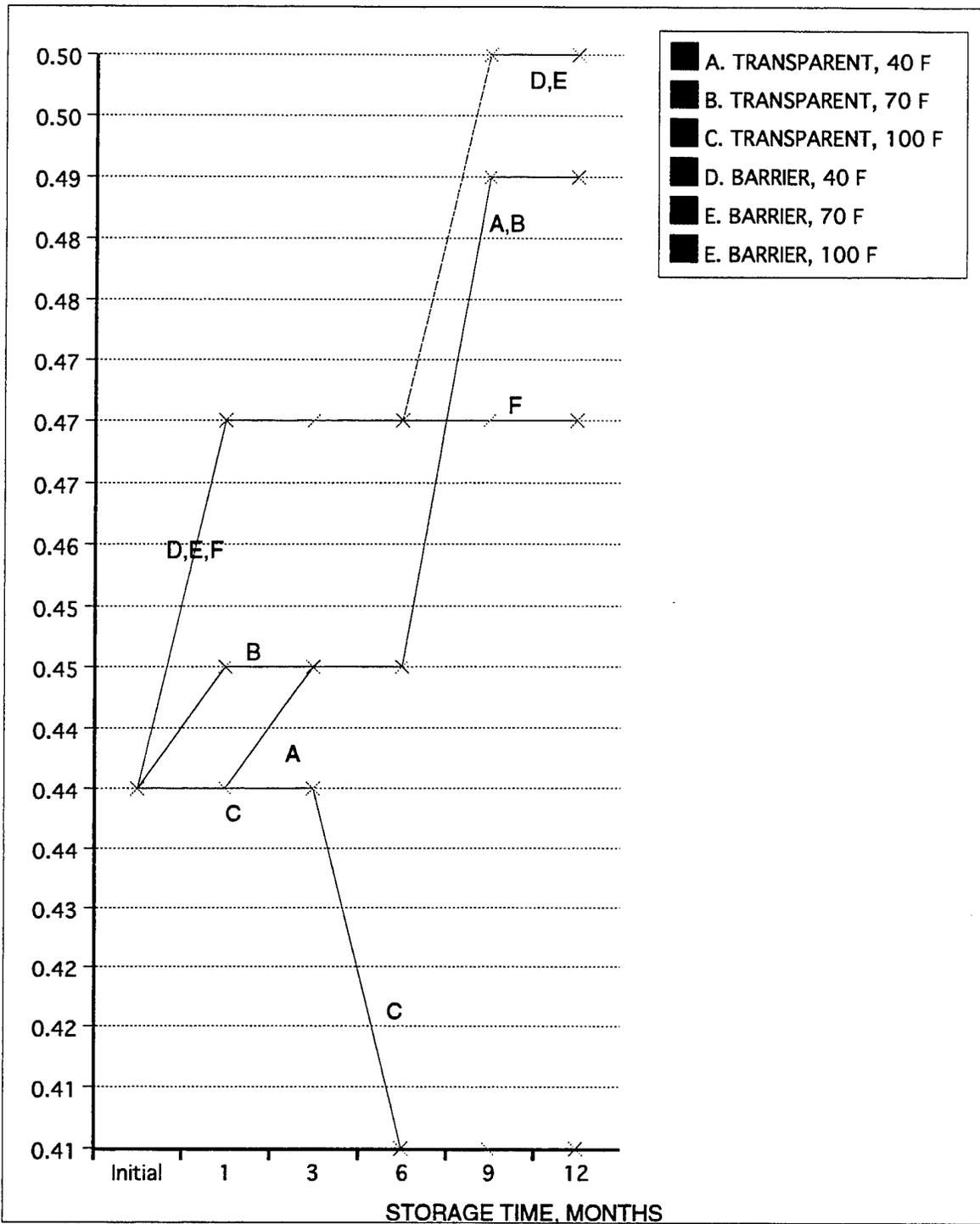


Fig. B-8 - WATER ACTIVITY, MINERAL FORTIFIED CHERRIES

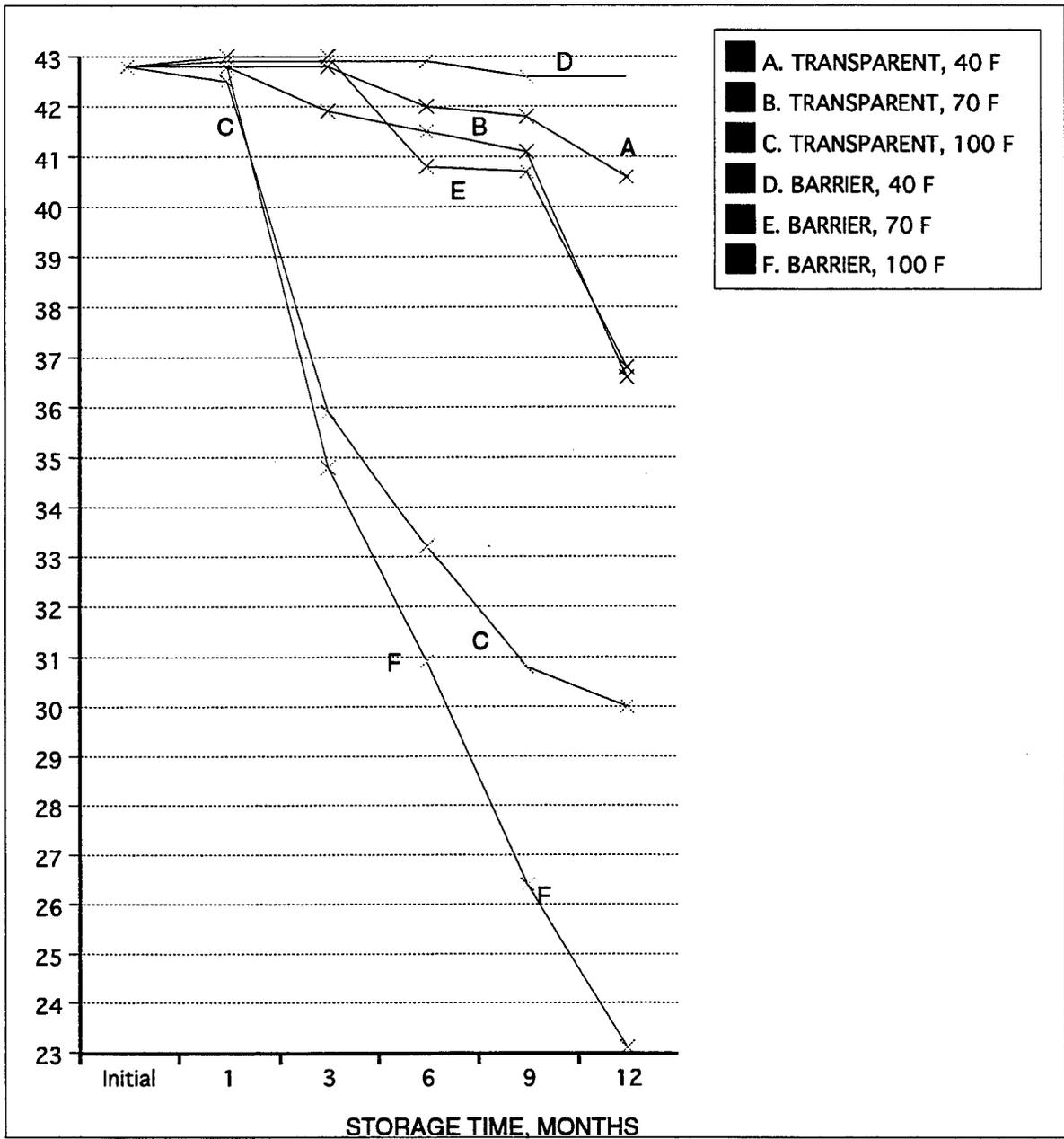


Fig. B-9 - REFLECTANCE COLOR, HUNTER "L" , VITAMIN FORTIFIED APPLE CUBES

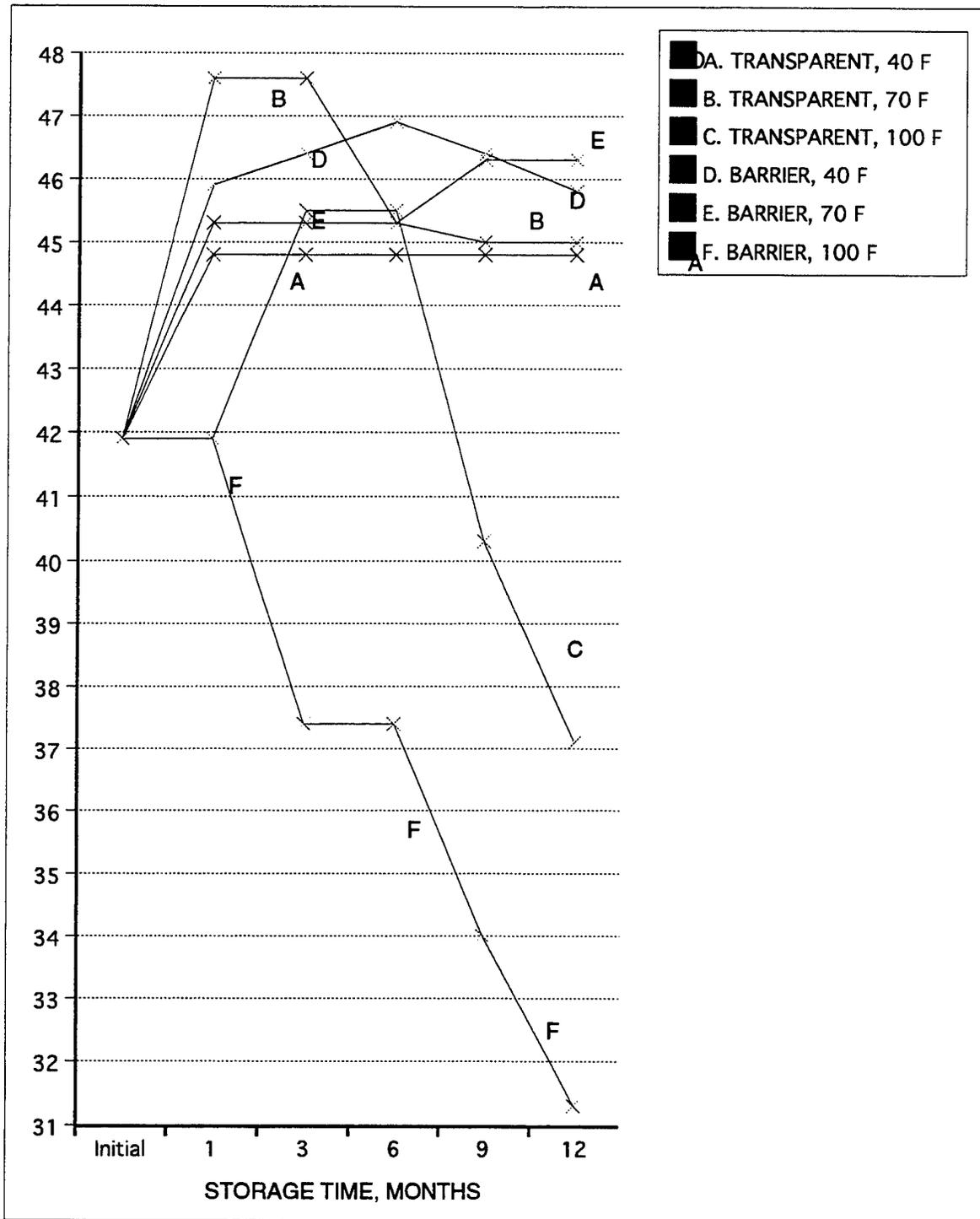


Fig. B-10 - REFLECTANCE COLOR, HUNTER "L" - MINERAL FORTIFIED APPLE CUBES

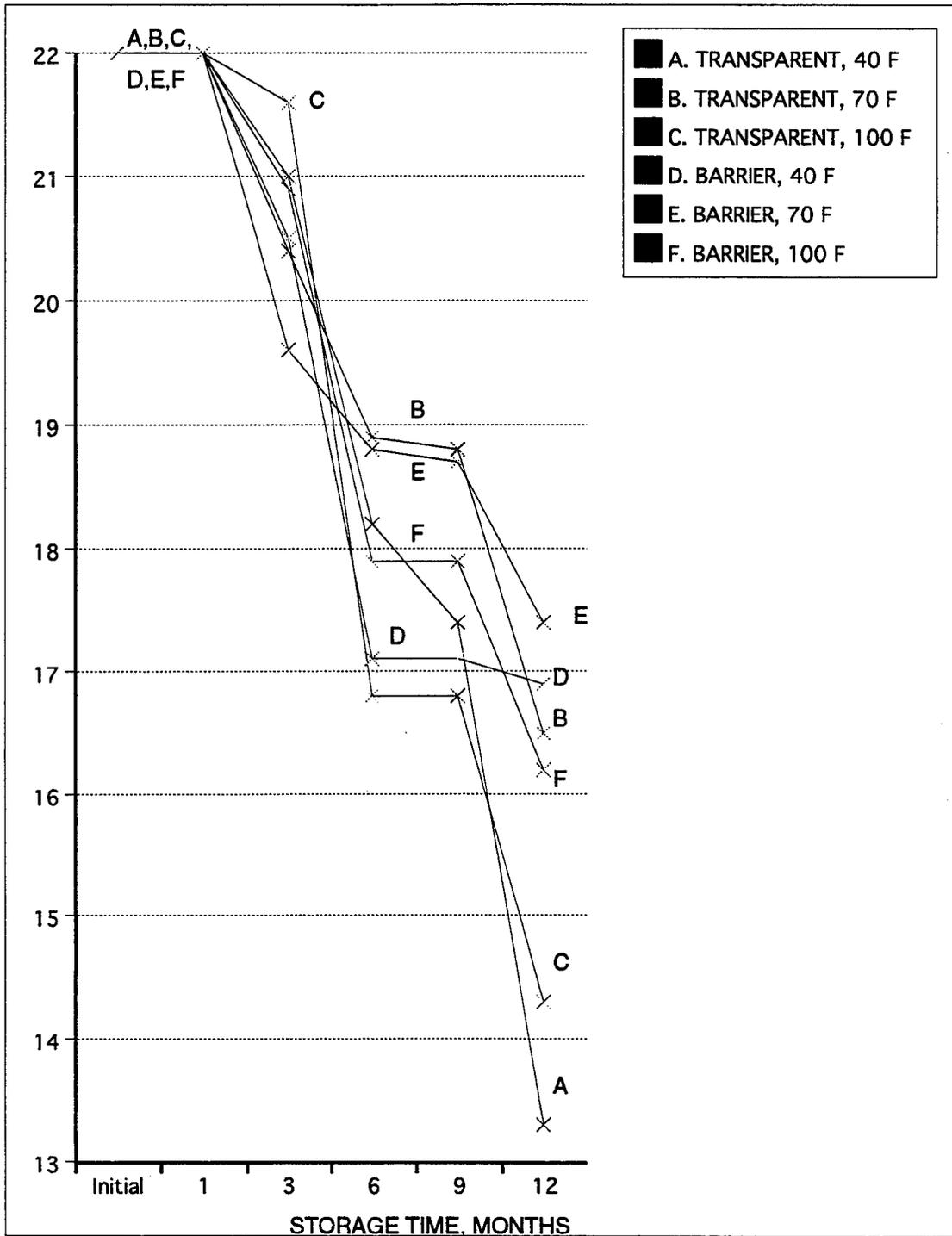


Fig. B-11 - REFLECTANCE COLOR, HUNTER "L" VITAMIN FORTIFIED CHERRIES

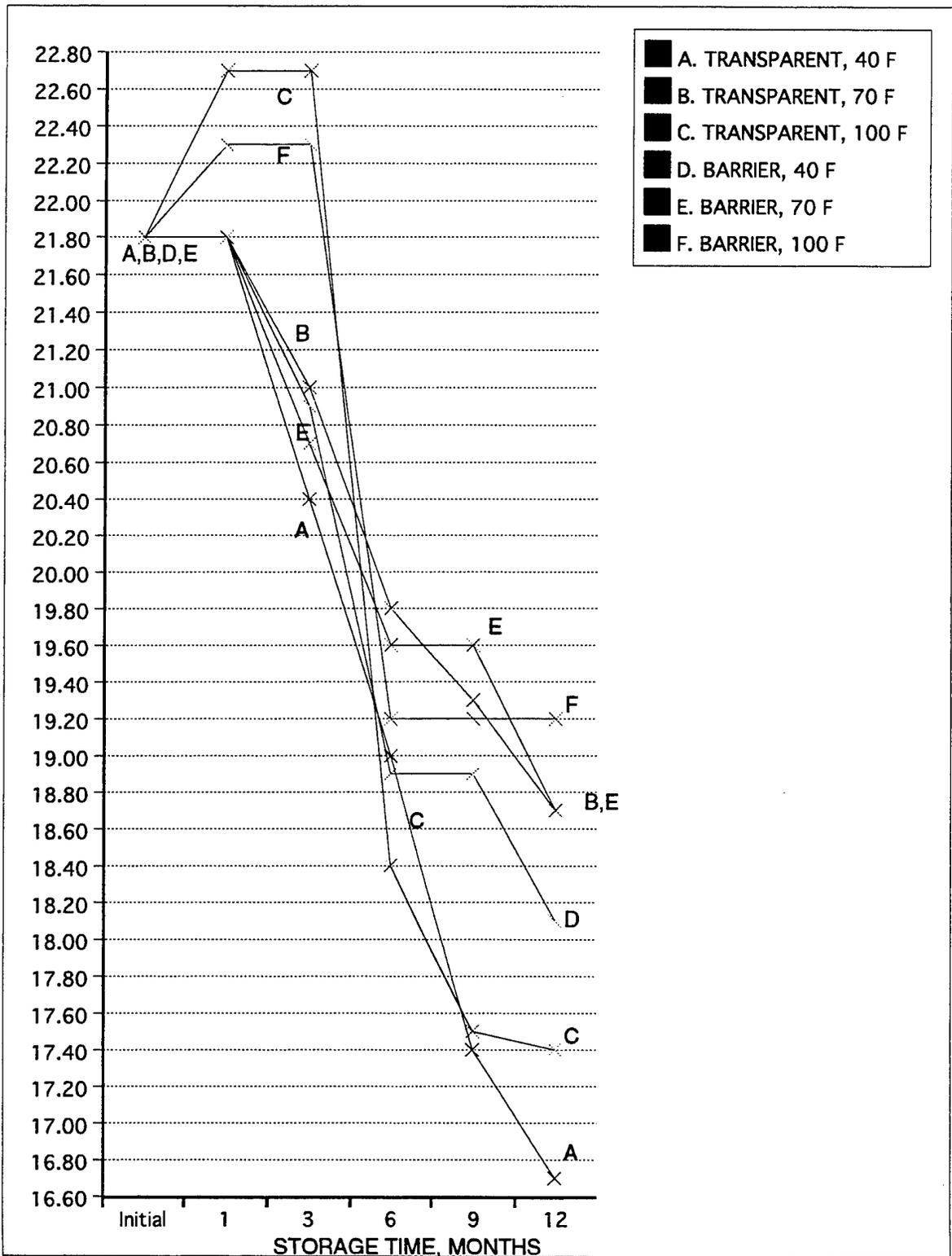


Fig. B-12 - REFLECTANCE COLOR, HUNTER "L" - MINERAL FORTIFIED CHERRIES

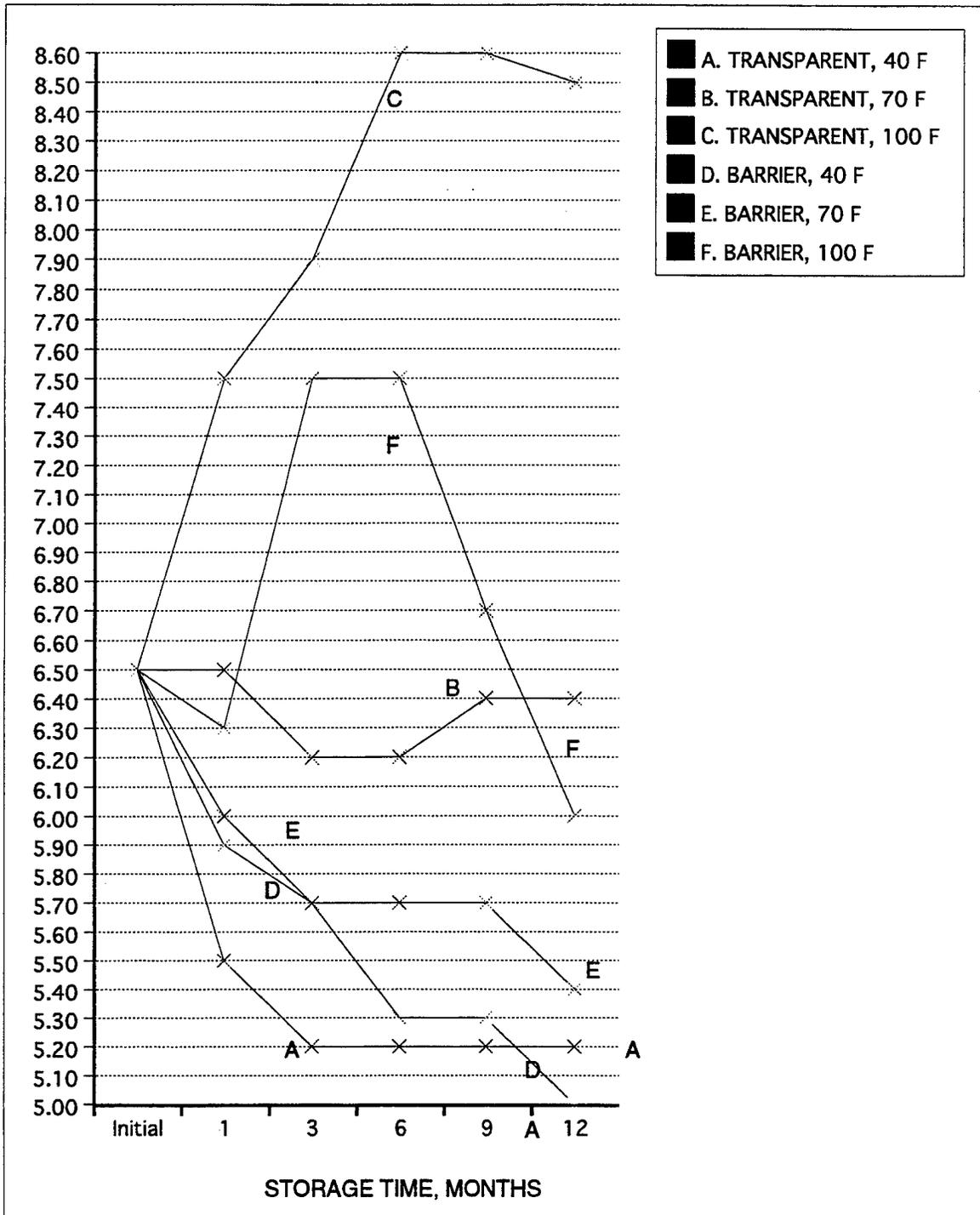


Fig. B-13 - REFLECTANCE COLOR, HUNTER "a" - VITAMIN FORTIFIED APPLE CUBES

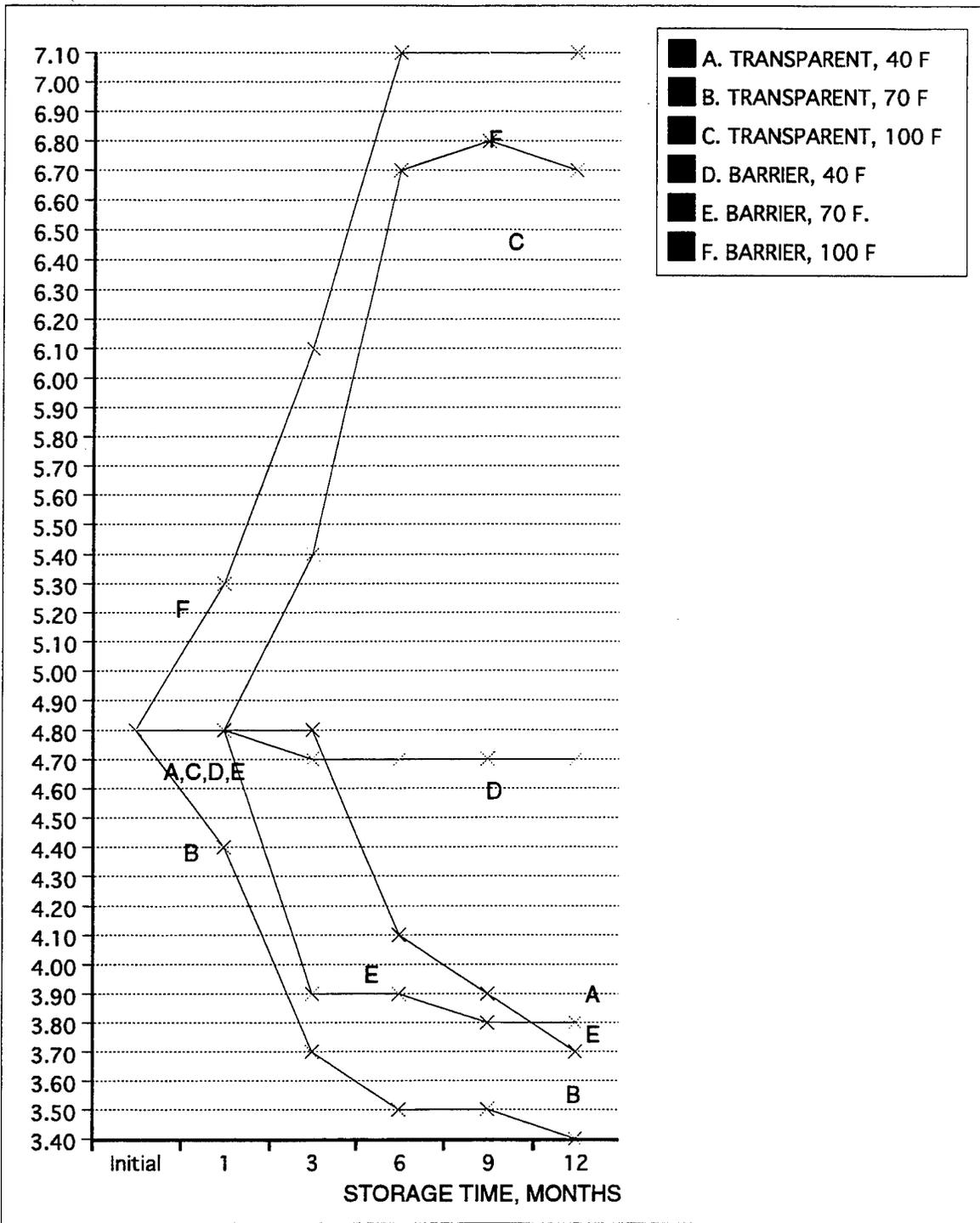


Fig. A-14 - REFLECTANCE COLOR, HUNTER "a" MINERAL FORTIFIED APPLE CUBES

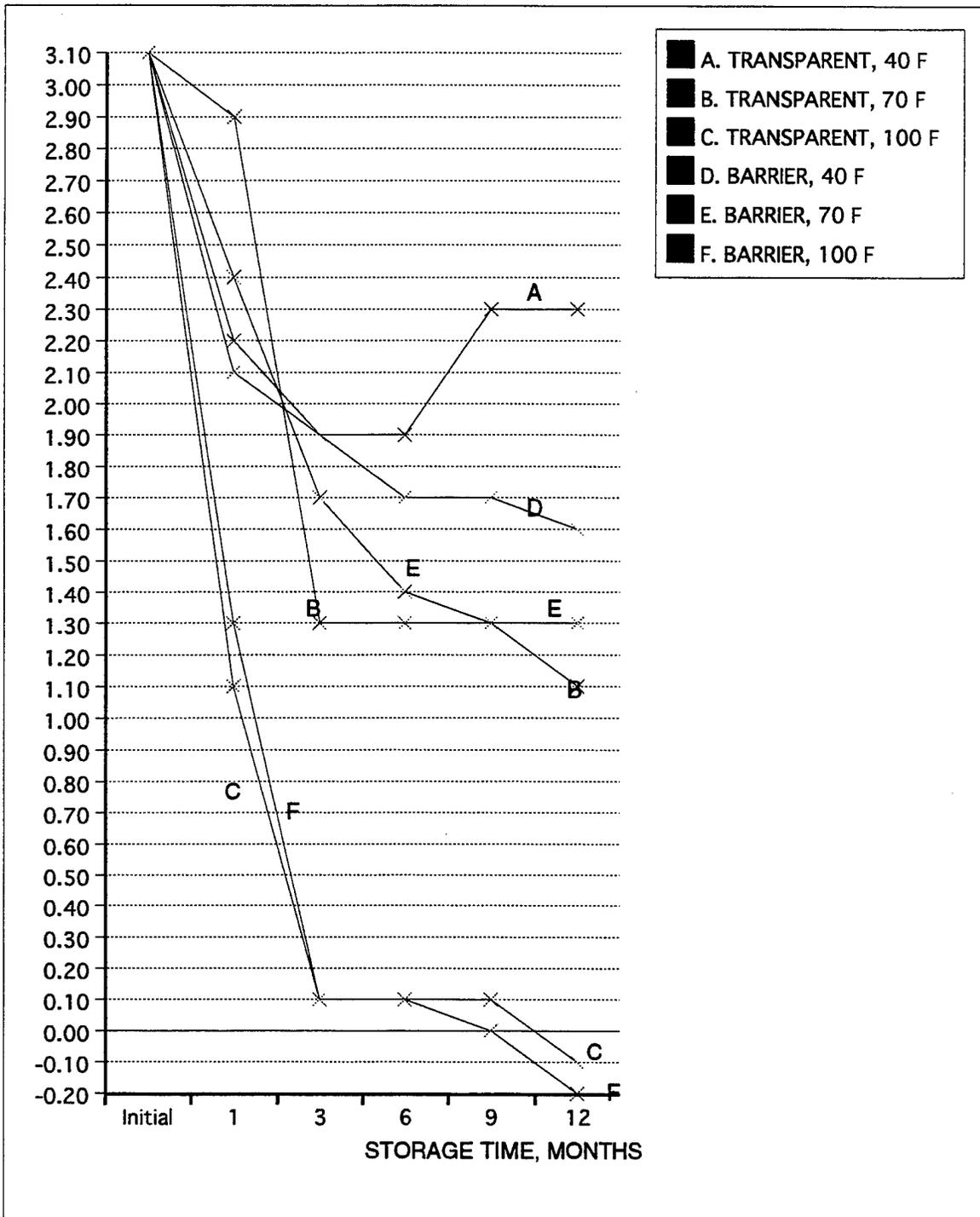


Fig. B-15 - REFLECTANCE COLOR, HUNTER "a" - VITAMIN FORTIED CHERRIES

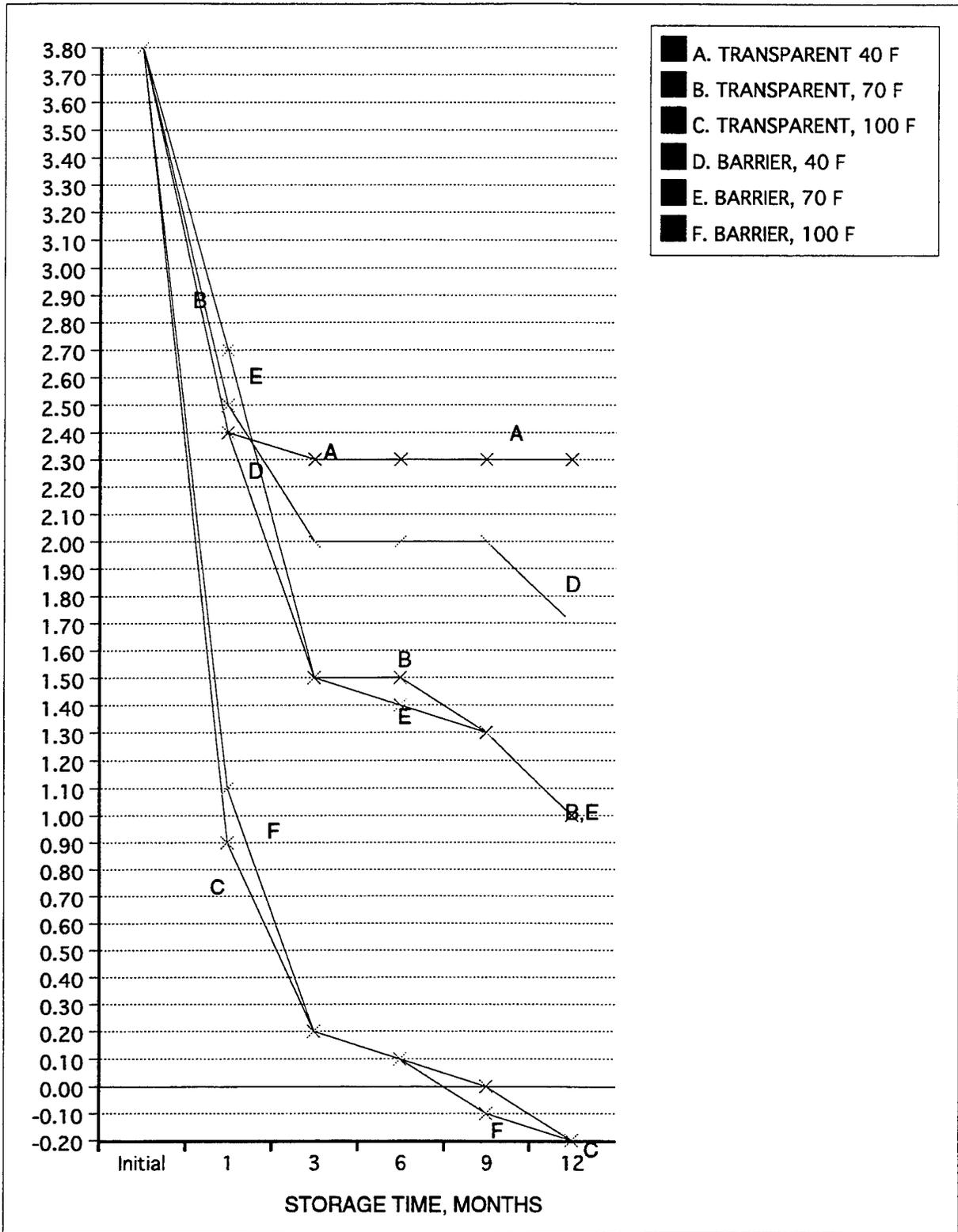


Fig. B-16 - REFLECTANCE COLOR, HUNTER "a" - MINERAL FORTIFIED CHERRIES

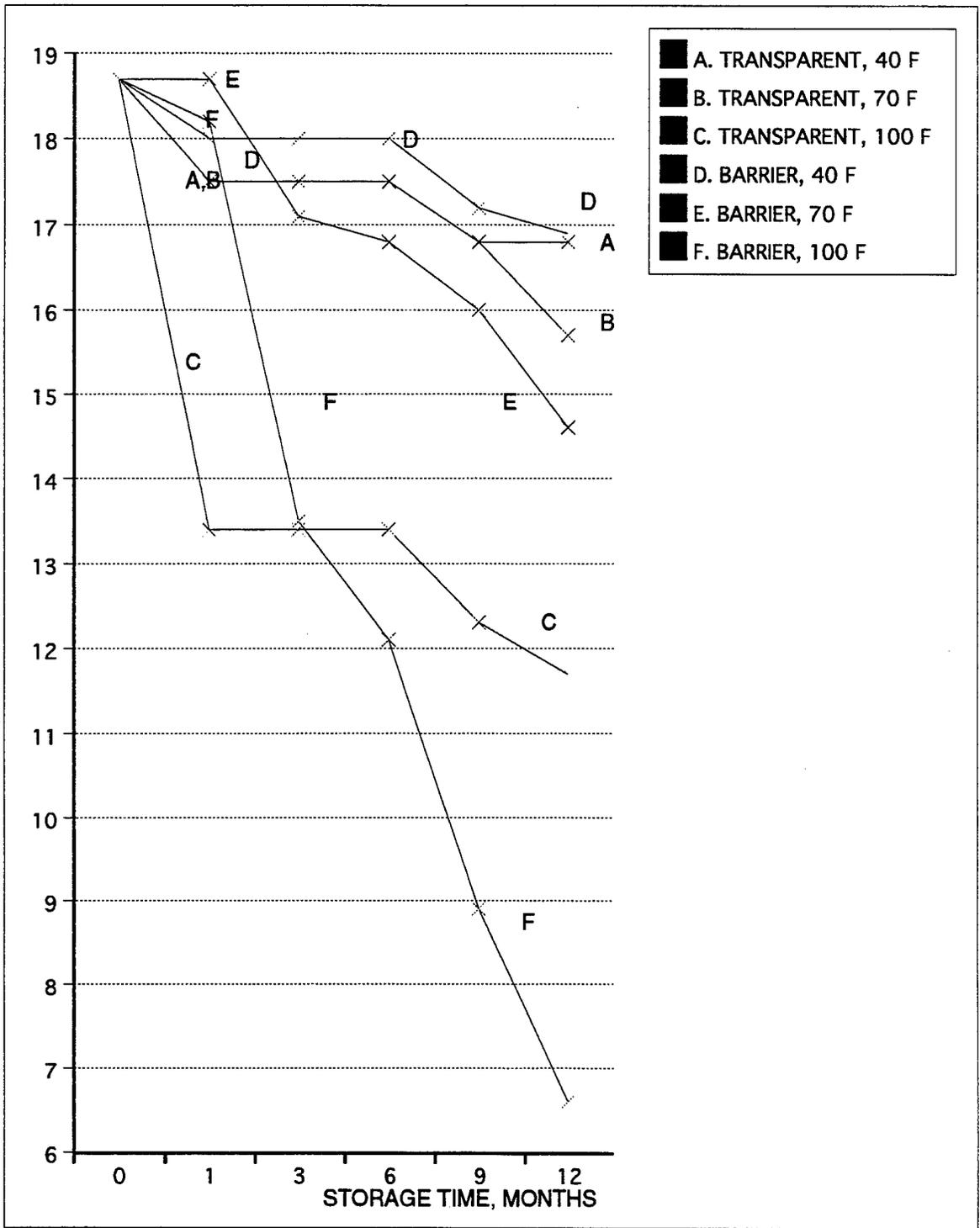


Fig. B- 17 -REFLECTANCE COLOR, HUNTER "b" - VITAMIN FORTIFIED APPLE CUBES

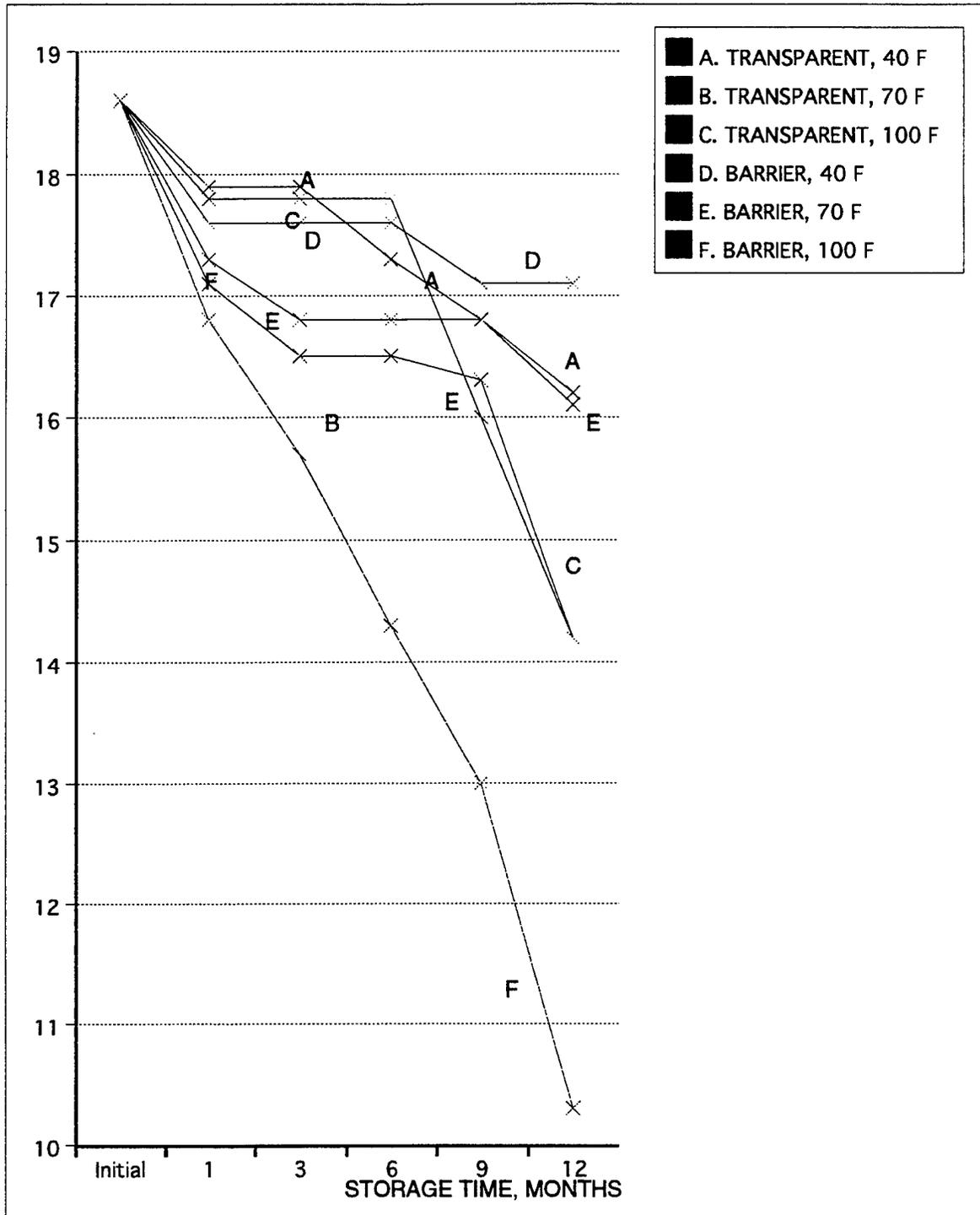


Fig. B-18 - REFLECTANCE COLOR, HUNTER "b" - MINERAL FORTIFIED APPLE CUBES

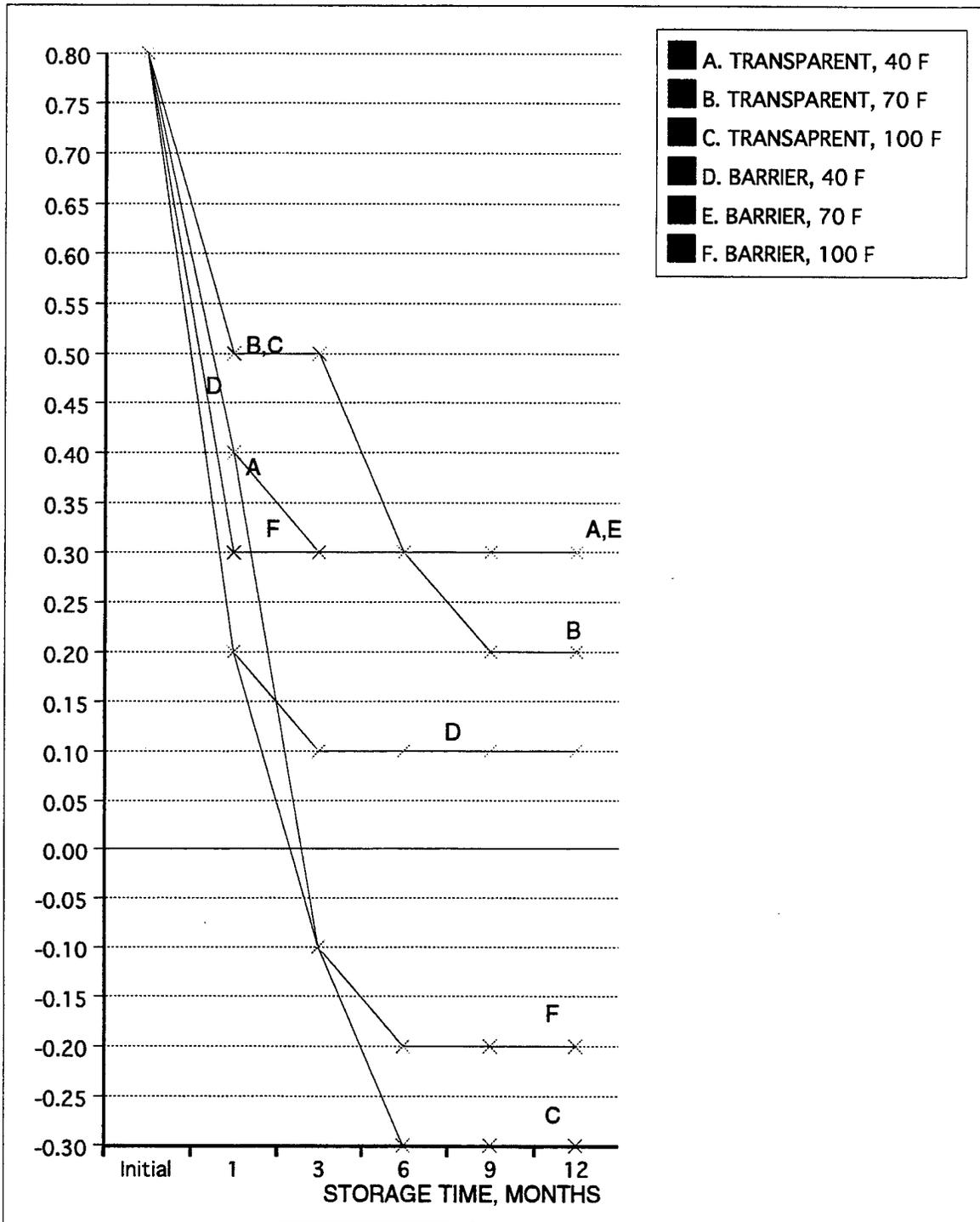


Fig. B-19 - REFLECTANCE COLOR, HUNTER "b" - VITAMIN FORTIFIED CHERRIES

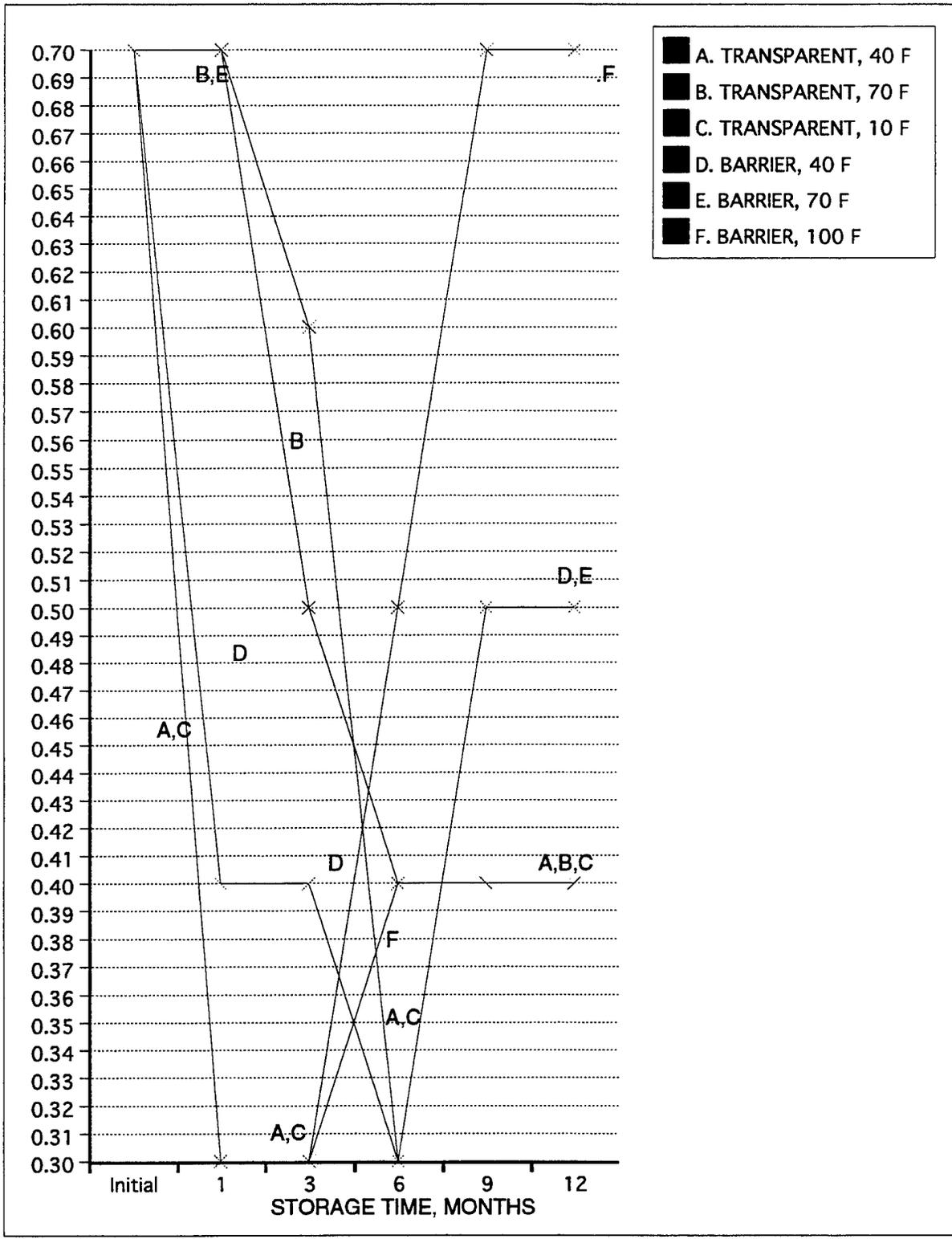


Fig.B- 20 - REFLECTANCE COLOR, HUNTER "b" - MINERAL FORTIFIED CHERRIES

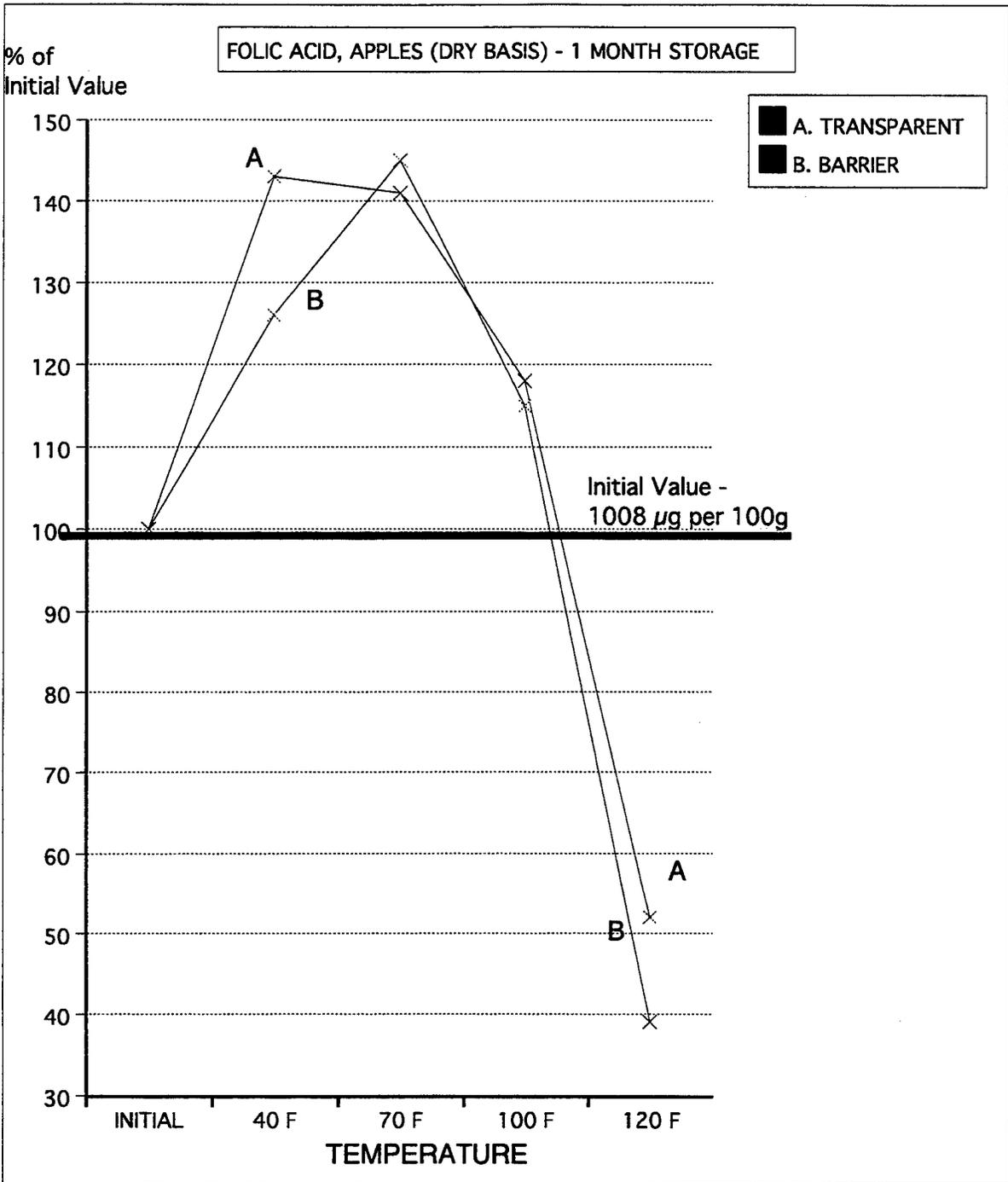


Fig. B-21 - FOLIC ACID CONTENT - APPLE CUBES (DRY BASIS)

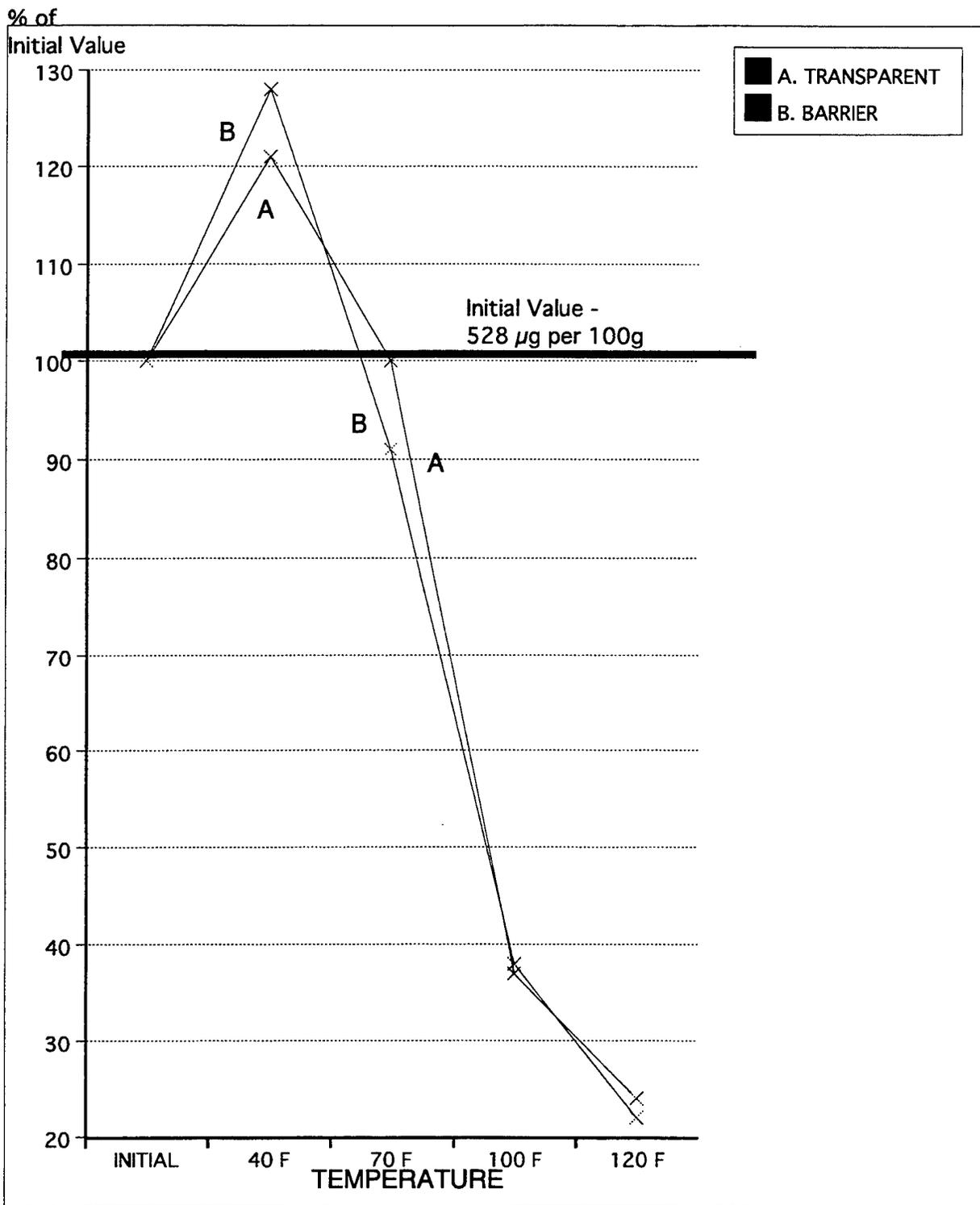


Fig. B-22 - FOLIC ACID CONTENT - CHERRIES (DRY BASIS)

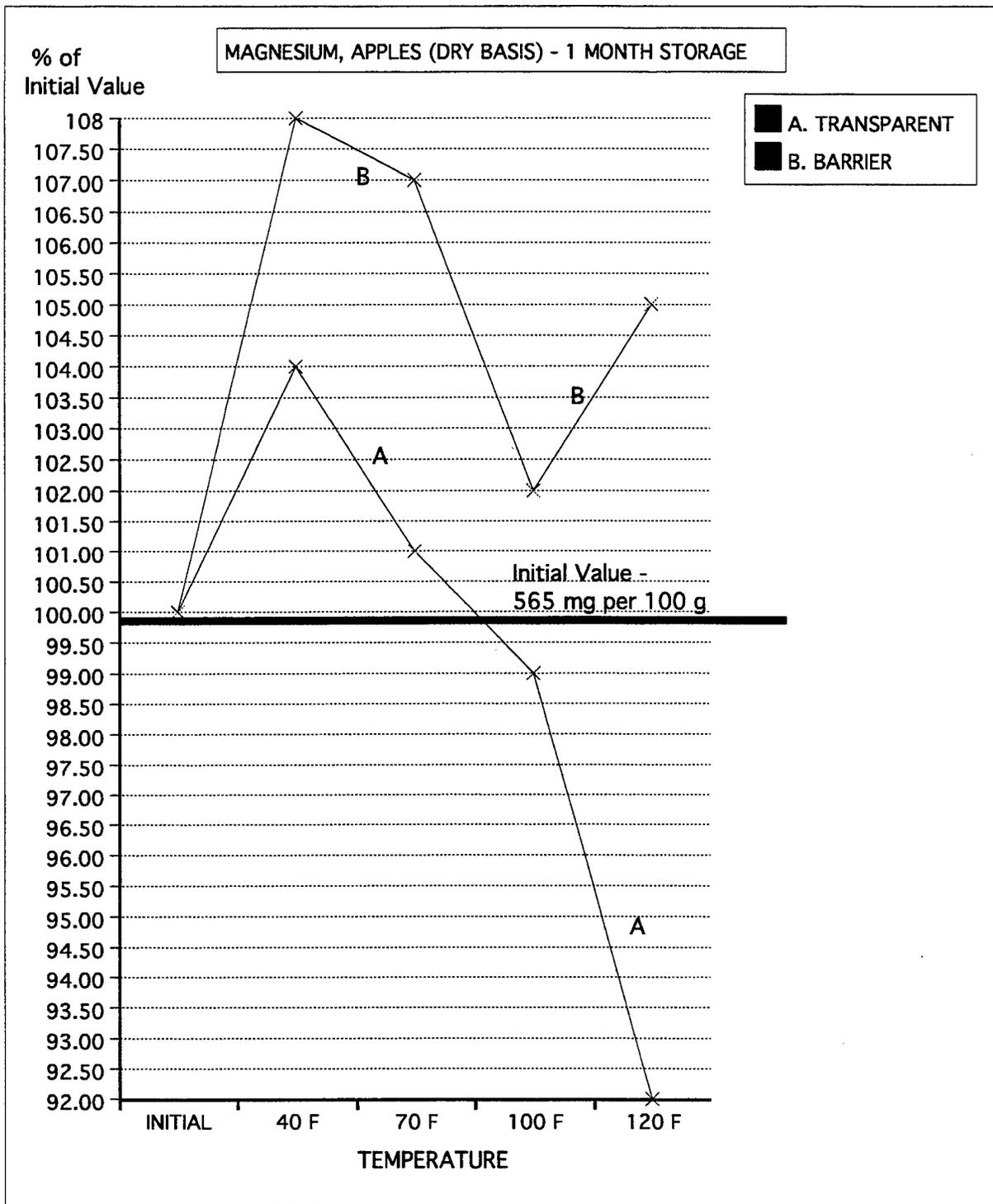


Fig. B-23 - MAGNESIUM CONTENT, APPLE CUBES (DRY BASIS)

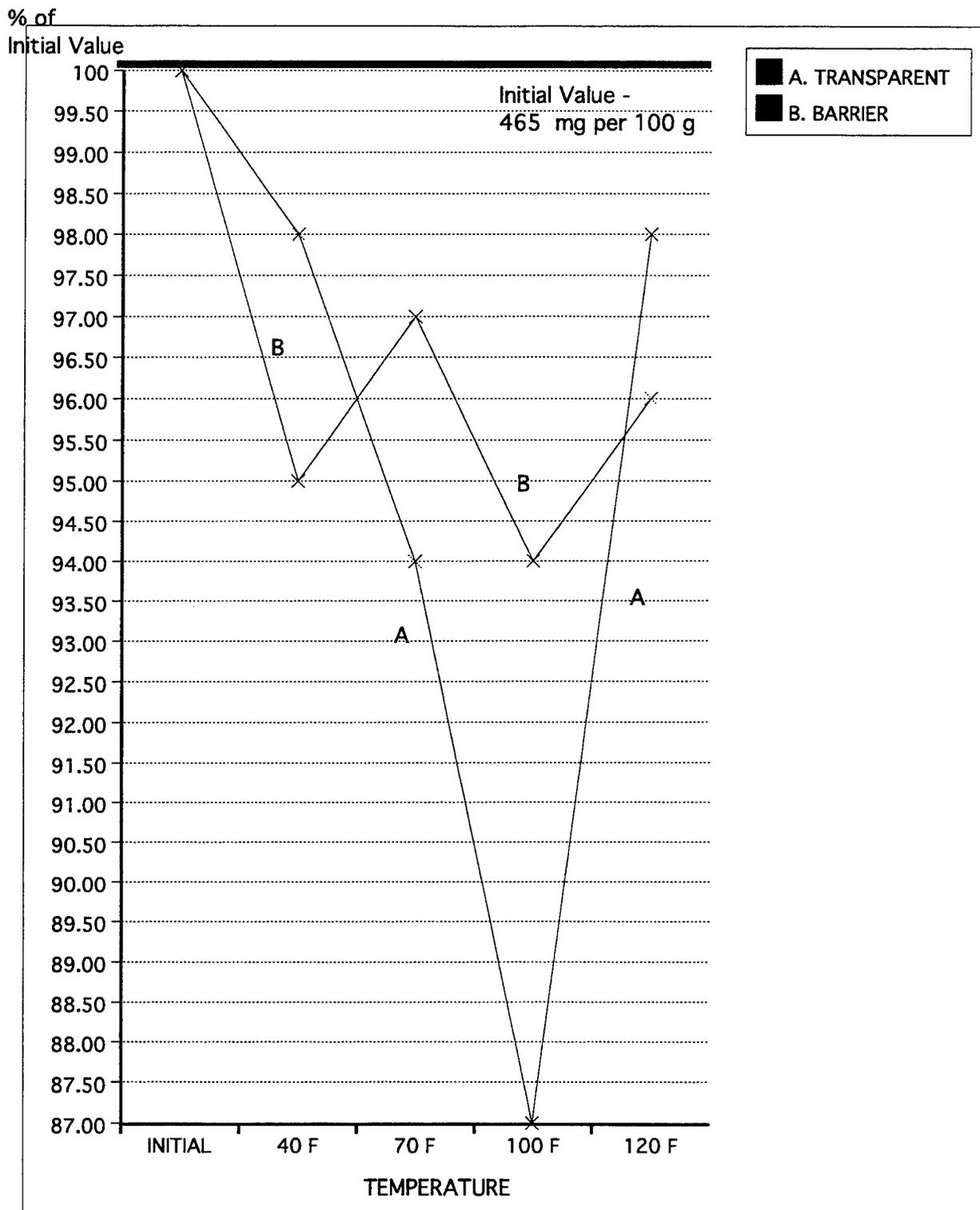


Fig. B-24 - MAGNESIUM CONTENT, CHERRIES (DRY BASIS)

% of Initial Value

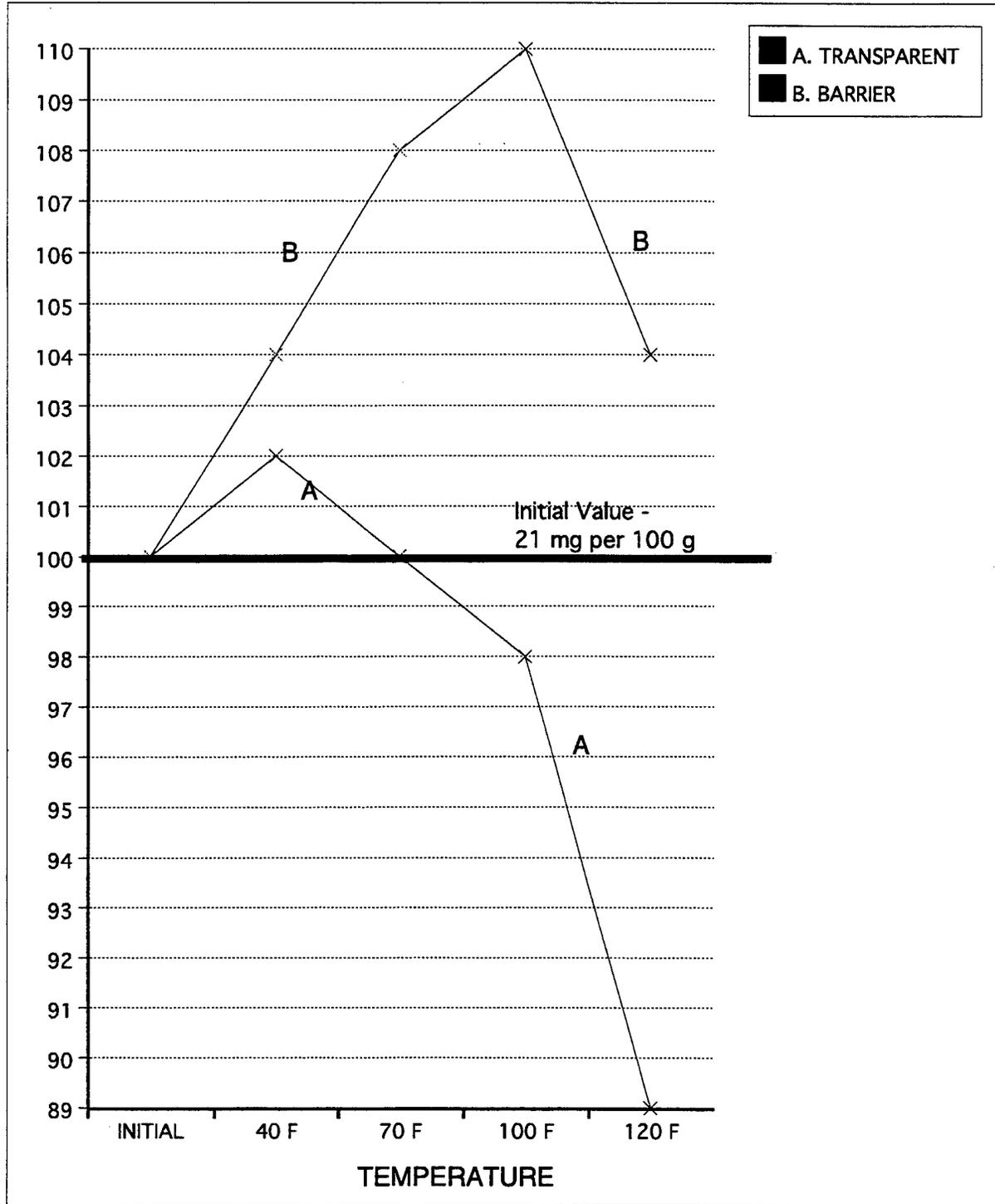


Fig. B-25 - Zinc Content - Apple Cubes (Dry Basis)

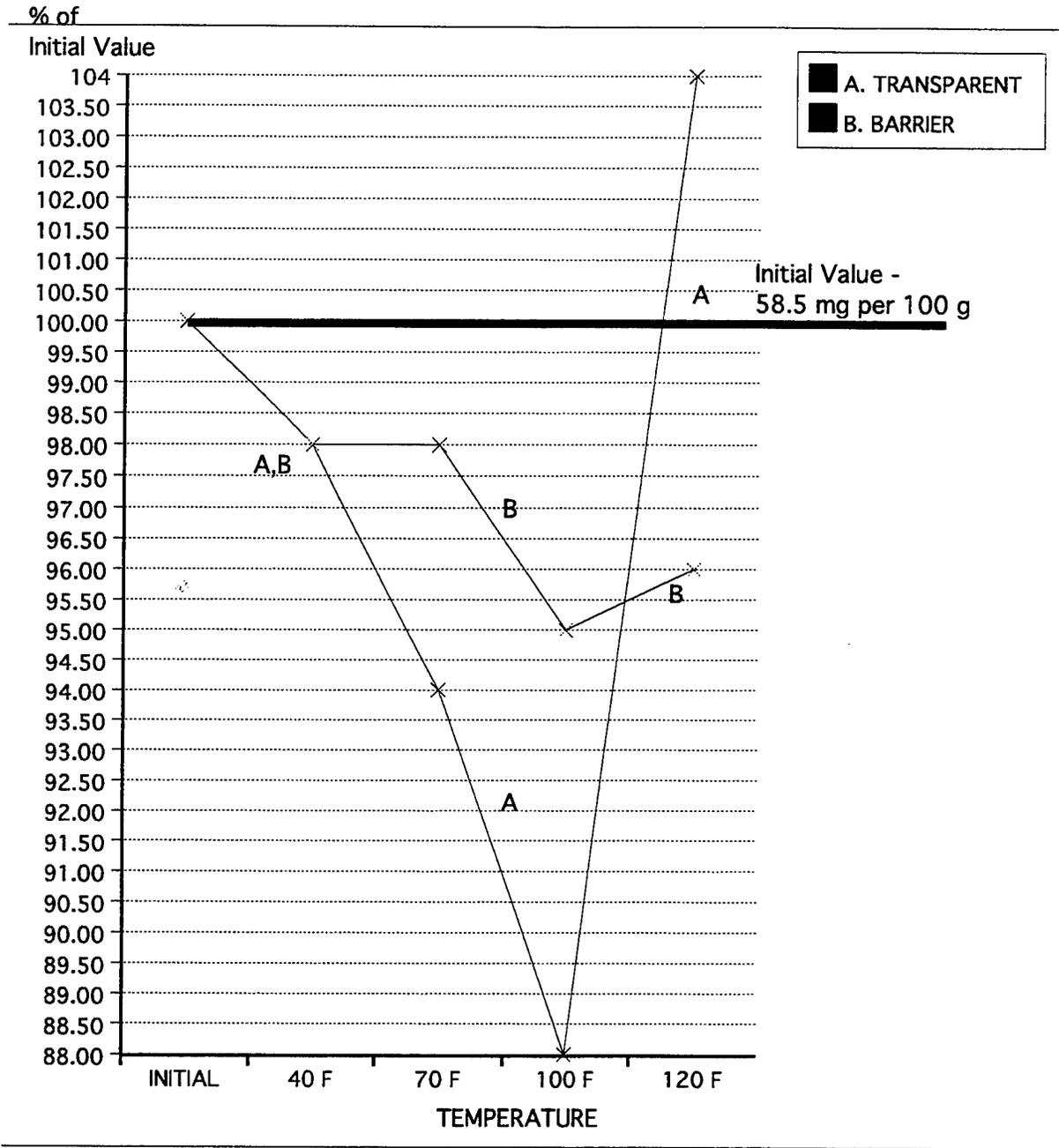


Fig. B-26 - ZINC CONTENT, CHERRIES (DRY BASIS)

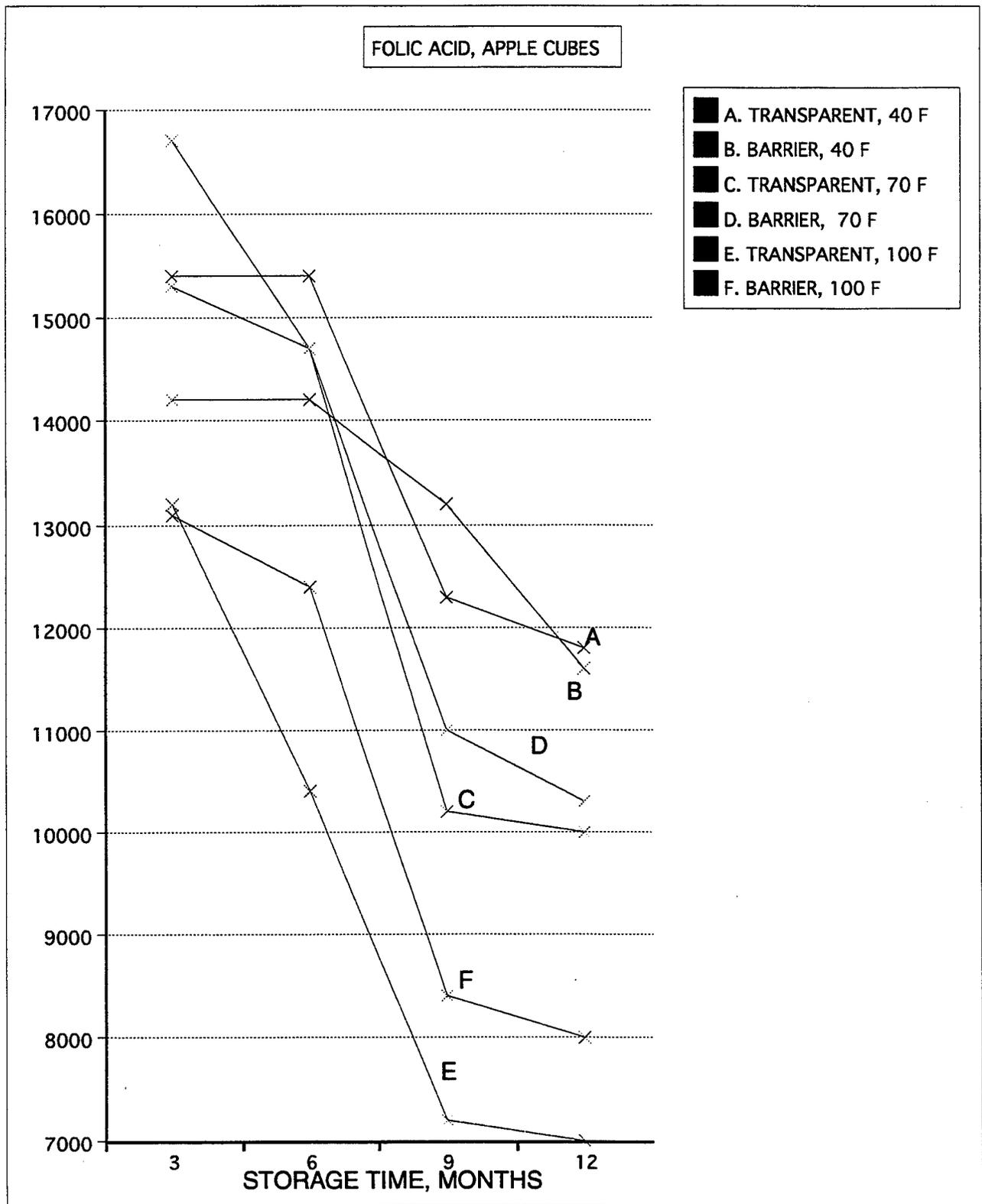


FIGURE B-27 - FOLIC ACID CONTENT - APPLE CUBES, HPLC METHOI

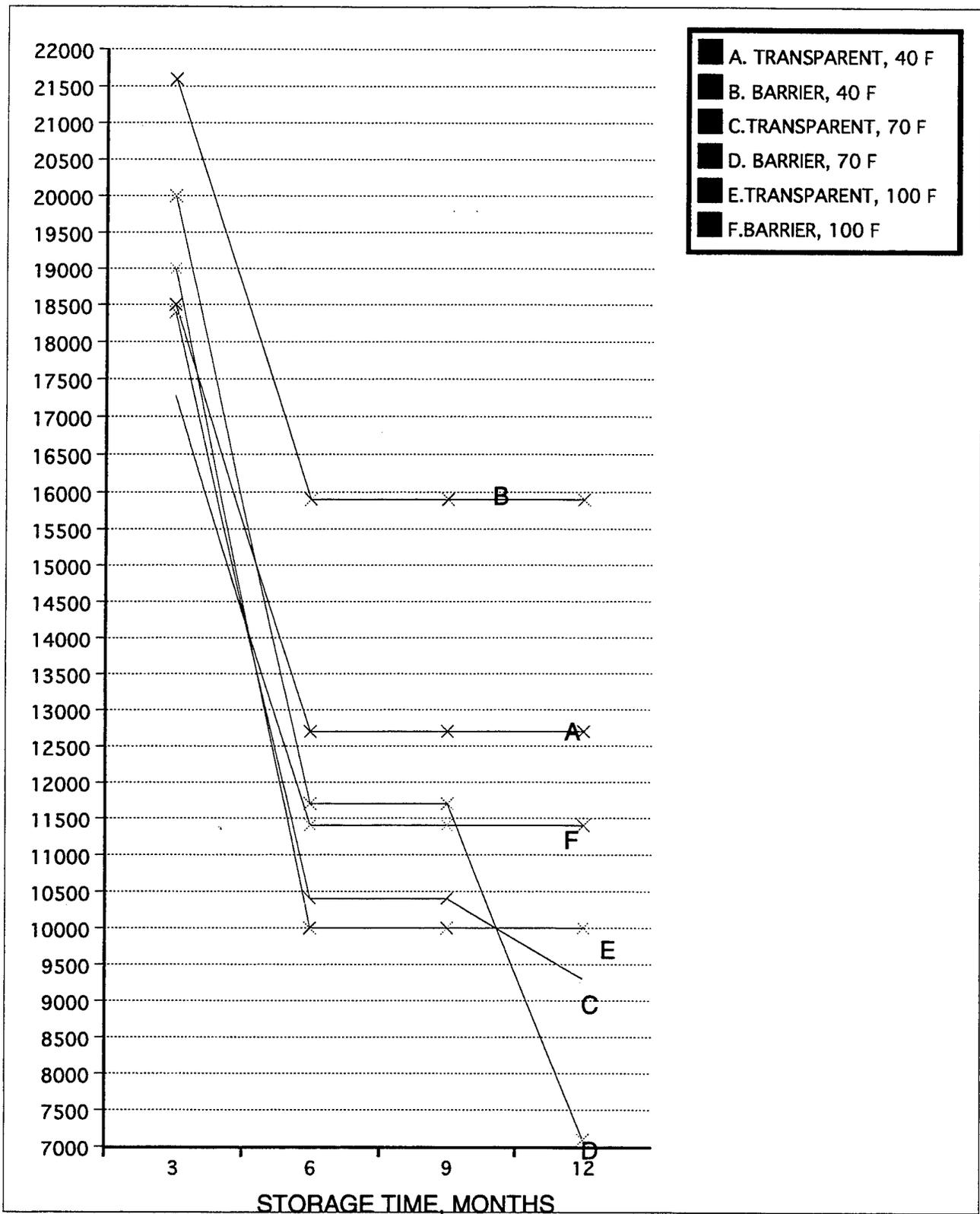


FIGURE B-28 - FOLIC ACID CONTENT - CHERRIES, HPLC METHOD

**APPENDIX C - DATA ANALYSIS FOR CHEMICAL AND  
PHYSICAL ANALYSES**

Table C-1 - Summary of Data Analysis

Effect	Apples		Cherries	
	F	Prob.	F	Prob.
<b>A. Percent Moisture</b>				
Temperature	0.04	0.84NSD	0.18	0.05 NSD
Time	0.77	0.38 NSD	1.08	0.30 NSD
Packaging Material	0.00	0.97 NSD	0.00	0.00 NSD
Infusion	0.00	0.98 NSD	0.03	0.01 NSD
Temp. x Time	2.56	0.12 NSD	2.04	0.01 NSD
Temp. x Pkg.	0.05	0.83 NSD	0.09	0.02 NSD
Temp. x Inf.	0.16	0.74 NSD	0.58	0.16 NSD
Time x Pkg.	0.78	0.38 NSD	0.08	0.02 NSD
Time x Inf.	0.14	0.71 NSD	0.98	0.27 NSD
Pkg. x Inf.	0.01	0.93 NSD	0.18	0.05 NSD
Temp. x Pkg. x Inf.	0.07	0.79 NSD	1.40	0.39 NSD
Time x Pkg. x Inf.	0.10	0.76 NSD	0.06	0.02 NSD
Temp. x Time x Pkg.	1.73	0.20 NSD	0.00	0.00 NSD
Temp. x Time x Inf.	0.35	0.56 NSD	0.13	0.04 NSD
Temp. x Time x Inf. x Pkg.	0.24	0.63 NSD	0.16	0.04 NSD
<b>B. Water Activity</b>				
Temperature	1.92	0.17 NSD	3.99	0.05 *
Time	2.65	0.11 NSD	0.32	0.58 NSD
Packaging Material	2.64	0.11 NSD	2.91	0.10 NSD
Infusion	4.00	0.05 *	0.20	0.66 NSD
Temp. x Time	2.41	0.13 NSD	1.56	0.22 NSD
Temp. x Pkg.	1.11	0.30 NSD	6.75	0.01 **
Temp. x Inf.	3.98	0.05 *	0.97	0.33 NSD
Time x Pkg.	0.80	0.38 NSD	0.88	0.35 NSD
Time x Inf.	0.28	0.60 NSD	0.70	0.41 NSD
Pkg x Inf.	3.51	0.07 NSD	0.71	0.40 NSD
Temp. x Pkg. x Inf.	2.72	0.11 NSD	2.45	0.13 NSD
Time x Pkg. x Inf.	0.13	0.72 NSD	0.73	0.40 NSD
Temp. x Time x Pkg.	0.69	0.41 NSD	2.69	0.11 NSD
Temp. x Time x Inf.	0.28	0.60 NSD	1.37	0.25 NSD
Temp. x Time x Inf. x Pkg.	0.03	0.87 NSD	2.32	0.13 NSD

(Continued)

Table C-1 - Summary of Data Analysis (Continued)

C. Reflectance Color, Hunter "L"

Temperature	0.69	0.41	NSD	6.38	0.02 *
Time	0.05	0.82	NSD	0.73	0.40 NSD
Packaging Material	0.27	0.60	NSD	2.90	0.10 NSD
Infusion	0.87	0.36	NSD	1.60	0.21 NSD
Temp. x Time	0.30	0.59	NSD	1.68	0.26 NSD
Temp. x Pkg.	0.27	0.60	NSD	6.21	0.02 *
Temp. x Inf.	0.65	0.43	NSD	4.89	0.32 *
Time x Pkg.	0.09	0.76	NSD	0.32	0.58 NSD
Time x Inf.	0.93	0.34	NSD	0.63	0.43 NSD
Pkg. x Inf.	0.53	0.47	NSD	2.04	0.16 NSD
Temp. x Pkg. x Inf.	0.34	0.56	NSD	4.38	0.04 *
Time x Pkg. x Inf.	0.36	0.55	NSD	0.76	0.39 NSD
Temp. x Time x Pkg.	0.16	0.69	NSD	0.99	0.32 NSD
Temp. x Time x Inf.	0.29	0.59	NSD	1.00	0.32 NSD
Temp. x Time x Inf. x Pkg.	0.19	0.67	NSD	1.82	0.18 NSD

D. Reflectance Color, Hunter "a"

Temperature	0.89	0.35	NSD	1.31	0.26 NSD
Time	0.02	0.90	NSD	1.64	0.21 NSD
Packaging Material	0.00	1.00	NSD	0.54	0.46 NSD
Infusion	0.09	0.77	NSD	0.63	0.43 NSD
Temp. x Time	0.05	0.83	NSD	1.21	0.28 NSD
Temp. x Pkg.	0.01	0.92	NSD	0.94	0.34 NSD
Temp. x Inf.	0.10	0.75	NSD	2.30	0.14 NSD
Time x Pkg.	0.06	0.80	NSD	0.54	0.47 NSD
Time x Inf.	0.03	0.87	NSD	0.75	0.39 NSD
Pkg. x Inf.	0.00	0.98	NSD	0.71	0.39 NSD
Temp. x Pkg. x Inf.	0.00	0.97	NSD	1.13	0.29 NSD
Time X Pkg. x Inf.	0.00	0.99	NSD	0.28	0.60 NSD
Temp. x Time x Pkg.	0.01	0.91	NSD	0.19	0.66 NSD
Temp. x Time x Inf.	0.04	0.85	NSD	0.34	0.56 NSD
Temp. x Time x Inf. x Pkg.	0.01	0.94	NSD	0.02	0.89 NSD

(Continued)

Table C-1 - Summary of Data Analysis (Continued)

E. Reflectance Color, Hunter "b"

Temperature	0.11	0.74	NSAD	2.71	0.11	NSD
Time	0.01	0.91	NSD	0.08	0.78	NSD
Packaging Material	0.15	0.70	NSD	0.34	0.56	NSD
Infusion	0.10	0.75	NSD	1.61	0.21	NSD
Temp. x Time	0.04	0.84	NSD	0.18	0.68	NSD
Temp. x Pkg.	0.13	0.72	NSD	1.72	0.20	NSD
Temp. x Inf.	0.18	0.68	NSD	5.12	0.03	*
Time x Pkg.	0.06	0.81	NSD	0.13	0.72	NSD
Time x Inf.	0.06	0.80	NSD	0.06	0.80	NSD
Pkg. x Inf.	0.23	0.64	NSD	0.71	0.40	NSD
Temp. x Pkg. x Inf.	0.16	0.69	NSD	3.09	0.09	NSD
Time x Pkg. x Inf.,	0.04	0.85	NSD	0.18	0.67	NSD
Temp. x Time x Pkg.	0.15	0.70	NSD	0.04	0.85	NSD
Temp. x Time x Inf.	0.24	0.63	NSD	1.01	0.32	NSD
Temp. x Time x Inf. x Pkg.	0.05	0.8	NSD	1.81	0.19	NSD

F. Folic Acid (HPLC Method)

Temperature	0.46	0.51	NSD	0.25	0.62	NSD
Time	0.98	0.35	NSD	0.00	0.97	NSD
Packaging Material	0.24	0.63	NSD	0.77	0.39	NSD
Temp. x Time	0.02	0.90	NSD	0.24	0.63	NSD
Temp. x Pack.	0.19	0.67	NSD	0.52	0.48	NSD
Time x Pack.	0.44	0.52	NSD	0.14	0.72	NSD
Temp. x Time x Pack	0.49	0.49	NSD	0.14	0.72	NSD

\* 95%

\*\* 99%