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TECHNICAL REPORT
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THE EFFECT OF LIGHT QUALITY ON THE RIPENING OF DETACHED TOMATO FRUIT

by

C. C. Mpelkas
and
E. M. Kenyon

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13. ABSTRACT

A better knowledge of the factors affecting the rate and nature of ripening and its subsequent phase over ripening and spoilage of fresh fruits and vegetables could lead to control of this process. Such control could lead to substantial savings in the storage and distribution of such products in the Defense Subsistence feeding system.

Preliminary studies were conducted on the effect of light of various wavelengths and under a dark situation on detached tomato fruit, with humidity, temperature and CO_2 content of the atmosphere controlled. Color development, taste, firmness and chemical change (acid-base ratio) were used to study rates of ripening over an eight-day period.

Light which emits strongly in the red and blue regions of the spectrum appears to result in acceleration of ripening as measured by taste panel, chemical analysis, and color development. Thus, these wavelengths appear to play a key role in ripening rates and subsequent spoilage of tomatoes under controlled conditions of temperature, humidity and carbon dioxide atmosphere.

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Spoilage	7		7			
Storage stability	4					
Tomatoes	6,7		9			
Light (visible radiation)			6			
Humidity			6			
Temperature			6			
Controlled atmospheres			6			

FOREWORD

The purchase, distribution and storage of fresh produce destined for utilization in the Armed Forces subsistence feeding system is a multi-million dollar business. Spoilage losses during handling, even if a small percentage of the total, can be extremely costly. Hence, studies which contribute to an understanding of how fresh "living" produce, such as fruits and vegetables ripen, is of material interest to the Army.

This report presents a preliminary study of the effect of light of various wavelengths, and conditions of no light, have on the ripening of fresh detached tomato fruit. Cool white fluorescent, and Gro-Lux fluorescent lamps , as well as darkness conditions were used. Temperature, humidity and atmospheric CO_2 content were controlled.

The objective of this study was to determine the effect of light conditions on rate of ripening, with a view to the possibility of controlling the ripening of tomatoes and possibly other fruits and vegetables in the Army distribution system, resulting in the reduction of spoilage.

This study was conducted during a two-weeks active duty for training period with Major Christos C. Mpelkas, USAR, 17-29 August 1970.

Acknowledgement is made for the significant technical contributions made by Mr. Irving L. Dame, Jr., Food Laboratories, in setting up and controlling the test chamber used in these studies.

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ABSTRACT

A better knowledge of the factors affecting the rate and nature of ripening and its subsequent phase over ripening and spoilage of fresh fruits and vegetables could lead to control of this process. Such control could lead to substantial savings in the storage and distribution of such products in the Defense Subsistence feeding system.

Preliminary studies were conducted on the effect of light of various wavelengths and under a dark situation on detached tomato fruit, with humidity, temperature and CO_2 content of the atmosphere controlled. Color development, taste, firmness and chemical change (acid-base ratio) were used to study rates of ripening over an 8-day period.

Light, which emits strongly in the red and blue regions of the spectrum, appears to result in acceleration of ripening as measured by taste panel, chemical analysis, and color development. Thus, these wavelengths appear to play a key role in ripening rates and subsequent spoilage of tomatoes under controlled conditions of temperature, humidity and carbon dioxide atmosphere.

INTRODUCTION:

Several interesting observations have been recorded in technical literature which suggest a relationship between light and physiological responses of fruit ripening. As early as 1913, Duggar (5) reported that tomato fruit, exposed to sunlight, had improved ripening characteristics over those that were shaded. Results of Arthur (1), Smith(10) and Smith and Smith (11), showed that both quality and intensity of light influenced the development of anthocyanin in apples and carotenoids in tomatoes. Nettles, Hall, and Dennison (8) found that tomato fruit exposed to cool white fluorescent light had higher total carotenoids and color values than those ripened at the same temperature in darkness. According to Terrien, et al (13), the blue wavelength has been known to produce highly colored flowers, as well as develop higher lipid content in plants. Butler and Downs (3) made reference to mature apples as not turning old if kept in the dark while ripening. Ethyl alcohol accumulates rather than anthocyanin being formed. The apples can manufacture the red pigment only if they are exposed to light when are mature.

It is well known that tomato fruit grown under normal sunlight have up to twice as much ascorbic acid as those produced under greenhouse conditions. Dalal, et al (4) have reported that light has been recognized as an important environmental factor, relative to the ascorbic acid content of fruits and vegetables. Frazier, et al (6), McCollum (7), and Somers, et al (12), all indicated that light energy impinging directly on the tomato fruits effect their ascorbic acid content. Brown and Moser (2) reported that greenhouse tomato fruit had only about half the Vitamin C concentration of tomatoes grown in the field. Shewfelt and Halpin (9) revealed that plant growth stimulating fluorescent light sources produced a higher rate of color development on tomato fruit than conventional fluorescent sources.

MATERIALS AND METHODS:

Tomato fruit was harvested at the mature-green stage of development from field-grown plants of the CR-43 (Crack-resistant) variety. The fruits were selected carefully to obtain a high degree of uniformity of mature-green or pale green color. The mature-green stage was chosen in preference to the "breaker" or pink stage so that the light treatments could be evaluated through an extended ripening period.

The fruit was subjected to the following treatments:

1. Exposed to standard Gro-Lux fluorescent lamps -

   The Gro-Lux fluorescent sources are designed for use in plant growth and are manufactured by Sylvania Lighting Products Company.

2. Exposed to cool white fluorescent lamps -

   Cool white fluorescent lamps which are conventional sources producing wavelengths primarily in the visible spectrum, are made by various lamp manufacturers.

3. Held in darkness:

   For convenience the intensity levels in the light treatments were measured in foot candles. The Gro-Lux intensity averaged

147 foot candles and the cool white averaged 465 foot-candles. Since the energy emission of the Gro-Lux lamps is in the red and blue wavelengths, which controls some of the photochemical processes of plants, foot-candle readings are not too significant.

Table I presents the total energy emission in the various spectrum bands of the Gro-Lux and cool white fluorescent lamps.

TABLE I: Energy Emission in Arbitrary Color Bands of 40-Watt Fluorescent Lamps Given in Watts and Total Emission

Spectral Color	Nanometer Band	Std. Watts	Gro-Lux Percent	Cool White Watts	Cool White Percent
Ultra Violet	380	0.10	1.42	0.16	1.68
Violet	380-430	0.70	9.67	0.72	7.57
Blue	430-490	1.96	27.07	1.98	20.78
Green	490-560	1.02	14.02	2.35	24.67
Yellow	560-590	0.10	1.42	1.74	18.27
Orange	590-630	0.44	6.05	1.69	17.75
Red	630-700	2.86	39.55	0.81	8.47
Far-red	700-780	0.06	0.80	0.07	0.81
TOTAL		7.24	100.00	9.52	100.00

The spectral energy distribution curves of the lamps are presented in Figures 1 and 2.

Each treatment consisted of 50 tomato fruits. The distance from the light source to the fruit was 12 inches. Fruits under each light treatment were located near the center of the illuminated area for uniform light exposure. Black cloth was used to prevent interference of one light treatment with another. Four 40-watt fluorescent lamps in two 2-lamp fixtures were used for each light treatment. The fruit undergoing treatment were positioned stem-end down throughout the test period. Fruit under each fluores cent light source received 16 hours of light exposure during each 24 hours. The temperature range in the chamber was 75 to 80°F during the light period and 70°F during the dark period. Relative humidity ranged between 65 to 70%. The carbon dioxide atmospheric level was raised to a concentration of 1%. Carbon dioxide was used to see if the green tomato fruit could act as a photosynthetic organ, and demonstrate enhanced photosynthesis with an increase in the carbohydrate content of the fruit.

The quality factors that were studied included color development S/A ratio, texture. Flavor was evaluated by organoleptic testing. Fruit was removed from each treatment on 0,3,6 and 8 days for quality control studies.

Observations as to color and texture were recorded. The fruits from each treatment were then cored and pureed. A Hunter Mechanical Force Gauge was used to test the firmness of the fruit. A Hunter Color Difference Meter was used - Model D38 Tristimulus Calorimeter - to measure the total reflectance (L), the redness (a) and yellowness (b) values of the puree.

The a/b ratio was used as an index of red color development and as objective support for the visual observations.

RESULTS:

Color and firmness descriptions for the fresh fruits held at 0, 3, 6 and 8 days in each of the three treatments is given in Figure 3, along with the Hunter Difference Meter values for the raw purees prepared from the fruits. Changes in the a/b color index values for the different treatments are also shown in Figure 3.

COLOR

The Dark Treatment developed color slowly. After 8 days, the a/b index of the puree was 0.82. The cool white fluorescent sources resulted in an increase in the rate of color development. Fruits from this treatment produced raw puree that had an a/b value of 0.95 after the 8-days exposure.

Results from the standard Gro-Lux fluorescent source revealed a more rapid color development than the other two treatments.

After 8 days, the fruit had uniform red color producing a puree with a/b value of 1.67. The a/b values for fruits exposed to the standard Gro-Lux lamps were higher after 6 days exposure than was obtained under cool white lamps in 8 days, see Figure 4. Yet, the light sources were equal in terms of the amount of electrical energy consumed.

The difference was in the distribution of radiation in the visible spectrum. The difference in light quality had no apparent effect on the temperature of the exposed fruit. Evidently, the influence of light energy on the ripening of tomato fruits is affected by the intensity and quality (wavelength) of the light received. Certain wavelength patterns appear to be more important than others. Standard Gro-Lux fluorescent source maintains its major emission in the visible red and blue regions of the spectrum, while the cool white source has its energy output in the blue, yellow and green bands.

ORGANOLEPTIC

Figure 5 shows color photographs of the color production due to the various treatments at the end of 8 days. The upper three photographs show the successive increase of color development from the Dark Treatment through the cool white to the Gro-Lux lamp treatment for the whole fruit.

The lower two photographs show sections of the fruits at 0 to 8 days showing best results with the Gro-Lux treatment.

In addition to color development, light energy affects the quality characteristics of ripening, such as flavor,odor and texture. A preliminary organoleptic test was conducted to evaluate the flavor texture and appearance of the fruits of the different treatments. The results revealed that the evaluation from the 17 taste panelists who were involved in the test, indicated that the group preferred the Gro-Lux treated fruit;

cool white as their second, and the dark treatment as their third choice. The factors that were evaluated were color, odor, flavor, texture and appearance.

FIRMNESS

Tomato fruit samples from the three treatments were measured for textural firmness at 0, 3, 6 and 8 days, using the Hunter Firmness Gauge and these results were reported in Figure 3.

Figure 6 is a plot of the Hunter Gauge readings in pounds vs days using measurements taken on the side of the whole fruit. This shows a somewhat greater increase in softness up to 8 days, of both the lighted samples over the dark samples as the green fruits approached ripe stage.

CHEMICAL CHANGES DURING RIPENING

The composition of tomato fruit is known to vary during ripening undergoing complex metabolic changes which are not too well understood.

The flavor character of the tomato is developed from numerous chemical constituents of the fruit among which the acidity and sugar components are of particular importance. Figure 7 shows the values obtained for total acidity as citric acid, sucrose and reducing sugars. Total sugar, and s/a ratio were determined and are also shown. These data can only be considered preliminary, representing single determinations, but are of interest as indicating trends.

Figure 8 shows a plot of total sugar % vs time and Figure 9 shows acid vs time made from data in Figure 7. Total sugar varied in the three light conditions from 0 to 8 days, ending higher in the cool white and dark samples than with the Gro-Lux. Total acidity, however, rose in the dark sample and fell in both light exposed fruit.

Figure 10 is a plot of total sugar acid ratios for the three light conditions and shows a trend of falling s/a ratio for the dark samples, and a rising trend for the light-treated samples and was the highest in the Gro-Lux light condition. This would indicate a flavor sweeter in character for the light-treated vs the dark samples and this was substantiated by organoleptic evaluation.

CONCLUSIONS

In terms of color changes as measured by the Hunter Color Difference system, the standard Gro-Lux showed a more rapid color development than the cool white or dark treatment and a higher absolute value after 8 days under the conditions used. Firmness as measured by the Hunter Gauge did not appear to be a good ripeness indicator, but more readings might permit statistical analysis and show significance, if any.

Limited organoleptic taste tests indicated a preference for Gro-Lux (1), cool white (2) and dark treatment (3) - in that order.

Chemical tests on sugar and acid development indicated trends. Further work is needed. Sugar acid ratios showed a greater "sweetness" in the light-treated vs dark samples substantiated by the taste panel results.

These results indicate the Gro-Lux light appears to accelerate ripening and dark conditions retard it. Due to the limited time available for the study more work should be conducted to confirm this work and to extend the findings.

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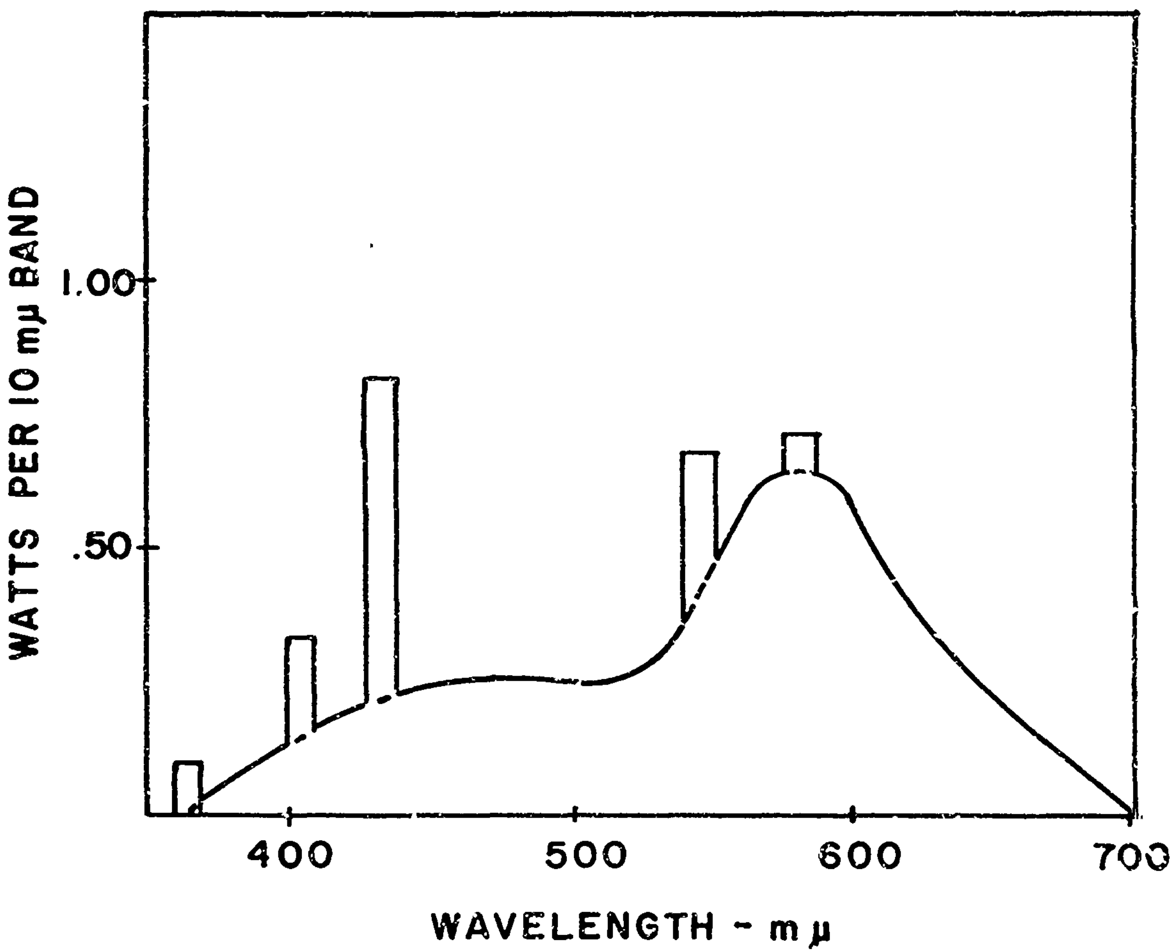


Figure - 1

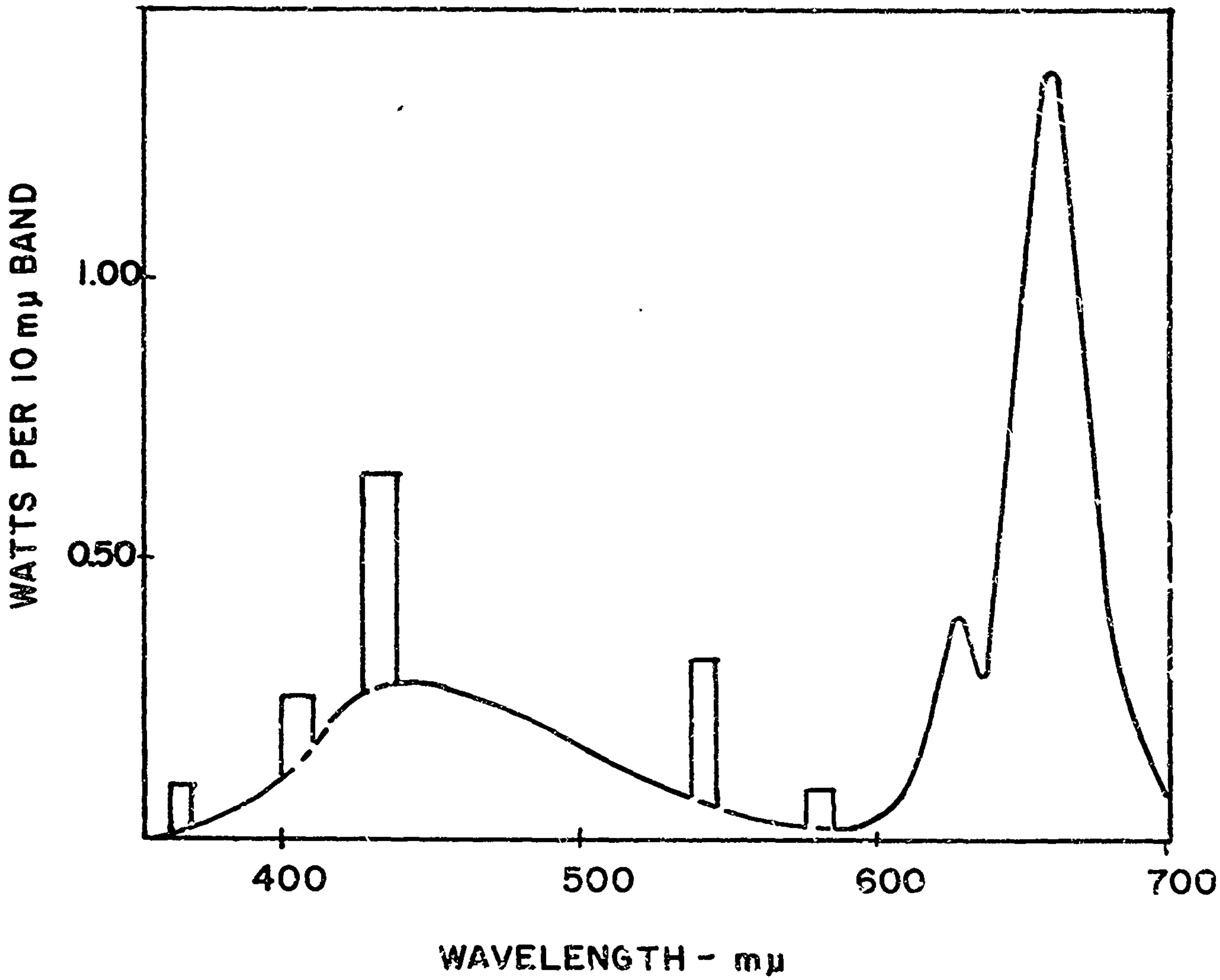


Figure - 2

Treatment	Holding Period (Days)	Firmness test w/Hunter Gauge Readings in Pounds Calyx	Stem	Side	Observed Firmness	Observed Color	Color Readings (Puree) Hunter Difference Meter L	a	b	a/b
Initial Analysis	0	6.34	5.42	6.27	Very hard	Mature green	48.6	-13.5	23.2	-0.28
Darkness	3	7.25	6.00	6.92	Very hard	Mature green	50.9	-13.5	24.9	-0.54
	6	3.67	3.75	4.25	Firm	Light red	42.5	15.5	20.8	0.74
	8	3.19	3.50	4.08	Firm	Light red	41.3	16.8	17.9	0.82
Cool White	3	5.50	5.45	5.67	Hard	Breaker	50.1	-10.7	26.9	-0.39
	6	3.75	3.00	3.33	Firm	Light Red	43.2	14.8	19.4	0.76
	8	3.58	3.33	3.08	Firm	Light Red	35.3	14.8	15.6	0.95
Standard Gro-lux	3	4.34	4.67	4.17	Firm	Turning	53.4	-7.4	24.0	-0.30
	6	3.57	3.67	3.75	Firm	Red	40.0	24.9	14.4	1.73
	8	3.51	3.33	3.58	Firm	Red	32.7	24.8	15.1	1.67

Figure - 3

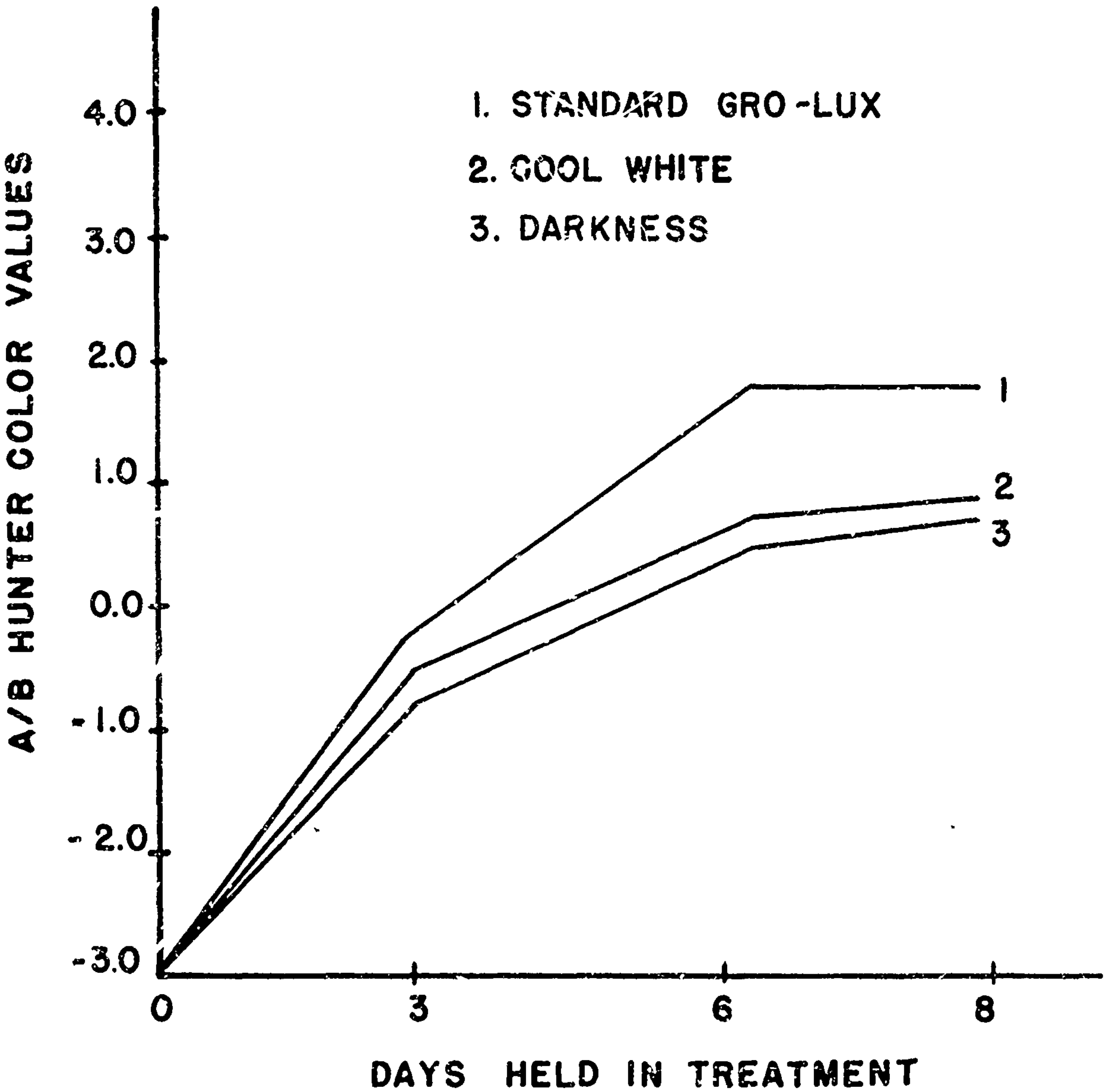

1. STANDARD GRO-LUX
2. COOL WHITE
3. DARKNESS
A/B HUNTER COLOR VALUES
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
0
3
6
8
1
2
3
DAYS HELD IN TREATMENT

Figure - 4

8-DAY DARKNESS

8-DAY COOL WHITE

8-DAY GRO-LUX

0-DAY
SECTIONS

8-DAY SECTIONS
THREE TREATMENTS

FIGURE 5 COLOR DEVELOPMENT OF TOMATO SAMPLES FOR THREE LIGHT CONDITIONS (0-8 DAY PERIODS)

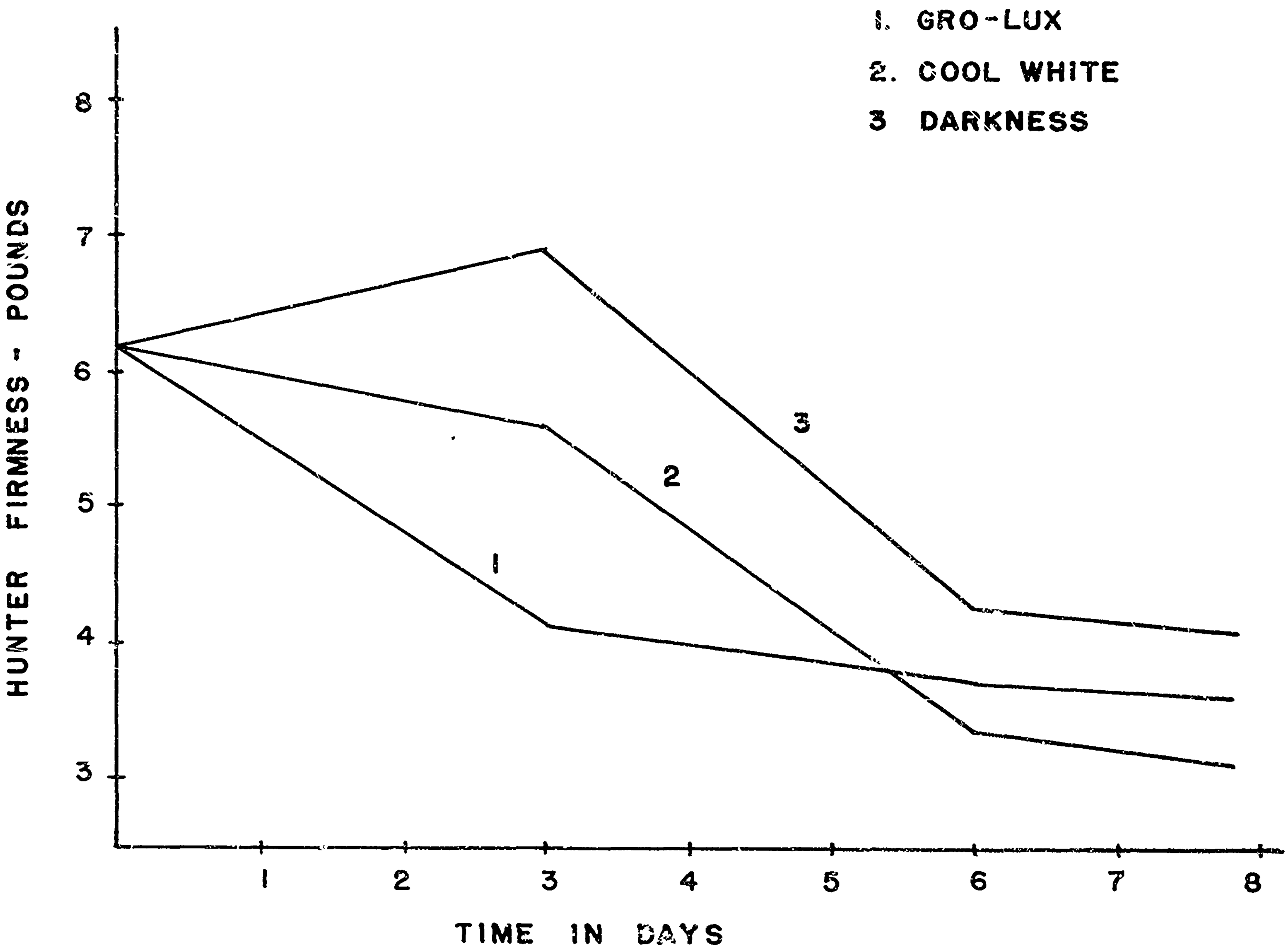

1. GRO-LUX
2. COOL WHITE
3 DARKNESS
HUNTER FIRMNESS - POUNDS
8
7
6
5
4
3
1
2
3
4
5
6
7
8
TIME IN DAYS

Figure - 6

CHEMICAL ANALYSES

RIPENING PERIOD

ANALYSES (% by wt)	0 Days	3 Days			6 days			8 days		
	Initial	Gro-Lux	Cool White	Dark	Gro-Lux	Cool White	Dark	Gro-Lux	Cool White	Dark
Citric Acid	0.50	0.57	0.57	0.38	0.53	0.50	0.49	0.43	0.50	0.60
Dextrose	2.64	3.02	3.59	3.02	2.79	3.02	3.66	3.13	3.53	3.67
Sucrose	0.10	0.11	0.09	0.20	0.20	0.07	0.13	0.07	0.10	0.12
Total Sugar	2.74	3.13	3.68	3.22	2.99	3.09	3.79	3.20	3.63	3.79
S/A Ratio	5.49	5.45	6.45	8.47	5.65	6.18	7.73	7.45	7.25	6.31

Figure - 7

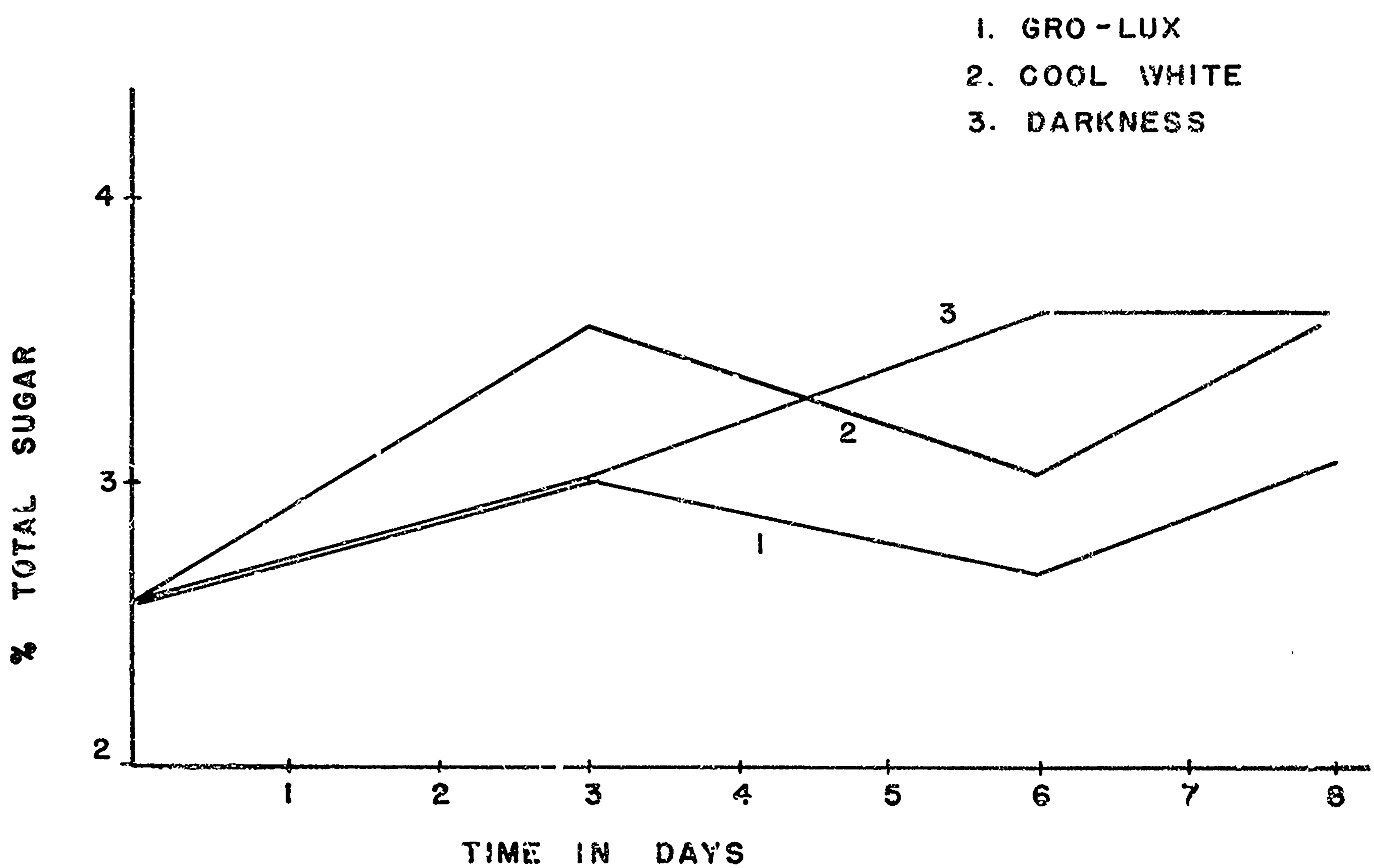

1. GRO-LUX
2. COOL WHITE
3. DARKNESS
% TOTAL SUGAR
4
3
2
1
2
3
4
5
6
7
8
TIME IN DAYS

Figure - 8

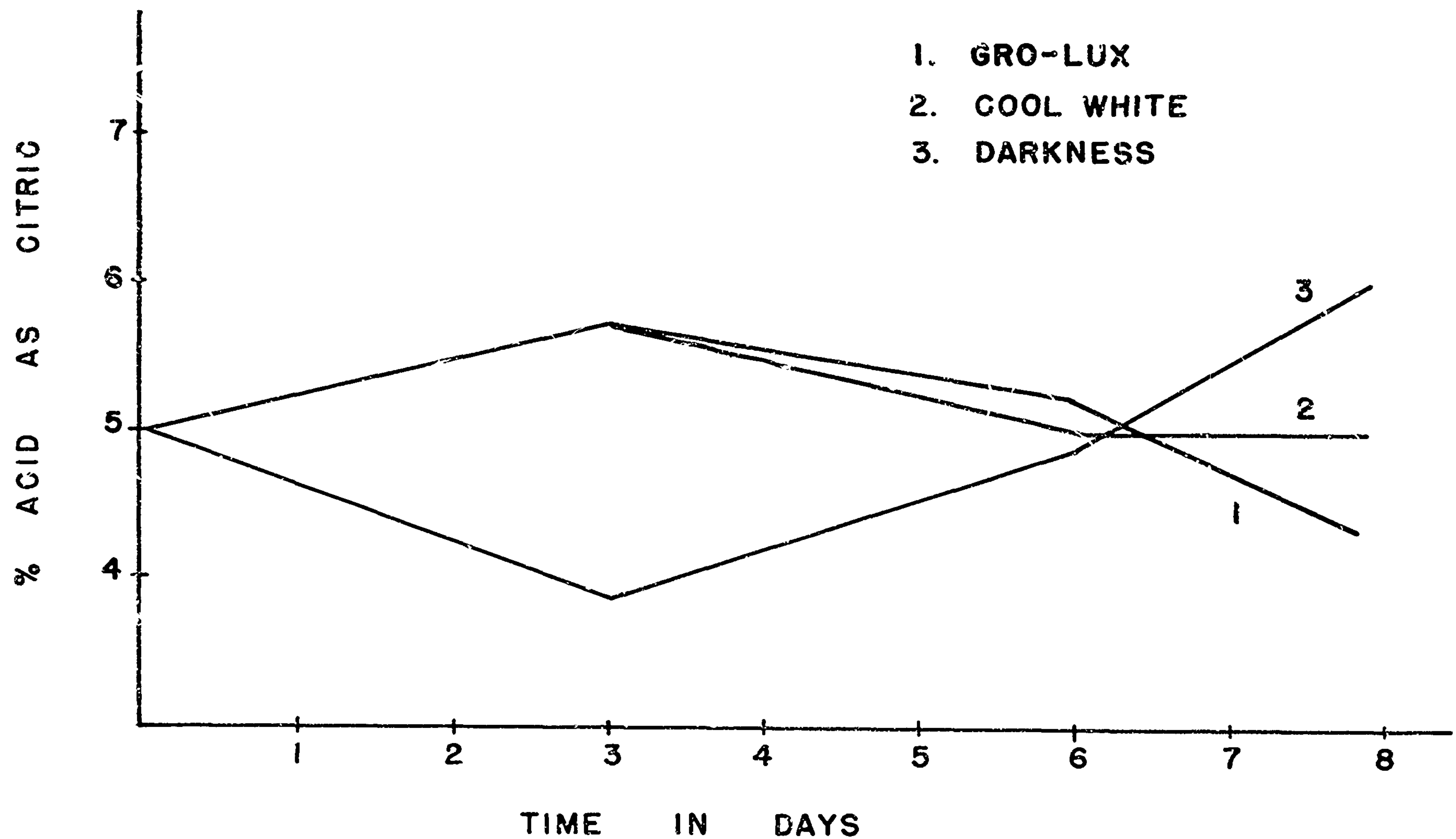
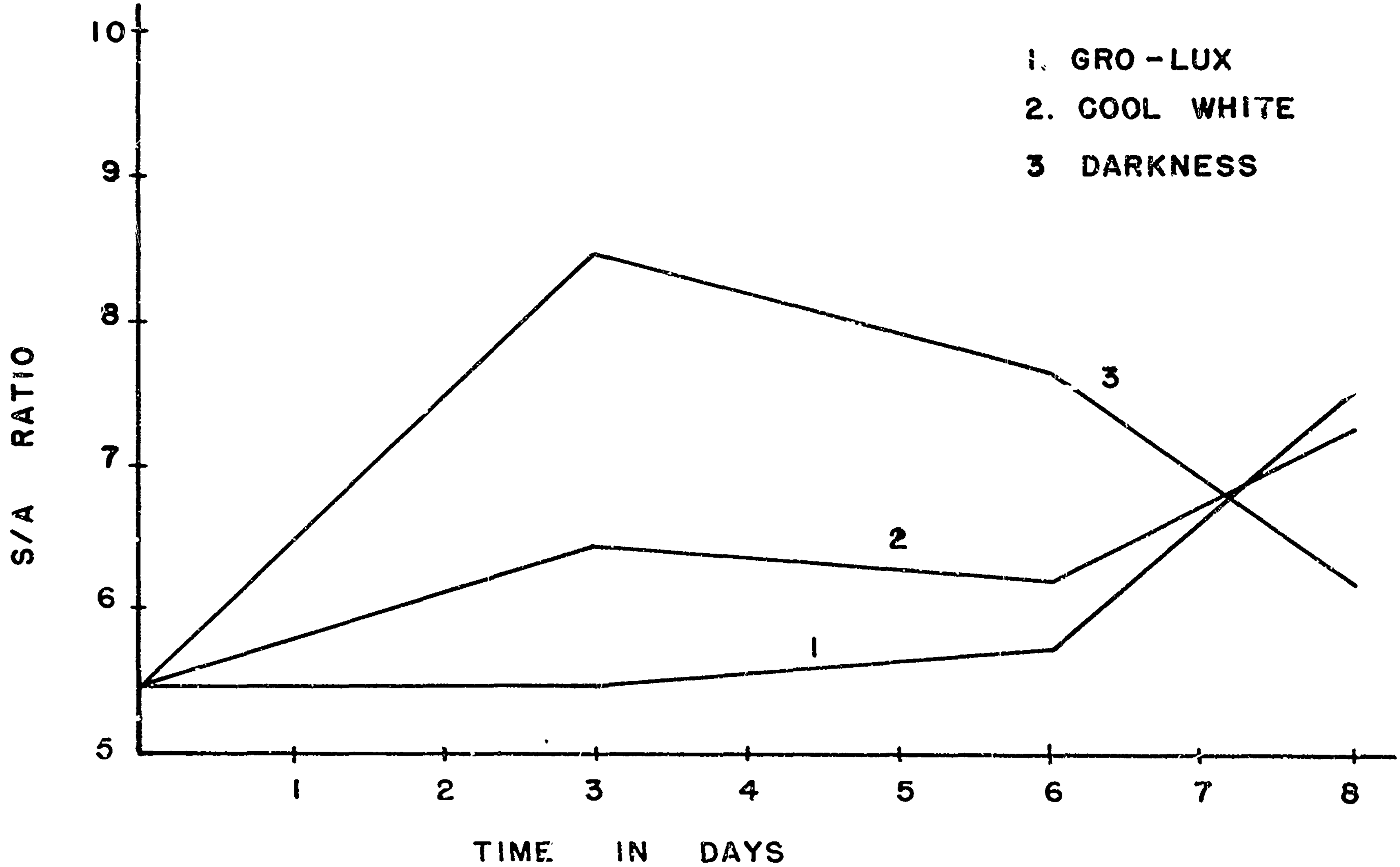

1. GRO-LUX
2. COOL WHITE
3. DARKNESS
% ACID AS CITRIC
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
TIME IN DAYS

Figure - 9



1. GRO-LUX
2. COOL WHITE
3 DARKNESS
S/A RATIO
10
9
8
7
6
5
1
2
3
4
5
6
7
8
TIME IN DAYS

Figure - 10