THE MEASUREMENT OF THE VARIATION OF ENERGY IN THE "VITA SPECTRUM" OF THE SUNSHINE IN KANSAS

by

RICHARD LAWRENCE PYCHA

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INTRODUCTION

The biological action of sun radiation, such as pigmentation of the skin, prevention of rickets in animals and children on a deficiency diet, and the cure of tuberculous lesions, has been found to be produced by the ultraviolet rays of the "vita region".[1] The other rays have little action except that of heat and as they heat the living cells, may quicken the action of the "vita rays".

The "vita region" is a part of the invisible portion of the sun's spectrum. The total invisible portion of the spectrum has wave lengths below 390 millimicrons while the visible portion ranges between 390 and 810 millimicrons. The "vita region" includes wave lengths between 292 and 312 millimicrons, that have the property of regulating calcium and phosphorus metabolism in the animal organism. This has been determined by raising a lot of chickens in the nutrition room back of window glass which lets through no rays under 312 millimicrons in length and another lot back of cel-o-glass which lets through about forty percent of the rays under 312 millimicrons in length. The chickens

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1. The term "vita region" was suggested by J. S. Hughes to designate that portion of the spectrum which is concerned in the regulation of calcium and phosphorus metabolism.

behind the window glass developed rickets in from six to twelve weeks, while those behind the cello-glass developed normally.

Since the proper use of sun radiation or artificial radiation for biological purposes depends upon the dosage, the problem of accurately measuring the energy in the "vita region" of the sun's spectrum under varying conditions is one of importance at the present time. Some of the methods now in use for making this determination are the following:

Thermocouple and Spectroscope. This method is direct. A beam of sunlight is passed through a series of quartz prisms (quartz transmits ultra-violet light) of a spectroscope to spread the beam into its various wave lengths. The energy in the different parts of the spectrum are measured by means of a thermocouple.

Degree of Calcification of Bones. This is a comparative method in which chicks or some experimental animals are fed on a rachitic diet and exposed to the sunlight for varying lengths of time. An analysis of the bones is then made to determine the degree of calcification. The results are obtained merely in a comparative form.

Lithopone Paint Method. This is a chemical method given by Clark (1924) which depends upon the darkening of a

sensitive lithopone paint by the ultra-violet rays. A paste made of lithopone paint and distilled water is placed between quartz plates and exposed to the light. The degree of darkening is determined by comparing with certain grey paints.

Acetone-Methylene Blue Gauge. This is another chemical method and was described by Webster, Hill and Eidinow (1924). It depends upon the decomposition of acetone in a water solution by radiant energy. When methylene blue is present in the solution it is bleached by the compounds resulting from the decomposition of the acetone. The amount of bleaching of the dye is used as a measure of the intensity of the "vita rays" in the light being tested.

The purpose of this investigation was to measure by the Acetone-Methylene Blue Gauge the intensity of the "vita rays" in the sunshine of Kansas every day for a years time. Since a rise in temperature accelerates chemical reactions and it was thought by most investigators that a great part of the bleaching of the methylene blue in the summer was due to the heat, a determination of the temperature coefficient of this reaction was made.

The author is deeply grateful to Professor J. S. Hughes for his many helpful suggestions, both in carrying out the method outlined and in drawing conclusions from the data obtained.

METHOD

The laboratory was not equipped with suitable spectroscopes and thermocouples to make a direct measurement of the "vita rays". Since a chemical method had to be used, the acetone-methylene blue method was chosen as it seems to come nearest meeting the needs of nutrition workers.

The rays which are active in bleaching the acetone-methylene blue reagent, coincide very closely with those which are concerned with ordinary bone development. According to the work of Russell and Massengale (1927) there is a close agreement between the results obtained by the acetone methylene blue gauge and the degree of calcification of the bones of growing chicks.

In this method a reagent put out by Siebe Gormand of England was used which is made up from a 0.1 percent solution of methylene blue; 5.8 c.cm. of this is added to 30 c. cm. of acetone and made up to 100 c.cm. with water. The acetone is decomposed by the ultra-violet rays into acetic acid, formic acid and other substances. This is partly an oxidation process and can be measured by the reduction of the methylene blue which results.

The standard reagent is placed in a small quartz tube

(3mm. internal diameter) which is closed with a rubber stopper and exposed to the sunlight for the full sunshine period of the day. The tube is placed in an open space that is shaded in no way from the sun and is placed so that the axis of the tube is at right angles to the rays of the sun.

A series of ten tubes with varying strengths of copper nitrate solution is used as a scale in estimating the degree of bleaching. The tubes are of the same size as the quartz tube used in exposing the reagent and are sealed after the solution is put in, to prevent evaporation which would deepen the color. The most concentrated tube of copper nitrate solution matches the standard reagent in color. The other tubes are diluted so as to give ten equal divisions on the scale. The difference in color between each of these tubes represents one unit on the acetone-methylene blue scale. These tubes are placed in a frame with a white paper background, handy for comparison. At the end of each day the tube which has been exposed is matched with these tubes to determine the number of units of bleaching of the acetone-methylene blue solution. For example the tube is placed in the rack between the tubes which nearly match it and then carefully examined to see which it is nearer like. If it matches tube 3 the reading is then (10-3) or 7 units.

During the summer when the readings were high, it was

necessary to use three tubes for one days reading, the tubes being changed at 11 o'clock and at 2 o'clock.

Daily readings have been taken by the acetone-methylene blue method during the past year, beginning January 10, 1927. The standard reagent put out by Siebe Gormand of England was used so that the results should be comparable to those of other workers using the same standard reagent. A record of the conditions at the time of exposure was also kept; the temperature, kind of day, and the total hours of sunshine. The unit readings are recorded in Table 1.

GENERAL RESULTS

The reading on the first bright clear days was only two units. This reading increased slowly until the last of April when the reading was five units. Beginning at this time the increase in the readings was much more rapid until the maximum reading for the summer, sixteen units, was reached on July 7, (see figure 1). The maximum reading remained the same on clear bright days until the ninth of August. On the 31st of August which was a bright clear day, the reading was fifteen units. Beginning at this time there was a rapid decrease in the readings until the middle of October which was six units. The decrease then was gradual

TABLE 1

Daily Reading on the Acetone-Methylene Blue Gauge at Manhattan, Kansas, for the Year, 1927

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.(28)
1		3	0	0	5	4	13	14	7	0	0	2	2-
2		0	1	3	2	8	15	0	15	6	3.5	2	0.5
3		2.5	2	3	5.5	7	12	10	10	8	4.5	2	2-
4		0	2	2	0.5	10.5	15	15	13	8	1	2.5	2-
5		1	0	2	1	1	10	16	12	2	1	3	2-
6		2.5	2	1	0	8	14	13	11	0	0	3	0.5
7		1	2	0	0	8	15	11	14	7	0	0	2-
8		2	2	0	5.5	10	15	15	13	6.5	0	3	2
9		1	-	0.5	0.5	12	16	16	14	6.5	0	0	2-
10	2	1.5	-	2.5	0.5	14	16	13	14	6	0	0	2
11	1.5	2	-	2	6	6	12	13	14	2	0	0	2
12	0	0	-	0.5	2.5	0	12	13	14-	6	4	0	
13	2	0	3.5	0	7	0	2	12	14-	6	2	2-	
14	2	1.5	2.5	0.5	6.5	8	13	11	14-	6-	0	2-	
15	2	2	3	2	9	10	16	3	14-	6-	3	0	
16	1.5	3	0	1.5	10	1	10	4	13	6-	2	2-	
17	0	0	2	1.5	9	7	16	5	12	6-	0	2-	
18	0	1.5	0	0	8	12	15	12	8	6-	0	2-	
19	1	1.5	0.5	1	5	13	10	9	13	6-	0	1.7	
20	0	2.5	0	0	6.5	6.5	8	14	12	5.5	0	1.7	
21	0	0	2	1	5	13	16	13	8	5.5	0	1.7	
22	1	2.5	2	2	5	13.5	16	14	9	5.5	0	1.7	
23	1.5	2.5	0	0	10	13	15	12	11	5	0	0	
24	1.5	0.5	2	0	10	14	16	5	0	5	2.5	0,5	
25	0	2	2.5	5	10	15	15	6	0	5	3	2-	
26	0.5	1	2.5	5	10	14	16	14	0	5	2	0	
27	0	0.5	0	5	12	14	15	15	0	5	0	0	
28	2.5	0	1	5	7.5	15	3	2	0	4	3.5	2-	
29	1.5	-	0	5	2.5	13	4	8	2	1	3.5	2-	
30	2.5	-	0	5	10	11	9	12	0	4	3.5	0	
31	2.5	-	0	-	8	-	12	15	-	4.5	-	1	

until December 21, which was one and seven tenths units (obtained by taking one third of the reading for three consecutive bright days). The reading was two units on January 9, 1928.

A chart has been made showing the general trend of the daily readings. Each time a new high reading was obtained, as the readings increased, and a new lower reading was obtained as the readings decreased (on bright clear days) a point was established on the chart. (figure 1)

DETERMINATIONS OF A TEMPERATURE COEFFICIENT

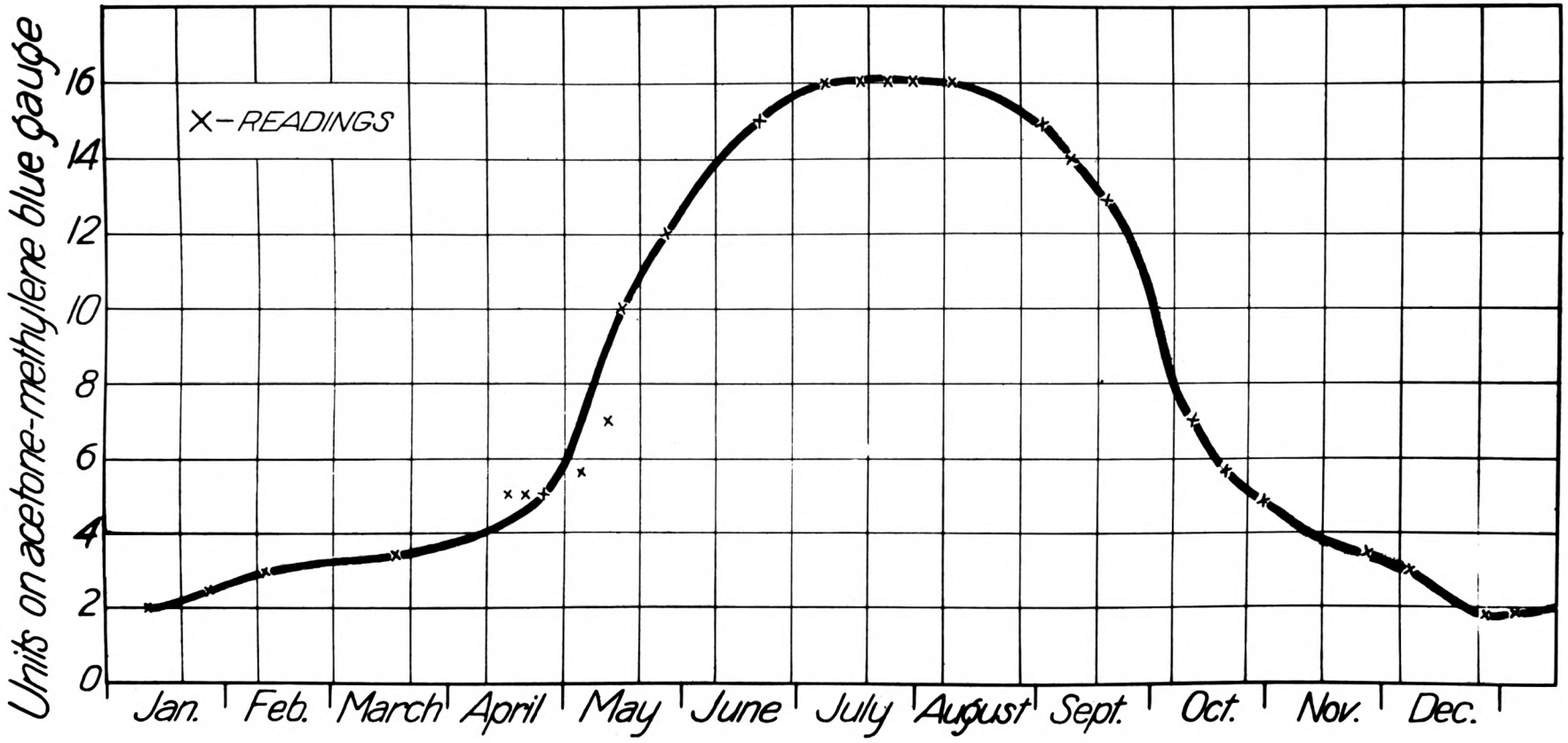
There has been a great deal of discussion as to why the summer readings are so much higher than the winter readings. Since chemical reactions are accelerated by heat, the opinion of most investigators has been that a part of the higher summer readings were due to the higher temperature of that time, and that these readings should be corrected for temperature changes.

According to Webster, Hill and Eidinow (1924), "A rise in temperature of 10 degrees C., say from 15 degrees to 25 degrees C., accelerates the bleaching and makes the reading about 0.6 too high".

Hill (1927) found the temperature coefficient of the

Seasonal variation in the "Vita" portion of the Solar spectrum as measured by the acetone-methylene blue method

Readings taken on bright, cloudless days at Manhattan, Kansas, 1927



acetone-methylene blue reaction to be 1.15 to 1.2 for 10 degrees C. A difference of 10 degrees C. above or below 20 degrees would make a difference of about one half a degree on the scale. His method for working out this coefficient was not given.

In order to determine whether the high summer readings were due to the intensity of "vita rays" alone or in part to the heat, a study of the influence of temperature on this reaction was made. Several methods for finding a temperature coefficient were tried before one was found that proved satisfactory.

First a quartz tube of the acetone-methylene blue solution was placed in an ice and water bath and another tube in a water bath at 37 degrees C. and exposed to the rays of a mercury vapor lamp. No definite results could be checked due to slight irregularities in the depth to which the tubes were immersed, to a thin film of oil which was usually present in the water used, and to a film of dust which collected on the water's surface during a long period of exposure.

Next the method of exposing the quartz tube of acetone methylene blue to the rays of a mercury vapor lamp run in the cold was tried. The lamp was placed out of doors on a night when the temperature was 0 degrees F. The next day

the solution was exposed to the lamp's rays for the same period of time, indoors at 72 degrees F. The unit reading taken indoors was higher.

By placing a voltmeter across the terminals and an ammeter in the line, it was found that not as much current went through the lamp when it was placed in the cold. The results are shown in the following table:

TABLE 11

Current Readings Taken With Lamp at Different Temperatures

Temperature at Lamp	Voltmeter Reading	Ammeter Reading	Current in Watts
0 Deg. F.	26	7.0	182
72 Deg. F.	80	5.5	440

This experiment was duplicated and the same results were obtained. Since there is not as much current going through a lamp run in the cold as when it is run in a warmer place, a temperature coefficient worked out by this method cannot be correct, because the quality of the light varies with the number of watts going through the burner.

Another method was tried which proved satisfactory. In this method a quartz bottle was used which was fitted

with a two hole stopper. Through one hole was placed a thermometer and through the other a glass rod holding two quartz tubes of the acetone-methylene blue solution. (The two tubes were used merely as a check). The bottle was then placed in a salt and ice bath leaving the top surface of the bottle about a quarter of an inch above the surface of the water in the bath to give free surface for exposure. This apparatus was placed under a mercury vapor lamp for four and one-half hours at a distance of twenty four inches from the burner of the lamp. with the temperature kept constant at 0 degrees C. The same bottles and tubes were later placed in a water bath kept at 37 degrees C. and exposed for four and one-half hours at twenty four inches. (The same bottle and tubes were used as a difference in tubes might cause a slight variation in the results).

The readings both at 0 degrees C. and 37 degrees C. for four and one-half hours, at twenty four inches were six and one-half units. This experiment was repeated several times and it was found that the bleaching of the acetone-methylene blue solution was the same amount regardless of temperature when the exposure was for the same period of time and at the same distance from the lamp. The results of these experiments are summarized in Table lll.

These results would indicate that temperature has but

very little effect on the bleaching of the acetone-methylene blue solution. Since the method of reading is accurate only within one-half unit, a very small coefficient could not be detected. If there were some method whereby the readings could be taken in small fractions of a unit, perhaps this coefficient could be detected.

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Readings on the Acetone-methylene Blue Gauge Taken under the Mercury Vapor Lamp with Varying Temperatures.

Temperature of Solution	Distance from Light	Tube	Reading in Units
0 Degrees C.	24 inches	A	6.5
		B	6.5
37 Degrees C.	24 inches	A	6.5
		B	6.5
0 Degrees C.	30 inches	A	4.5
		B	4.5
37 Degrees C.	30 inches	A	4.5
		B	4.5
20 Degrees C.	30 inches	A	4.5
		B	4.5

DISCUSSION OF RESULTS

The trend of the daily readings, in themselves, show that higher summer readings are not caused in any great degree by the high temperature. This has been an unusual year in that the summer was abnormally cool and that October was a record breaking month for heat and yet the readings were much higher in the summer months.

On May 16, with a temperature of 88 degrees F. there was a reading of ten units, while on June 25, at the same temperature and approximately the same length of exposure there was a reading of fifteen units. On July 24, under the same conditions the reading was fifteen units, and on October 24, which also had a temperature of 88 degrees F. there was only five units. These readings show a range of eleven units difference with no change in conditions except season.

On July 10, there was a reduction of sixteen units for approximately eight hours of exposure at a temperature of 98 degrees F. while on August 9, there was also a reduction of sixteen units during the same length of exposure, but at a temperature of 74 degrees F. This made a difference of 24 degrees in temperature and no variation in the reduction.

Between these two dates, there was a variation in temperature from 74 degrees F. to 98 degrees F. but the readings remained sixteen units on clear bright days.

The readings of two units as the minimum and sixteen units as the maximum of the year, making a ratio of eight to one, coincide very closely with the results obtained by Tisdall and Brown (1927) who worked with rats to find the antirachitic effect of sunshine over a years time. This also seems further proof that heat had but very little effect on the results obtained by the acetone-methylene blue gauge, as heat has no preventative or curative power over rickets.

Hess and Wienstock (1927) have found that the shorter ultra-violet rays were more effective in the prevention and cure of rickets. Since the results obtained by both experiments tally so closely, the higher readings of the summer months must be due to more of the shorter ultra-violet rays reaching the earth during the direct sunshine of that season.

Other investigators, using the acetone-methylene blue gauge for measuring "vita rays" have obtained results that compare favorably with these. Hill (1927) taking readings in several places in England, Switzerland, and Egypt found that the winter readings were much lower than those in the

summer and that there was a great loss of biologically active ultra-violet radiation in smoky cities. The winter readings at Assouan Egypt resemble those in Kansas during the summer months.

There have been little data obtained upon the number of units of "vita radiation" as measured by the acetone-methylene blue gauge, necessary to insure health. Russell and Massengale (1927) found that chicks recieving a restricted ration in which the mineral elements were proportioned so as to cause severe rickets in a short time, needed irradiation daily for a length of time that would give a reading of about one-half unit on the scale in order to secure maximum bone development. Since less irradiation is required for normal development if the mineral elements in the diet are properly balanced, this indicated that something less than one-half unit of radiation is required for health under normal conditions.

These results are in accordance with those obtained during this investigation by chicks which were fed on a well balanced ration and kept behind cel-o-glass in the nutrition room. From Table 1 it can be seen that there was an average daily reading of 1.1 units during January, 1.4 during February and 1.3 during March. Since the chicks were behind a window and could recieve the sunshine but about

one-half the time and cel-o-glass transmits but about 40 percent of the "vita rays" the chicks recieved about one-fourth unit of irradiation daily. They developed normally with this.

From these results it will be seen that the winter sunshine has enough "vita radiation" to insure health. The reason that rickets in children and other disorders in older people caused by an insufficient amount of "vita radiation" is common during these months is due to the fact that the sunshine is not utilized.

CONCLUSIONS

1. The sunshine of Kansas contains an appreciable amount of health giving rays during the winter months as well as in the summer months.

2. There is eight times as much "vita radiation" during the summer as during the winter months.

3. The increase in the summer readings is not due to the higher temperatures of that time.

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