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Effects of Winter Solar Irradiation and of Cod Liver Oil on Production and Fertility of Eggs.

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In early November, 1927, a small colony of hens and cockerels from a flock of white leghorns of uniformly good grade of stock which had summered out of doors were divided into 3 groups of 6 hens and one cockerel each. They were placed in an experimental house, each compartment of which was provided with transparent windows of about 10 square feet, with southern exposure to light. One compartment was provided with cathedral or hammered vitaglass, while the other 2 were fitted with cathedral ordinary window glass. The diet fed throughout the experiment was the standard Wisconsin all-mash ration, consisting of 80 pounds yellow corn meal, 20 pounds shorts, 5 pounds bone meal, 5 pounds limestone grit and 1 pound salt. Group 1 was enclosed behind ordinary window glass with 2% by weight of cod liver oil (Squibb's) added to the diet, group 2 behind quartz-containing glass (vitaglass) and group 3 behind ordinary window glass only. The hours of feeding were regular and the quantities of food given were ample but constant. Temperature, amount of sunshine and other elements of the weather changed from day to day but were the same in all compartments. No attempt was made to keep the temperature in the experimental chicken house within a certain range; during 6 months of experimentation the temperature varied from 60° F. to —20° F. In brief, the experimental conditions were similar to those existing on a Minnesota farm; the only variables controlled were the presence or absence of the shorter ultraviolet rays of winter sunlight or cod liver oil in the ration.

Starting in January, 1928, all eggs from each of the 3 groups were gathered, and incubation of the weekly product was made.

Production of Eggs. The total gathering of eggs each week from all compartments and the percentage of production under each of the 3 experimental conditions, are given in the tabulation.

Curve 1 of Fig. 1 shows the production under ordinary window glass and 2% by weight of cod liver oil added to the diet. The point *A* indicates the value of the average percentage production over period of the experiment. The line *a b*, indicates the average rate of

TABLE I.

Influence of presence or absence of the ultraviolet region (290 to 320 millimicrons) of winter sunlight or of cod liver oil in the ration.*

Date, 1926	Eggs total	Production, %			Fertility, %		
		Vita-glass	Ordinary glass	Ordinary glass and cod liver oil (2% by wgt.)	Vita-glass	Ordinary glass	Ordinary glass and cod liver oil (2% by wgt.)
1-18	32	27	33	40	100	100	85
1-25	36	31	28	41	80	70	80
2- 1	40	33	22	45	54	55	61
2- 8	33	35	21	54	75	60	77
2-15	37	33	29	38	75	80	85
2-22	29	39	20	41	55	17	40
3- 2	29	39	20	41	55	16	75
3- 9	33	35	24	40	75	50	54
3-16	44	44	11	45	95	40	85
3-23	36	40	20	40	33	0	70
3-30	35	43	11	46	80	25	94
4- 6	38	47	13	40	77	40	73
4-13	36	30	12	58	55	50	81
4-20	35	23	17	60	100	66	86
Average		36	20	44	72	47	75

* All the hens were fed the Wisconsin standard ration and were kept under identical conditions of warmth, ability to exercise and the like. The only variable factor, as far as is known, was the character of the spectral filter used or the addition of cod liver oil to the ration.

increase in production of eggs. Curve 2 shows the results with exposure under vitaglass, and curve 3 gives the results obtained with ordinary window glass, the standard Wisconsin ration being fed. The significance of the points *B* and *C* and the lines *c d* and *e f* are analogous to those made with reference to point *A* and line *a b* in connection with curve 1.

These data and curves show that the greatest production of eggs is under ordinary glass with the addition of 2% cod liver oil to the diet. Next in order, and approximating during the latter part of March the production in Group 1, is the production under vitaglass with the standard Wisconsin ration. The least production is in Group 3, under ordinary glass only. The slopes of the lines *a b*, *c d* and *e f* indicate that production is increased from January to May under vitaglass or ordinary glass and cod liver oil, but that the production is decreased at a fairly constant rate under ordinary glass only.

Fertility of Eggs. The tabulation gives a record of the number of eggs incubated and the percentage of fertility in the 3 groups. The weekly product was incubated for one week only; the shells were opened and the eggs classified as fertile or nonfertile. We did

not carry any of these incubations to the point of hatching. Curve 1 of Fig. 2 shows the fertility under ordinary window glass and 2% cod liver oil; curve 2, the fertility under vitaglass, and curve 3, the fertility under ordinary window glass, the standard Wisconsin ration being fed in all cases. It is noted that the curves of percentage fertility for the 3 groups are of the same type and practically coincide during the months of January and February. From February

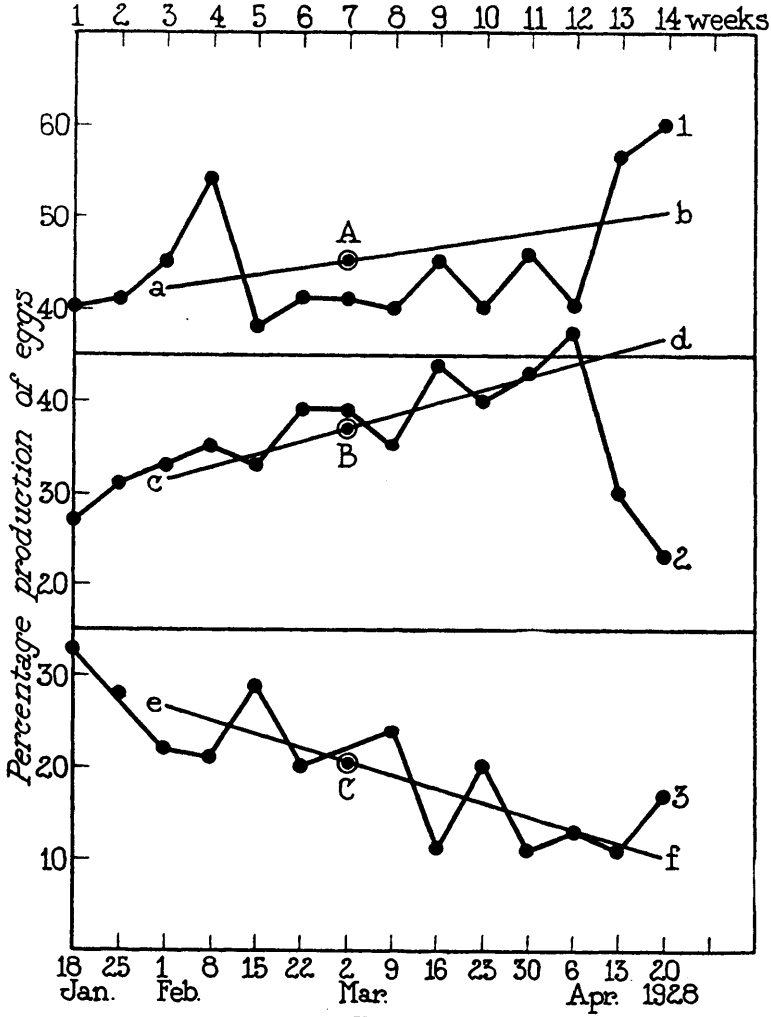

FIG. 1.

Weekly changes in percentage production of eggs during the winter months; curve 1, percentage production under ordinary window glass and 2% by weight of cod liver oil added to the diet; curve 2, under quartz-containing glass (vita-glass), and curve 3, under ordinary window glass.

15 on, however, the curves of percentage fertility of eggs are radically different. The lines *a a* and *a b* show the approximate average rate of increase of fertility when the stock is kept behind ordinary glass with cod liver oil in the diet and behind vitaglass respectively. The line *a c* curve 3, indicates that the rate of fertility of eggs under

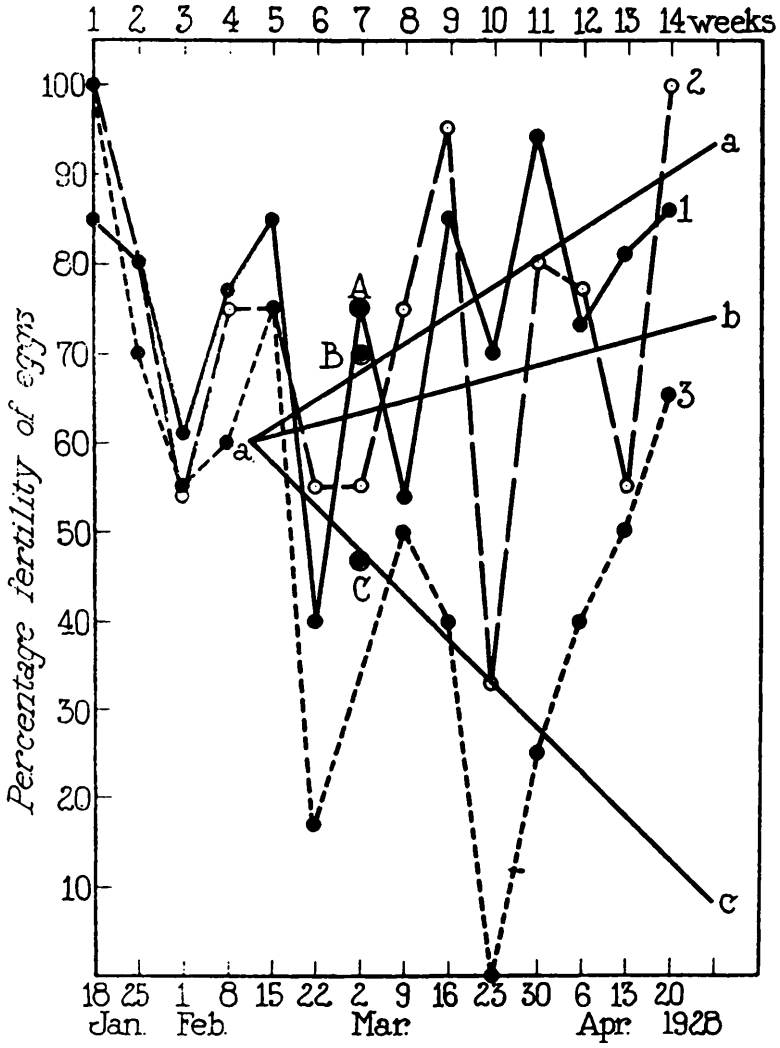

FIG. 2.

Percentage fertility of eggs during the winter months as affected by cod liver oil and winter solar irradiation; curve 1 shows the percentage fertility of the total production of eggs under ordinary window glass and 2% cod liver oil added to the standard Wisconsin ration; curve 2, under quartz-containing glass (vitaglass), and curve 3, under ordinary window glass and with the standard Wisconsin ration.

ordinary glass and the standard Wisconsin ration decreases, with, however, a noticeable increase in fertility when the month of April is reached. This marked increase in fertility may be attributed logically to the considerable increase in ultraviolet content of the sunlight during April and to the fact that other untoward physiologic conditions, such as low temperatures, did not exist, as in the midwinter months.

The tabulation contains data showing the average percentage of total production and average percentage fertility of each group during the 14 weeks of the experiment. The average percentages of production and fertility are about the same under vitaglass or ordinary window glass with cod liver oil, and these percentages are practically double the percentages obtained when ordinary glass and the standard ration only are used.

The transmissions of vitaglass and ordinary glass and the ultraviolet content of winter sunlight. Vitaglass transmits about 20% of radiation in the range of so-called vital rays (290 to 320 millimicrons), 70% in the ultraviolet region, 290 to 400 millimicrons, 90% of the visible region, 400 to 750 millimicrons, and 70% of the infra-red incident rays. Ordinary window glass does not differ appreciably from vitaglass in its transmission of the infra-red and visible portions, but transmits only 2% of solar energy in the region 290 to 320 millimicrons and 35% of the total ultraviolet from 290 to 400 millimicrons. The content and energy of the ultraviolet portion of winter sunlight have been measured by several investigators; reports of conditions in Kansas and Maryland were made recently by Hughes and Pycha,[1] and by Clark.[2] Hughes and Pycha, in their measurement of vita rays (rays which have the special property of regulating calcium and phosphorus metabolism in the animal organism), used the acetone methylene-blue method and concluded that there was an average daily reading of 1.1 unit during January, 1.4 unit during February, and 1.3 unit during March. In young growing chickens kept back of celoglass (which transmits 35 to 40% of the vita radiation of the sunlight) and which, therefore, received less than half a unit of irradiation a day rickets did not develop, whereas in control group of chickens behind ordinary window glass rickets developed in from 6 to 12 weeks. Clark found the average ultraviolet content of sunlight in Baltimore during January to be 1.2 methylene-blue units, during February 1.7 units, and during

[1] Hughes, J. S., and Pycha, R. L., *Tr. Illuminating Engineering Soc.*, 1928, xxiii, 233.

[2] Clark, Janet H., *Am. J. Hyg.*, 1929, ix, 646.

March, 2.3 units. Our own determinations, although not made as methodically or as intensively as those of Clark or Hughes and Pycha, showed that the average ultraviolet content of sunlight in Rochester, Minnesota (away from smoke and in the open country) were 1.2, 1.4 and 1.3 methylene-blue units during January, February and March, respectively. Since the vitaglass, by reason of solarization and films deposited by weather and other conditions, did not transmit more than 50% of the total ultraviolet content of sunlight, we may conclude that the average ultraviolet received by stock placed behind vitaglass was not in excess of half of a methylene-blue unit. The reception of solar radiation in the region 290 to 310 millimicrons did not exceed 15% and the intensity of solar radiation in this range of wavelengths amounted to about 100 ergs for each square centimeter each second. Clark stated that, to get the maximal antirachitic effect, the daily length of exposure multiplied by the methylene-blue units must equal 2.5. Since the vitaglass transmits on the average half a unit, it appears that the ultraviolet content of the winter sunlight for a daily period of 6 to 8 hours is ample to maintain normalcy, so far as the antirachitic factor is concerned. Other observations on the antirachitic effect of December sunlight in Toronto have been made by Tisdall and Brown,[3, 4] and by Fleming[5] regarding winter sunlight in Washington. Tisdall and Brown concluded that the rays from December sunlight which have passed through vitaglass had an antirachitic effect which is roughly one-fourth of the value of the direct rays, whereas the rays through ordinary glass had no rachitic properties. Fleming concluded that normal bone calcification was produced in the rats under vitaglass during the winter months in Washington.

There is apparently a close parallelism between the effects of ultraviolet light or the content of vitamine D in cod liver oil in the prevention of rickets in chickens and the efficacy of these agents in either producing increase in, or maintaining normalcy of, production and fertility of eggs, provided a diet rich in mineral content and accessory vitamines (other than vitamine D) is fed. The production of eggs is greatly influenced by the presence of the antirachitic factor in the diet or the environment even though there is plenty of lime in the ration. The irradiation of hens with such ultraviolet

[3] Tisdall, F. F., and Brown, Alan, PROC. SOC. EXP. BIOL. AND MED., 1927, xxiv, 446.

[4] Tisdall, F. F., and Brown, Alan, PROC. SOC. EXP. BIOL. AND MED., 1927, xxiv, 449.

[5] Fleming, W. D., *Mil. Surgeon*, 1928, lxii, 592.

light as passes from winter sunlight through quartz glass, or the presence of cod liver oil in the diet, markedly increases the amount of lime in the shell as compared with the eggs from hens kept on the standard Wisconsin ration under ordinary window glass. Furthermore, Hart, Steenbock,[6] and their collaborators showed that the feeding of cod liver oil, or the irradiation of hens with ultraviolet light (Cooper-Hewitt quartz lamp) after a long confinement to a rachitic ration with resultant decrease in production of eggs again stimulates and increases production of eggs, and that irradiation with ultraviolet light improves the hatchability of the eggs. Hughes, Titus and Moore[7] found that the percentage of eggs hatched from the layings of hens exposed to direct sunlight or to irradiation by mercury quartz lamps was of the order of 75% and that the hatchability in a control group housed behind ordinary window glass dropped to 53%. They also stated that cod liver oil at the rate of 0.5 cc. for each hen daily produced eggs which hatched as well as those from hens receiving direct sunlight.

The results of our experiments and those of other investigators indicate 2 practical conclusions: (1) those who use fowls as experimental animals and who are desirous of maintaining normal stock, production of eggs, fertility and hatchability without the use of quartz-mercury lamps during the winter months in the north temperate zone may do so by the installation of mediums reasonably transparent to the ultraviolet region of sunlight from southern exposures or by the addition of cod liver oil to the diet and (2) to the poultryman who is desirous of obtaining the same results, it is probable that the use of cod liver oil will prove adequate and sufficiently inexpensive to warrant its use.

Conclusions: 1. Sufficient ultraviolet light is transmitted by such quartz-containing glasses as vitaglass or helioglass in the winter months in Minnesota to keep production and fertility of eggs at a high level.

2. Ordinary window glass screens out irradiations from winter sunlight which are beneficial to the maintenance of high production and fertility of eggs.

3. It appears that these results are due either to the transmission of solar energy in the region 290 to 320 millimicrons or to the greater transmission of the ultraviolet (320 to 400 millimicrons) of sunlight by quartz-containing glass.

[6] Hart, E. B., Steenbock, H., Lepkovsky, S., Kletzien, S. W. F., Halpin, J. G., and Johnson, O. N., *J. Biol. Chem.*, 1926, lxv, 579.

[7] Hughes, J. S., Titus, R. W., and Moore, J. M., *Science*, 1925, lxii, 492.

4. The addition of 2% cod liver oil to the standard Wisconsin ration gives results the equal of or slightly superior to those obtained with winter sunlight passed through an ultraviolet transmitting medium.

5. From our experiments and those of other investigators there is evidence that the presence or absence of the antirachitic factor vitally affects the production, fertility and hatchability of eggs.

ERRATUM.

In the article entitled Hemodynamics of Arteriosclerosis, Influence of Elastic Factor on Circulation, by George Fahr, Jay C. Davis, and Russell Spittler, 1930, xxvii, 325, the second paragraph should be changed to read as follows:

"In drawing conclusions as to the external work of the heart from our experiments, we consider as well established by Starling and Vischer that the diastolic volume of the heart is an index of the energy consumption of the heart and therefore a measurement of the work of the heart, provided the heart muscle function remains constant throughout the period under consideration."