GROWTH AND REPRODUCTION OF CHICKENS SUBJECTED TO MICROWAVE RADIATION

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ABSTRACT

White Leghorn hybrid chickens of different ages were subjected to CW microwave radiations at a frequency of 6 GHz and at densities of 0.02 and 400 picowatts/cm^2. Microwaves were produced by a Varian LD 807 travelling wave tube. Continuous or periodic exposure of chickens during the growing stage did not affect their growth or feed conversion efficiency in comparison with non-treated controls. Hens subjected continuously, from 1 day old, to microwave treatment at the low or high densities showed significantly higher percent hen-day rate of lay, during 169 to 476 days of age, and significantly lower egg weight than the untreated birds. The low-density treatment resulted in significantly higher fertility than the high level of treatment. Egg quality, mortality and several other traits studied were unaffected by the treatments.

INTRODUCTION

The widespread use of microwave generating equipment for communications and for other industrial and domestic uses has aroused considerable concern for possible effects of such radiations on biological systems.

According to Dodge (3), Osipov reviewed Russian data for the period 1933 to 1965 related to the effect of microwave energy on biological systems. These reports suggest detrimental as well as beneficial effects of microwaves. Olsen *et al.* (5) reported that microwave radiation produces both thermal and non-thermal effects in biological systems.

Deichmann *et al.* (2) carried out tests on birds by exposing 10-day-old Bantam chicks to microwaves, at densities of 0.017 watt/cm^2 and 0.27 watt/cm^2, for 5 hr per day on each of 10 days over a total period of 12 days. In both treatments a chick passing through the center of the beam would stagger and demonstrate muscular flaccidity or collapse, which occurred immediately after the start of exposure. Tanner (6) carried out tests on 14-week-old chickens using power levels in the range of 10 to 30 mW/cm^2 at a frequency of 16,000 Mc/s (16 GHz) and at a pulse repetition rate of 8,000 pulses per sec. He reported that a few seconds after the onset of radiation, sustained extensor activity of a wing and leg occurred when the antenna was mounted above the cage. Tanner *et al.* (8) showed non-thermal effects of microwaves on chickens using a 9.3 Gc/s (9.3 GHz) microwave generator pulsed at 416 pulses per sec at a peak power of 94 kw. Subsequently, Tanner *et al.* (9) exposed 10-day-old chicks to a pulsed 16 GHz field at an intensity of 20 mW/cm^2, and observed that the chicks became weak and some collapsed within 5 to 20 sec after entering the microwave field. The above workers also observed that adult birds, subjected to the same microwave frequency at a density of 45 mW/cm^2 (45×10^9 picowatts), became hyperactive and, in their attempts to escape, either initiated flight or collapsed. Tanner *et al.* (7) suggested the use of microwaves to eliminate bird hazards to aircraft.

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All tests on birds reported above involve high-frequency radiations at densities well above the maximum safety level for humans of 10 mW/cm^2 averaged over 0.1 hr at frequencies of 10 to 100 GHz, set by the Canadian Standards Association (1). The project reported here aims specifically to test the effect of microwave radiation on chickens at the frequency and density which prevail at ground level in the immediate vicinity of a typical microwave relay tower. There does not appear to be any information on the effect of this type of low-density continuous radiation on domestic birds.

MATERIALS AND METHODS

Two copper-screened cages each 6.96 m wide, 3.65 m long and 2.28 m high, were constructed in a well insulated, force-ventilated and windowless poultry house. Each cage was subdivided into four pens each 1.74 m by 3.65 m. Two waveguide radiators were suspended from the ceiling in each cage, one for each pair of adjacent pens, to provide a uniform field density pattern at ground level. The microwave transmission system allowed for power adjustment to each cage.

The microwave generator employed was a Varian LD 807 travelling wave tube connected in a standard configuration. This generator emitted CW microwaves at a frequency of 6 GHz. The power was adjusted to provide a microwave field density of 0.02 picowatts/cm^2 in one cage. This low level is similar to that observed at ground level in the immediate vicinity of a typical microwave relay tower, as measured by a Polarad Model FIM field intensity meter. In the second cage the power was adjusted to provide a microwave field density of 400 picowatts/cm^2. This higher level, 20,000 times greater, was considered well above levels prevailing in the immediate vicinity of a typical microwave relay tower but at the same time it is well below the maximum safety level for humans set by the Canadian Standards Association (1), as stated earlier.

At frequent intervals the field density in each cage was measured with a Stoddard NW-62B field intensity meter, using a calibrated parabolic antenna probe. The minimum discernible power sensitivity of the field intensity meter corresponds to 0.005 picowatts/cm^2 (or 5×10^{-15} watts/cm^2), and the power level in the non-irradiated areas was below this due to the shielding effect of the copper cages.

The actual variation in power density within the 400 picowatt/cm^2 cage did not exceed 7.5% of the desired density, whereas at the low level of 0.02 picowatts/cm^2 it did not exceed 25% of the desired level over the entire experimental period.

Nine hundred and ninety day-old Single Comb White Leghorn hybrid chicks were sorted at random into 22 lots, with 40 females and five males in each lot. This provided for two replications of each of 11 treatments. Five treatments involved irradiation of groups of birds during five different ages of life, at the low level, five additional treatments involved irradiation of five age groups at the high level, and one treatment was the non-irradiated control. There were two replications of each treatment. The ages of treatment and the density levels used for each treatment group are shown in Table 1. The groups of birds were placed in pens in copper-screened irradiation cages for the period indicated in Table 1, after which they were removed to similar pens in another area of the same building where the irradiation density was below 0.005 picowatts/cm^2 during the remaining period of the experiment.

Table 1. Schedule of microwave radiation treatments

Treatment	Radiation density* 0.02 picowatts/cm²	Treatment	Radiation density 400 picowatts/cm²
1	Control, nontreated		
2	Treated 1 to 56 days of age	7	Treated 1 to 56 days of age
3	Treated 57 to 112 days of age	8	Treated 57 to 112 days of age
4	Treated 113 to 168 days of age	9	Treated 113 to 168 days of age
5	Treated 169 to 224 days of age	10	Treated 169 to 224 days of age
6	Treated 1 to 476 days of age	11	Treated 1 to 476 days of age

*1 picowatt = 10^{-12} watts.

All experimental chickens were fed a complete chick starter, grower, and breeder mash at appropriate ages. Chickens were provided with 14 hr of illumination at 10.8 to 21.6 lumens/m² to 12 weeks of age, followed by 8 hr to 20 weeks, which was then raised to 12 hr. This was increased gradually during the first four months of lay to 16 hr, which was maintained for the balance of the test period. At 12 weeks of age the numbers of birds in each pen were reduced at random to 20 females and three males. Data recorded included body weight, feed consumption and periodic water consumption, mortality and its cause, egg production by 28-day periods, egg weight, shell thickness and albumen quality. The last three measurements were made on 10 eggs taken at random from each pen over a 2-day period at the stages of the experiment indicated in Table 5.

Commencing with the third 28-day period of lay, 80 eggs from each treatment (40 per replicate) were saved and incubated for fertility and hatchability tests. A total of seven hatches, extending into the 12th period of lay, were taken as shown in Table 5.

Experimental data were subjected to two separate analyses of variance. First, data on all treatments were analyzed. When no significant differences were obtained, then only data on the continuously irradiated low and high treatments and the control were analyzed. This second analysis was used to determine if the three extreme treatments showed any significant differences. When this second test showed significant differences, Duncan's multiple range test was used to determine which levels were significantly different.

RESULTS AND DISCUSSION

Body weights of the pullet chicks at 8 weeks of age and at 20 weeks of age as well as efficiency of feed utilization for these periods are presented in Table 2. Between-treatment differences in body weight at 8 weeks and at 20 weeks of age, as well as in efficiency of feed utilization for these periods, were not significant when the analysis of variance was carried out on all treatments. The same was true when comparisons were made only on the continuous low- and high-irradiated groups and the untreated control, treatments 6, 11 and 1, respectively.

Data on sexual maturity, rate of lay and feed efficiency for egg production are presented in Table 3. There was a maximum difference between treatments of 12 days in age at 50% lay, but such treatment differences were not significant. Analysis of variance of percent lay from 169 days of age to 476 days of age, when the test was terminated, showed no significant difference between treatments when all treatments were considered. However, when the analysis was limited to those

Table 2. Mean body weights of pullets at 8 weeks and at 20 weeks of age and efficiency of feed conversion for each period for different microwave treatments

Treatment*	Body weight		Kg feed per kg body weight	
	8 wks., g	20 wks., kg	0 to 8 wks.	0 to 20 wks.
1	643	1.60	2.72	5.00
2	629	1.57	2.83	5.11
3	637	1.53	2.79	5.18
4	634	1.58	2.72	5.04
6	624	1.53	2.68	4.92
7	631	1.58	2.84	5.14
8	651	1.55	2.86	5.20
9	629	1.56	2.92	5.22
11	643	1.57	2.73	5.16

*At 8 weeks of age, treatments 4 and 9 had not been exposed to radiation whereas at 20 weeks of age these two treatments had been exposed to radiation only from 113 to 140 days of age.

Table 3. Sexual maturity, rate of lay, feed efficiency and grams egg per hen day average during 169 to 476 days of age, by treatments

Treatment*	Days of age at 50% lay	Percent lay	Kg feed/ kg eggs	Grams egg/ hen day
1	165	70.7	2.98	41.5
2	169	71.6	3.00	
3	173	68.4	3.00	
4	163	72.9	2.90	
5	163	70.8	2.96	
6	164	79.4	2.78	44.9
7	164	69.8	2.94	
8	165	70.0	3.02	
9	161	70.9	3.04	
10	167	74.2	2.94	
11	167	80.2	2.72	45.2

*Treatments 1 (control), 5 and 10 had not been exposed to irradiation prior to sexual maturity.

Table 4. Effect of microwave treatment of hens on egg weight, shell thickness and Haugh units

Treatment	Means for entire test period		
	Egg wt., g	Shell thickness	Haugh units
1	58.15	13.11	79.01
2	55.98	13.44	76.70
3	58.08	13.62	77.57
4	56.75	13.36	76.52
5	57.11	13.24	75.61
6	55.84	13.49	77.67
7	56.90	13.17	77.99
8	57.40	13.37	78.07
9	57.04	13.32	76.30
10	55.30	13.33	78.17
11	55.57	13.31	77.69

groups which were exposed to continuous radiation, then both the low and the high treatments (6 and 11) showed significantly higher egg production ($P < 0.01$) than the control, but the difference between the two levels of irradiation was not significant. The high and low continuously irradiated birds showed higher feed efficiency than the control, but such differences were nonsignificant. Water consumption, recorded for 1 week during the peak of production, showed no significant treatment effect.

Mean egg weight for the entire test period (Table 4) did not show any significant effect due to treatments when all treatments were subjected to an analysis of variance. However, when egg weight of hens on continuous high- or low-density treatment was compared with that of the control, the treated hens had significantly lower egg weight than the controls. Following this result, egg production of hens on the continuous treatments and that of the controls was calculated as grams of egg produced per hen day on the average over the entire test period (Table 3). It was found that on this basis there was no significant difference between treatments. Therefore, the effect of microwave irradiation was only to increase frequency of ovulation as manifested by increased rate of lay, possibly through the stimulation of the pituitary. This increased rate of lay in treated birds resulted in the usual decreased average egg weight (4) but it did not affect the overall yield of egg matter. Shell thickness and albumen quality parameters (Table 4), as well as the sorting into Canadian Government egg grades by experienced graders, did not show any significant difference due to treatments.

Fertility results based on seven settings of eggs at various stages of lay (Table 5) showed a significant difference between treatments involving continuous irradiation. The low-density treatment resulted in significantly ($P < 0.05$) higher fertility than the high-density treatment, whereas neither of these treated groups was significantly different from the controls. The significant difference in fertility between the high- and the low-density radiation may be due to the chance low fertility of some of the three males used in each pen. Hatchability, as percent of fertile eggs, showed no significant difference between any of the treatments. Chick weight at hatching (Table 5) followed the same trend as egg weight.

Table 5. Fertility and hatchability, percent, by period of lay and treatment, and mean weight of chicks hatched

			Continuous treatment			
	Untreated control		Low		High	
Period of lay	Fert.	Hatch*	Fert.	Hatch	Fert.	Hatch
3	96.0	89.6	98.0	96.0	92.0	86.8
4	92.0	88.9	100.0	94.0	94.0	100.0
5	97.0	90.2	97.0	97.9	92.0	95.4
6	97.0	92.0	99.0	97.0	96.0	91.0
7	96.0	94.0	97.0	96.0	97.0	92.0
8	94.9	98.2	97.4	100.0	97.4	95.2
12	98.3	89.8	96.6	91.6	90.0	96.3
$\bar{x}$	95.9 *ab*	91.8	97.8 *a*	96.1	94.0 *b*	93.8
Chick wt. (g) $\bar{x}$		35.8		34.1		33.8

*Hatchability is calculated as percent of fertile eggs.
a,b Fertility means which do not show any common letters are significantly different ($P \leq 0.05$).

Table 6. Effect of microwave treatment of chickens on growing and laying period mortality

Treatment	Percent mortality	
	0 to 140 days	141 to 476 days
1	6.2	13.3
2	11.4	23.8
3	6.2	25.0
4	3.3	14.6
5	4.2	17.4
6	5.6	24.4
7	4.2	17.3
8	2.2	16.6
9	3.1	20.8
10	2.2	31.2
11	6.2	11.1

Incidence of mortality during the growing and reproductive periods is shown in Table 6. The level of mortality was quite normal in all treatments, and there were no significant treatment effects. Most of the mortality in all treatments was due to Marek's disease and leucosis, but the incidence of these diseases did not show any significant treatment effect.

It is therefore concluded that continuous exposure to microwaves, even at a density of 20,000 times that occurring in the immediate vicinity of a typical microwave transmission tower, will have minimal, if any, effects on laying chickens.

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