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INFLUENCE OF LOW-LEVEL ELECTRIC AND MAGNETIC FIELDS ON THE GROWTH OF YOUNG CHICKENS

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ABSTRACT

Groups of 25 incrossbred male baby chicks were continuously exposed in two experiments to a calculated average power density of 33 μW/cm^2 with a UHF signal at 880 MHz and a VHF signal at 260 MHz, a low frequency electric field (3,400 V/m at 60 Hz and 3,600 V/m at 45 Hz), a low frequency magnetic field (1.2 G at 60 Hz, 1.4 G at 45 Hz). Comparable nonirradiated controls also were included in the experiments. Growth rate, feed utilization, livability, activity and behavior to 28 days of age were criteria for determining response to exposure.

Growth rate was depressed in chicks exposed continuously to a UHF signal (880 MHz) to approximately 4 weeks of age. Chicks exposed to a VHF signal (260 MHz) were generally intermediate in body weight between the controls and the UHF exposed birds. Continuous exposure to the low frequency magnetic field resulted in significantly reduced growth rate to 28 days of age. Exposure to a low frequency electric field consistently depressed growth rate but not significantly so. No observable differences were noted in bird behavior as a result of radiation exposure.

INTRODUCTION

Growth, behavioral and other physiological changes due to continuous exposure of various animals to low level (below 10 mW/cm^2) CW (continuous wave) electromagnetic fields have been reported. Korbel [1] using low intensity power levels (.50 to .76 mW/cm^2) at frequencies from 300 to 920 MHz noted consistent long-term hypoactivity, greater emotionality, longer latency of recovery from electroconvulsive shock and differential stress reaction as measured by adrenal weight in rats. Guy et al. [2] reported that microwave radiation of the cat at 918 MHz with power levels below 2.6 mW/cm^2 induced an increase in brain temperature with maximum changes occuring in the thalamus region and subsequent effects on somatosensory receptors in the cat's paw. Krueger et al. [3] noted a reduction of adrenal gland weight, body weight, and feed consumption of incrossbred chicks when exposed to a near field of UHF signal at 880 MHz with a calculated average power density of 24 μW/cm^2. Using the same facilities and operating at the same frequency and power level, Giarola et al. [4] observed a reduction in body and spleen weights in laboratory rats when exposed to a continuous UHF signal through 47 days of age. Hamid et al. [5] exposed chickens to extremely low power levels (0.02 to 400 picowatts/cm^2) of continuous microwave signals at 6.0 GHz and noted no effects on growth and reproduction of chickens, a result to be expected from such low power densities.

The objective of this paper is to report the results obtained from experiments with chicks exposed to electromagnetic fields at 880 and 260 MHz, and to low frequency (45 Hz and 60 Hz) electric and magnetic fields. This is a continuation of previous work with chicks and rats exposed to a UHF signal at 880 MHz, which has been reported in other publications.

EXPERIMENTAL PROCEDURE

A description of the apparatus used to irradiate chicks and rats with continuous electromagnetic fields at 880 MHz has been documented in previous publications [3], [4], [6], [7]. Facilities recently have been extended to include not only VHF (260 MHz) signals, but also low frequency (such as 45 Hz and 60 Hz) electric and magnetic fields.

An adapter from a coaxial line (50 ohms) to a rectangular waveguide (0.736 m by 0.368 m) was built. A horn was constructed at the end of the adapter with appropriate dimensions so that the adapter and horn would sit on a metal cage (0.914 m by 0.610 m) designed to brood baby chicks. The adapter was connected to a VHF signal source consisting of a unit oscillator (General Radio Type 1215-C) capable of delivering approximately 200 mW of VHF power to a 50 ohm load. The power loss from reflections and from dissipation on the metal walls of the waveguide and horn were obtained from VSWR (Voltage Standing Wave Ratio) measurements with the horn in open space, and with the horn sitting on top of a metal surface. The

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lowest frequency of VHF signal with reasonable power loss was found to be 260 MHz ($[P_{out}/P_{in}]= 0.84$). This was the selected operational frequency. The calculated average power density was 33 $\mu W/cm^2$ and was obtained by dividing the total power on the brooding cage by the total floor space of the cage.

In order to expose the chickens to low frequency magnetic fields, a coil with 22 turns of insulated copper wire (AWG number 14) was wound around a metal chick brooding cage. The power dissipated by the coil was approximately equal to 8 W with an electric current of 4A flowing through the coil. A Hall probe was used to measure the magnetic field at various positions inside the cage. An average magnetic field of 1.25 G with a maximum variation from point to point of approximately $\pm$ 10% was measured.

A low frequency electric field was produced by replacing the top of a metal brooding cage with an electrically insulated aluminum plate with dimensions 0.4 m by 0.7 m. An audio oscillator in conjunction with a step-up transformer was used to apply a voltage of approximately 800 V between the aluminum plate and the metal brooding cage. The calculated electric field at the center of the cage was 3,500 V/m. The cage design was not too appropriate for an accurate measurement of the electric field to which the chicks were exposed, primarily because of the non-uniformity of the field, especially when the chicks were inside the cage. Variations of up to 100% in the electric field could exist. The primary concern in these initial electric field experiments was to determine if a growth depression could be produced, rather than to establish safe levels of exposure. Despite deficiencies in design, the data obtained on growth and feed consumption should be valid, particularly since all other environmental conditions were controlled and kept similar to those of the nonexposed group.

Twenty-five day-old male incrossbred chicks were utilized in each experimental group in the two experiments reported here (Experiments 5 and 6). Incrossbred chicks (crosses of inbred lines with consequent considerable genetic heterozygosity) were used because they are better buffered to environmental pressures than inbred or noninbred closed populations of birds.

The experiments consisted of a nonirradiated control group and four continuously exposed groups. The treated groups were exposed as follows:

(a) 33 $\mu W/cm^2$ of UHF at 880 MHz;
(b) 33 $\mu W/cm^2$ of VHF at 260 MHz;
(c) Low frequency electric field (experiment 5: 3,400 V/m at 60 Hz; experiment 6: 3,600 V/m at 45 Hz);
(d) Low frequency magnetic field (experiment 5: 1.2 G at 60 Hz; experiment 6: 1.4 G at 45 Hz).

The chicks in Groups (a) and (b) were exposed to the near fields of UHF and VHF signals. Near fields rather than far fields were used because control and treated groups had to be near each other and under identical nontreatment environmental conditions. The electromagnetic fields had to be contained within metal boundaries in order to prevent exposure of the nonirradiated control group. This condition does not diminish the importance of the results obtained, considering that animals are not always in a free space environment. The presence of metal boundaries, in fact, might constitute a more realistic environment for experiments of this type.

RESULTS

As in previously reported experiments growth rate was reduced (compared with comparable controls) when groups of chicks were exposed to a UHF signal (880 MHz) (Tables 1 and 3). The depression in growth, however, was not detectable and statistically significant until the chicks were approximately fifteen days of age or older. Continuous exposure to the VHF electromagnetic fields (260 MHz) also reduced growth rate. The data suggest that this response may be intermediate between that of the group treated with the UHF signal and the nonirradiated control group. Feed consumption per bird also tended to support this observation (Tables 2 and 4). Further tests will be needed to verify this supposition. Interestingly, when the feed intake values are converted to feed efficiency values, the UHF and VHF exposed birds converted feed to animal tissue at approximately the same rate as the controls. This would indicate that energy absorption from the signal sources by the birds had a minimal effect on utilization of feed consumed. Whether other physiological processes were affected from UHF and VHF energy absorption must be determined.

Exposure of chicks to low frequency electric or magnetic fields as described earlier consistently depressed growth rate when compared with nonexposed controls (Tables 1 and 2). The depression in growth was statistically significant for the birds living in the magnetic field. The depression effect became obvious after the chicks reached nine days of age.

Comparing across experiments to obtain some idea of the effects of exposure to 45 Hz as compared to 60 Hz, one notes little difference in relative performance of the treated birds when compared with the controls. There was a depressing influence of approximately 5% for birds in the electric field and 10% in the magnetic field at a body weight of 200 grams, irrespective of the frequency.

Efficiency of feed utilization appeared to be different for the two frequencies, 60 Hz versus 45 Hz. Feed conversion was consistently better than that of the controls at 60 Hz, but consistently poorer at 45 Hz. This type of interaction was not apparent when comparable birds were exposed to electromagnetic radiation. Whether this interaction is real, or occurred by chance, must be determined by additional tests.

No significant differences in livability were noted in either of the two experiments. Further, no detectable differences were observed in the activity

Table 1. The effect of four types of electromagnetic radiation on chick growth to 28 days of age (Experiment 5).

Treatments	No. Birds	Body Weight Means (g) 1 Day	9 Days	21 Days	28 Days
Nonirradiated Control	25	35.8a*	65.5a*	140a*	211a*
Continuous 260 MHz	25	35.0a	65.3a	133abc	196a
Continuous 880 MHz	25	35.6a	62.7a	122 c	172 b
60 Hz Electric Field	25	34.2a	65.5a	136ab	201a
60 Hz Magnetic Field	25	35.6a	67.0a	128 bc	188ab

*Means having the same letter are not significantly different (P≤.05).

Table 2. Feed utilization and livability of chicks exposed to four types of electromagnetic radiation (Experiment 5).

Treatments	Feed Consumed Per Bird To (g) 9 Days	21 Days	28 Days	Feed Efficiency*	Livability (%)
Nonirradiated Control	92.4	296.4	499.4	2.37	100
Continuous 260 MHz	84.7	282.7	462.7	2.36	100
Continuous 880 MHz	83.4	251.4	401.4	2.33	100
60 Hz Electric Field	80.8	266.8	433.8	2.16	96
60 Hz Magnetic Field	80.9	256.9	429.9	2.29	100

*Grams of feed consumed per gram of body weight.

Table 3. The effect of four types of continuous electromagnetic radiation on chick growth to 22 days of age (Experiment 6).

Treatments	No. Birds	Body Weight Means (g) 1 Day	9 Days	15 Days	22 Days
Nonirradiated Control	25	32.4	91.5a*	155a*	220a*
Continuous 260 MHz	25	32.2	91.1a	153a	210ab
Continuous 880 MHz	25	32.4	92.3a	154a	213ab
45 Hz Electric Field	25	32.2	86.0 b	143 b	209ab
45 Hz Magnetic Field	25	32.0	88.4ab	145 b	201 b

*Means having the same letter are not significantly different (P≤.01).

Table 4. Feed utilization and livability of chicks exposed to four types of electromagnetic radiation (Experiment 6).

Treatments	Feed Consumed Per Bird To (g) 7 Days	15 Days	22 Days	Feed Efficiency*	Livability (%)
Nonirradiated Control	102.9	243.7	424.8	1.93	96
Continuous 260 MHz	100.0	236.6	412.8	1.97	96
Continuous 880 MHz	104.9	232.7	413.5	1.94	96
45 Hz Electric Field	98.3	245.4	428.7	2.05	96
45 Hz Magnetic Field	104.4	232.7	415.7	2.07	100

*Grams of feed consumed per gram of body weight.

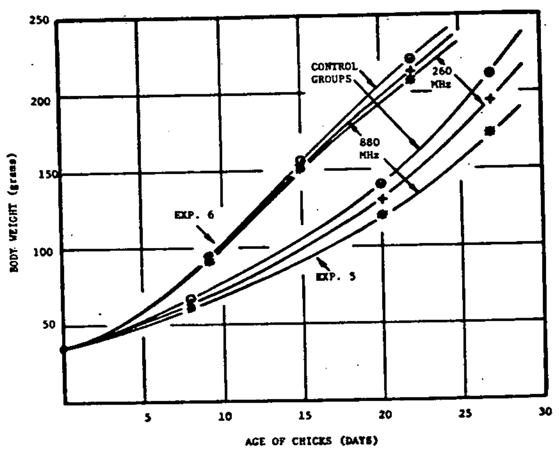

Figure 1. A Graphical representation of the effects of a UHF signal at 880 MHz and a VHF signal at 260 MHz on the growth rate of male baby chicks in two experiments. The difference in the growth curves of the two experiments is probably the result of differences in ambient temperature and plane of nutrition.

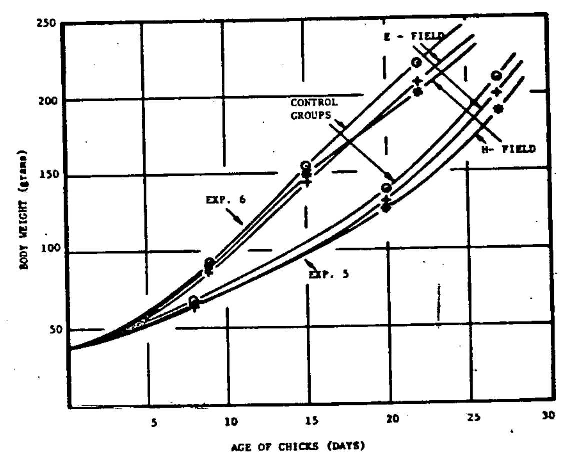

Figure 2. A graphical representation of the effects of low level electric and magnetic fields on the growth rate of male baby chicks in two experiments. The difference in the growth curves of the two experiments is probably the result of differences in ambient temperature and plane of nutrition.

or behavior of the various treatment groups.

Although the same type of chicks were used in both experiments, the growth curves are appreciably different (Figures 1 and 2). This was primarily the result of the diet used in each experiment. In experiment 5 a low protein and low energy diet was fed, while in experiment 6 a high protein and high energy diet was utilized. In addition, the room temperature during experiment 5 was somewhat higher and the humidity lower than in experiment 6. The difference in the growth curves between the two experiments could be the result of differences in energy intake of the chicks.

The growth depression due to treatments does not appear to be very dependent on the power absorbed (heat absorption) by the chickens from the electromagnetic fields. The average power absorbed per bird from the UHF signal at 880 MHz and the VHF signal at 260 MHz was calculated from measurements of the VSWR carried out during experimetn 6 when the birds were 20 days old. At 880 MHz the average power absorbed per chicken was 2 mW/bird, while an average power of less than 0.1 mW/bird was calculated at 260 MHz. If these powers are converted into kilocalories, they produce 0.04 Kcal/24 h and 0.002 Kcal/24 h for electromagnetic fields at 880 MHz and 260 MHz, respectively. The metabolic rate of the 20 days-old chicks is of the order of 30 Kcal/24 h, almost three orders of magnitude larger than the energy rate absorbed from the 880 MHz signal, and more than four orders of magnitude larger than the energy rate absorbed from the 260 MHz signal.

Preliminary measurements of the electric field at various points in a plane 0.14 m above the floor of the cage used to expose chicks to the UHF signal at 880 MHz indicate that the field distribution is not much different from that predicted for a rectangular waveguide carrying a TE_{10} mode. The electric field is nearly constant when measured along a direction parallel to the smaller side of the cage and varies approximately as a half sine function, with zeros at the metal walls and maximum at the center, when measured along a direction parallel to the larger side of the cage. During VSWR measurements it was noted that the power absorbed per chicken was not an appreciable function of position of the chicks in the cage. It was noted that maximum absorption occurred when the chicks were very close together near the center of the cage and minimum absorption occurred when the chicks were grouped near the side where minimum electric field existed. However, the average power absorbed for various positions of the chicks in the cage was never less than 15% of the average power absorbed when the chicks were near the center of the cage.

CONCLUSIONS

Observations to date indicate that continuous exposure to electromagnetic radiation at levels utilized in these studies have a depressing effect on growth rate and feed consumption of chicks to 4 weeks of age, but not on the utilization of feed consumed. Likewise, chicks exposed to electric and magnetic fields failed to grow as well as the controls. Feed utilization in the latter case varied depending upon the experiment.

The physiological and/or psychological mechanism associated with growth depression has not been resolved in these studies. It is felt that reduced growth is not the result of direct whole body heating of the chicks from the electromagnetic sources, but from some other stimulating mechanism. There are suggestions in the data that certain environmental conditions may have an effect on the type of results one obtains from exposure to electromagnetic fields.

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AN ANALYSIS OF HEAT RECEPTORS BY MEANS OF MICROWAVE RADIATION

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ABSTRACT

Using 2.8 cm wavelength microwave as a stimulus for the infrared sensors, we find evoked responses in boas (Boa constrictor) with chronically implanted electrodes. Our data suggest that the receptors operate on a thermal principle.

INTRODUCTION

Snakes from two widely different families, the pit vipers and the boas, are known to possess sensitive infrared sensors. A fascinating and fundamental question is whether the receptors act as thermal or photochemical sense organs. In a recent study in our laboratory, boas (Boa constrictor) were found to be very sensitive to 10.6 μ radiation produced by a carbon dioxide laser (1). The power densities used were between 1.9×10^{-3} and 3.4×10^{-3} cal cm^{-2} sec^{-1} and seemed to be well above threshold. Previous studies (2,3) had established that the receptors were sensitive in the near-infrared region of the spectrum; the new data showing sensitivity at 10.6 μ was strong evidence against a wavelength specific (photochemical) mechanism of activation for the boa's sensors.

If the infrared receptor of the boa does indeed operate on a thermal principle, then anything which warms the receptor tissues should serve as a stimulus. Electromagnetic radiation, regardless of wavelength, should be effective as a stimulus in proportion to the degree with which it is effective in producing temperature elevation of the receptor. In the study reported here, microwave radiation was used as the stimulus for the infrared receptors.

Methods

Two boas were used in this study. The boas had been chronically implanted with small skull screws over the telencephalon. Standard methods of electrode implantation were used and are reported elsewhere (1,4,5). A response to a discrete stimulus was determined by measuring the evoked response from the brain, using a differential amplifier and a signal averager (Princeton Applied Research waveform eductor).

Low power, continuous wave radiation was generated by a klystron (Varian X-13). The klystron was fed by a Narda Microline klystron power supply (Model 438B) and produced 227 mW of radiation at 10.725GHz (2.8 cm wavelength).

In order to provide a stimulus, the klystron was switched on by applying a dc voltage directly to the modulation input of the power supply. The klystron was connected by an 18 inch-long wave guide to a pyramidal horn (Douglas Microwave Co., Model 110x) with an aperture of approximately 5.6 by 7.3 cm. The horn was then "aimed" at the snake.

For these studies the inside of a Faraday cage was lined with a thick, lossy material in order to minimize reflections. The cage was checked with a crystal detector and no reflections were found. A circular, plastic, restraining cage containing the experimental animal was placed inside the absorber lined Faraday cage for studies. The plastic was found to be essentially transparent to microwave.

Microwave stimuli were typically presented at a rate of one every three seconds. An "averaged evoked response" to microwave stimuli consisted of the average of 90 evoked responses. The eductor was set to average the waveform for 500 msec after the initiation of the stimulus.

A control was obtained by blocking the microwave radiation from the snake's head with a piece of tinfoil. Implanted garter snakes, Thamnophis radix (known not to possess sensitive infrared sensors), were also used as controls.

Results

Averaged evoked responses after microwave stimulation were obtained from both boas tested. The responses looked much like those after laser stimulation (see figure 1-B) except that the

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