Effects of chopped sinusoidal voltages on the behavior and performance of laying hens

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Vidali, G., Silversides, F.G., Boily, R., Villeneuve, P. and Joncas, R. **Effects of chopped sinusoidal electrical voltages on the behavior and performance of laying hens.** Can. Agric. Eng. **38**:099-105. The effects of chopped sinusoidal electrical voltages were evaluated on laying hens between 23 and 43 weeks of age. One hundred and twenty hens were caged individually in six blocks of 20 birds each. The treatments were distributed in a randomized complete block design. In Experiment 1, voltage differences of 0, 3, 6, and 9 V were applied between the metallic nipple waterer and the metallic cage. In Experiment 2, differences of 0, 12, 15, and 18 V were applied. In Experiments 3, 4, and 5, the hens were placed three per cage. Voltage differences of 0 or 6 V were applied in Experiment 3; 0 or 12 V were applied in Experiment 4; and 0 or 18 V were applied in Experiment 5. Daily water and feed intake, laying rate, and behavior of the hens were measured. No effects which could be consistently attributed to voltage were found at these levels. Electrical resistance of 23 and 40 week old hens was measured and found to vary between 350 and 544 kilo-ohms. Although negative effects in farm animals may occasionally be attributed to stray electrical voltages, in these experiments, voltage differences as high as 18 V had no effect on production performance and behavior of laying hens, probably because hens are very poor electrical conductors. Key words: laying hens, stray voltage, behavior, production performance

L'effet des tensions sinusoïdales hachées d'amplitude constante a été évalué chez des poules pondeuses entre l'âge de 23 à 43 semaines. Cent vingt poules ont été placées dans des cages individuelles et réparties dans six blocs de 20 animaux chacun. À l'intérieur de chaque bloc, les traitements ont été distribués selon un plan en blocs complets entièrement aléatoire. Des tensions de 0, 3, 6, et 9 V ont été appliquées dans l'expérience 1 et dans l'expérience 2, les poules ont été soumises à des tensions de 0, 12, 15, et 18 V. Dans l'expérience 3, ces 120 poules ont été placées trois par cage, réparties en deux blocs de 60 animaux chacun et soumises à des tensions sinusoïdales hachées de 0 et 6 V. Ensuite, des tensions de 0 et 12 V dans l'expérience 4 et de 0 et 18 V dans l'expérience 5 ont été appliquées. Ces niveaux de tension ont été appliqués entre l'abreuvoir et la cage métallique. Dans ces expériences, la consommation d'eau et de moulée, la production d'oeufs et le comportement des poules ont été mesurés. Les tensions sinusoïdales hachées n'ont pas eu d'effet sur ces variables. La résistance au passage du courant des poules de 23 et 40 semaines d'âge a été mesurée et des moyennes de 350 et 544 kilo-ohms ont été trouvées. Même s'il y a des effets négatifs au champ attribués aux tensions parasites, dans cette expérience des tensions aussi élevées que 18 V n'ont pas eu d'effet sur la production et le comportement des poules. Ceci s'explique par le fait que les poules sont de pauvres conductrices de courant. Mots clés: poules pondeuses, tensions parasites, comportement, performance de production

INTRODUCTION

Stray electrical voltages are considered to be a stress factor contributing to poor production performance of pigs (Robert et al. 1991) and dairy cattle (Gorewit et al. 1989). A number of producers and veterinarians have attributed abnormal growth, reproduction, and behavior to the presence of these unwanted voltages. Research on the effects of stray electrical voltages has concentrated on dairy cattle and swine and has been summarized by Vidali et al. (1995).

The only controlled experiment on poultry that has been published in the scientific literature (Halvorson et al. 1989) demonstrated that a current equal to or greater than 5 mA affected the behavior of some turkey poults and that a current of 0.25 to 1 mA increased their mortality and decreased their water intake. Unfortunately, these authors provided no other data on production or behavior. Production data, taken simultaneously with measurements of the stray voltage, are essential for a proper evaluation of the effects of these voltages on poultry. A review of the experimental work done on dairy cows and pigs shows that, before the appearance of production and health problems, the first effects of stray voltages are behavioral modifications.

Observations in the field claim to show that small voltage differences have large effects on poultry production. Wilcox and Jordan (1986) reported the case of 10,280 laying hens in Pennsylvania with a production curve higher than normal and mortality of 0.7% per month. At the age of 43 weeks, these hens became nervous, feed intake and egg production decreased, and mortality increased. Voltages of 0.8 to 0.9 V were observed between the waterers and a reference ground and voltages of 1.3 to 1.5 V were measured between the cages and the reference ground.

More recently, engineers of an American power utility company were advised of problems attributed to stray voltage in a flock of 65,000 Leghorn females and 6,000 Leghorn males (confidential personal communication). Before 1991, egg production was at a normal rate of 130 cases of eggs per day and the fertility was between 94 and 95%. In 1992, the production decreased to between 100 and 110 cases of eggs per day, the fertility dropped to between 72 and 86%, and the chickens appeared to be in poor condition. In 1993, the production decreased to 80 to 100 cases of eggs per day, the fertility decreased to as low as 65%, and the appearance of the chickens worsened. The hens also became nervous to a point that the light had to be maintained at a low level. In the building where the chickens were most excitable, voltage differences of 0.06 and 6 V were measured. After several changes in the electrical system of the building, the problems disappeared.

Vidali et al. (1995) presented data concerning the effects of normal sinusoidal voltages and electrical pulses on laying hens. These two types of voltage are often found in agricultural buildings. Constant voltages of up to 9 V and random voltage pulses having an amplitude up to 18 V did not affect the behavior or egg production of hens. A third type of voltage, chopped sinusoidal voltages, is also found in agricultural buildings. This type of voltage appears on the grounding system in agricultural buildings and may be generated by defective variable-speed motors used to operate feed distributors and ventilation fans. The electronic variable speed control chops the sinusoidal voltage to modulate the effective voltage and control the speed of the motors. Models that do not use the zero-voltage switching technique may induce high voltage pulses between the ground and the metallic parts of the building.

The experiments described here were performed to study the effects of chopped sinusoidal voltages with constant amplitude (0 to 18 V) on the behavior and the production performance of laying hens. The electrical resistance of hens was also measured to determine the path resistance of hens to electrical currents.

MATERIAL AND METHODS

Voltage generation

A transformer and an auto-transformer were used to generate the voltages applied to the cage. The voltages were adjusted with a true RMS multimeter (Model 85S, Fluke Electronics Canada, Mississauga, ON). During the experiment, an electrostatic recorder (Model Hioki 8202-4 Micro Hi Corder, RCC Electronics, Toronto, ON) was used to measure the difference in potential between the cage and the waterer. The multimeter described above was used to measure the resistance of the hens' bodies to the passage of electrical current.

The chopped sinusoidal voltage was obtained using a variable transformer, a commercial light dimmer, and a low-voltage transformer (Fig. 1). An isolation transformer isolated the cage from the building electrical system. The dimmer chopped the sinusoidal wave to vary the effective voltage applied between the waterer and cage by modifying the conduction angle α of the TRIAC (Fig. 2) which varied the RMS value of the voltage (General Electric 1979). Figure 2 shows an example of a chopped sinusoidal wave produced with the conduction angle indicated by α. The angle α was maintained larger than 90°. A decrease in the conduction angle produces a corresponding decrease in the RMS value of the voltage. The maximum voltage (Vmax) is constant for a conduction angle α larger than 90°; Vmax is reduced when the conduction angle becomes smaller than 90°. With this arrangement, the RMS voltage varies with the adjustment of the dimmer. The positive or negative pulses produced during

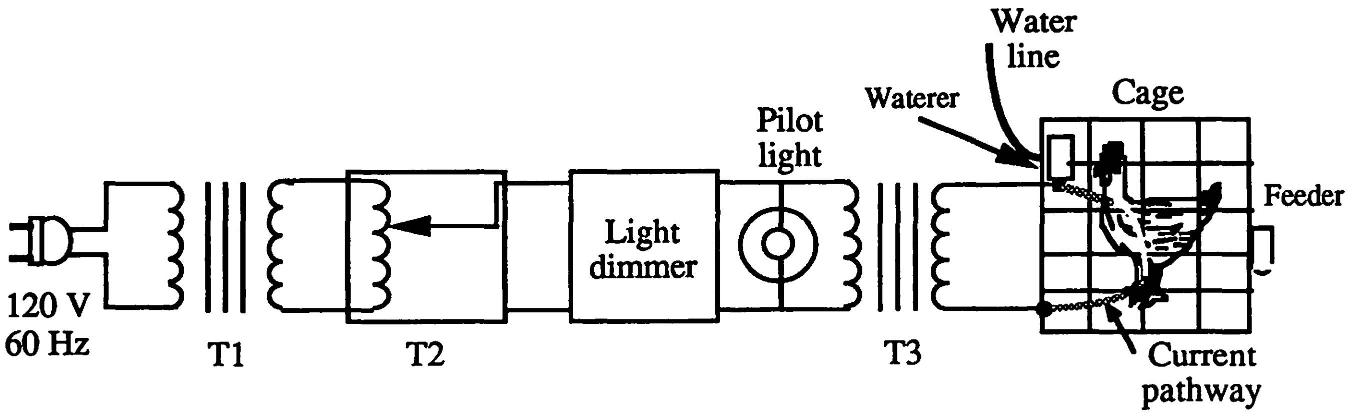

Fig. 1. Electrical circuit used to circulate the current through the body of laying hens. T1: isolation transformer 120 V:120 V, T2: auto-transformer, T3: low voltage transformer 120 V:24 V.

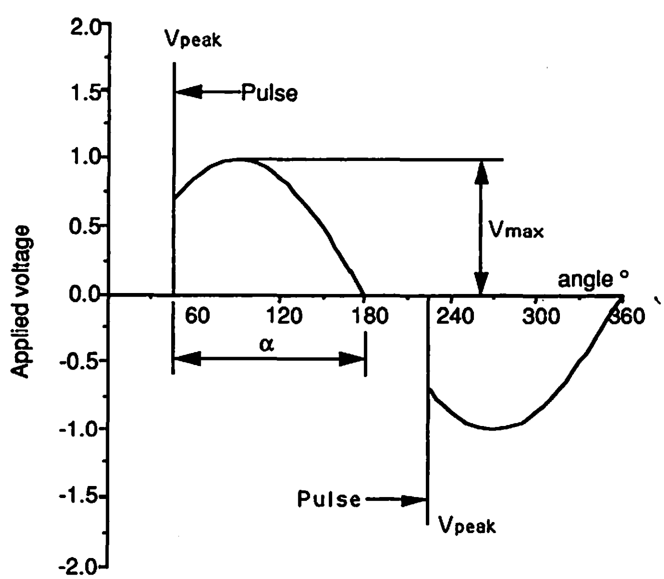

Fig. 2. Chopped sinusoidal wave. Vrms is the effective amplitude of the alternative voltage measured by a voltmeter, Vmax is the maximum amplitude of the sinusoidal wave.

Table I: Time (s/h ± SEM) spent by hens standing, resting, eating or drinking[1]

	Treatment (volts)	Standing	Resting	Eating	Drinking
Experiment 1					
	0	2807 ± 217	793 ± 217	848 ± 187	268 ± 91
	3	3275 ± 186	325 ± 186	1058 ± 160	312 ± 78
	6	2960 ± 186	640 ± 186	1147 ± 160	261 ± 78
	9	3148 ± 186	452 ± 186	723 ± 160	234 ± 78
Experiment 4					
	0	2647 ± 192	953 ± 192	826 ± 156	169 ± 76
	12	3064 ± 192	536 ± 192	883 ± 156	245 ± 76
Experiment 6					
	0	2893 ± 204	707 ± 204	954 ± 110	94 ± 31
	18	3009 ± 204	591 ± 204	1069 ± 110	180 ± 31

[1] In Experiment 1, each number represents 15 hens in individual cages while in Experiments 4 and 5, each number represents 30 hens in cages housed three hens per cage.

Table II: Frequency ($\overline{X}$/hour) of the hens at the feeders and waterers[1]

	Treatment (volts)	Eating frequency	Drinking frequency
Experiment 1			
	0	11.9	5.1
	3	12.2	7.2
	6	11.7	5.9
	9	8.8	4.1
	SEM	1.2	1.7
Experiment 4			
	0	3.9	1.8
	12	4.0	2.4
	SEM	0.6	0.5
Experiment 5			
	0	4.2	1.4
	18	4.9	1.8
	SEM	0.8	0.3

[1] In Experiment 1, each number represents 15 hens in individual cages while in Experiments 4 and 5, each number represents 30 hens in cages housed three hens per cage.

each half-cycle (Vpeak) result from the rapid switching and the inductive component of the conductors between the voltage source and the cage. The pulse amplitude was equal to or near 2.5 times the RMS voltage. For a voltage of 12 VRMS, the pulses had an amplitude of about 30 V. The multimeter described in the preceding paragraph was used to measure the voltages. All alternating voltage readings reported in this paper are RMS values.

The voltage was applied directly between the metallic nipple waterer and the metallic structure of the cage so that the hens were exposed to voltage every time they drank. The body of the waterers was made of plastic and the feeders were made of wood to ensure that the voltage came only from the nipple of the waterers.

Animal experimentation

One hundred and twenty laying hens (Babcock) between 23 and 43 weeks of age were used in these experiments. The hens were housed in individual cages at 23 weeks of age and received 14 hours of light per day with food and water provided on an ad libitum basis. The temperature was maintained at 20°C, the humidity was kept at 58%, the CO_2 concentration was about 400 ppm, and the NH3 concentration was about 0.5 ppm. These conditions meet the recommendations of the Canadian Council of Animal Care (1993).

The electrical resistance of a hen's body was determined using a voltage adjusted to limit the current passing through the body to less than 0.5 mA. The resistance of hens of 23 and 40 weeks of age to alternating (AC, 24 hens) and direct (DC, 12 hens) current was measured. Electrodes were placed on the tongue and on one or both feet to measure resistance to AC current and on the tongue and both feet to measure the resistance to DC current.

Electrical voltages were applied for three weeks in each experiment with a period of one week between experiments. The hens were distributed randomly in six blocks. Hens in Experiments 1 and 2 were caged individually and within the blocks groups of five hens received one of four treatments. Voltage differences of 0, 3, 6, and 9 V were applied in Experiment 1 and voltage differences of 0, 12, 15, and 18 V were applied in Experiment 2. For Experiments 3, 4 and 5, the hens were placed three per cage and received one of two treatments. Voltages of 0 and 6 V, 0 and 12 V, and 0 and 18

Table III: Feed consumption, water consumption, and number of eggs laid by hens caged individually (Experiments 1 and 2) and three to a cage (Experiments 3, 4, and 5)[1]

	Treatment (volts)	Feed consumption (g/hen per week)	Water consumption (mL/hen per week)	Eggs/hen per week
Experiment 1				
	0	689.2[ab]	1436.6[bc]	6.8
	3	708.1[ab]	1506.8[c]	6.5
	6	716.4[b]	1509.3[c]	6.8
	9	678.8[a]	1344.2[ab]	6.6
	SEM	10.5	50.9	0.1
Experiment 2				
	0	756.0[c]	1586.1[b]	6.4
	12	726.7[b]	1524.8[ab]	6.6
	15	754.4[c]	1517.1[a]	6.5
	18	709.8[a]	1576.6[ab]	6.6
	SEM	4.9	21.4	0.1
Experiment 3				
	0	728.4[b]	1756.6	5.8
	6	692.6[a]	1600.0	5.8
	SEM	6.1	48.4	0.03
Experiment 4				
	0	723.7	1682.8	5.4
	12	744.2	1543.8	5.5
	SEM	15.4	11.6	0.1
Experiment 5				
	0	718.9	1352.7	5.3
	18	734.3	1267.2	5.3
	SEM	39.8	53.0	0.3

[1] Each number represents 30 hens in Experiments 1 and 2 and 60 hens in Experiments 3, 4, and 5. Water consumption was measured for groups of five hens in Experiments 1 and 2 and 15 hens in Experiments 3, 4, and 5.

[a-c] The means of each column within an experiment with different letters are different at $P<0.05$.

V were applied in the Experiments 3, 4, and 5, respectively.

Throughout the experimental period the health of the hens was observed. No health problems were noted and mortality over the period was 10.8% which is well within commercially accepted values over this period of time.

For Experiments 1, 4, and 5, the hens' behavior was recorded on videotape. A video recorder with a programmable time-switch, a selector switch, and four cameras was used. In Experiment 1, the cameras were placed in front of each cage and recorded the behavior of groups of five hens receiving one of the four treatments in the same block. The hens in three blocks were observed during the light period for approximately 12 days after the application of voltage. One block was recorded each day for four hours (one hour per treatment). Each group of five hens was recorded for four hours for a total of 48 hours for the 12 groups of five hens (60 hens). In Experiments 4 and 5, the cameras were placed in front of groups of fifteen hens in two blocks receiving one of the two treatments. Because there were three hens in each cage, the head and the neck of one hen per cage were painted black and the behavior of the marked hen was followed. Hens were observed for four hours per day for the first four days after the application of voltage. A total of 16 hours was recorded for the eight groups of 15 hens (five hens marked per group). Forty hens were observed for two hours per group in each experiment. The time that the hens spent standing or sitting, the time spent eating or drinking, and the number of times that the hens ate or drank was evaluated from the videos.

In Experiments 1 and 2, the daily feed intake for each hen

Table IV: Quality of eggs ($\overline{X} \pm$ SEM) produced by hens caged individually (Experiments 1 and 2) and three to a cage (Experiments 3 and 5)[1]

Treatment (volts)	Egg mass (g)	Albumen height (mm)	Albumem mass (%)	Yolk mass (%)	Shell mass (%)
Experiment 1					
0	51.9 ± 0.7	8.2 ± 0.1	64.9 ± 0.3	25.0 ± 0.2	10.0 ± 0.1
3	52.5 ± 0.7	8.2 ± 0.1	64.6 ± 0.3	25.2 ± 0.2	10.2 ± 0.1
6	52.0 ± 0.7	8.2 ± 0.1	64.5 ± 0.3	25.5 ± 0.2	9.9 ± 0.1
9	52.8 ± 0.7	7.9 ± 0.1	64.4 ± 0.3	25.4 ± 0.2	10.3 ± 0.1
Experiment 2					
0	58.4 ± 0.7	7.4 ± 0.1	63.4 ± 0.3	27.4 ± 0.2	9.1 ± 0.1
12	57.4 ± 0.7	7.2 ± 0.1	62.9 ± 0.3	27.9 ± 0.2	9.3 ± 0.1
15	58.7 ± 0.7	7.5 ± 0.1	63.5 ± 0.3	27.5 ± 0.2	9.0 ± 0.1
18	57.9 ± 0.7	7.4 ± 0.1	63.3 ± 0.3	27.4 ± 0.2	9.3 ± 0.1
Experiment 3					
0	62.0 ± 0.7[b]	6.8 ± 0.1	62.2 ± 0.3	28.3 ± 0.3	9.5 ± 0.1
4	59.4 ± 0.4[a]	7.0 ± 0.1	61.9 ± 0.2	28.6 ± 0.2	9.5 ± 0.1
Experiment 5					
0	64.5 ± 0.5	6.8 ± 0.1	61.9 ± 0.2	29.0 ± 0.2	9.1 ± 0.1
18	63.0 ± 0.5	6.7 ± 0.1	62.0 ± 0.2	28.9 ± 0.2	9.1 ± 0.1

[1] In Experiments 1 and 2, each number represents the eggs from 30 hens. In Experiments 3 and 5, each number represents eggs from 60 hens in 20 cages.

[a-b] The means of each column within an experiment with different letters are different at P< 0.05.

was measured. The water intake was obtained for each group of five hens using graduated bottles connected to the waterers. For Experiments 3, 4, and 5, feed intake for the three hens in a cage and water intake for the 15 hens in a group were obtained.

Daily egg production was noted. Once a week, the eggs were collected, stored overnight at 4°C, then weighed and broken to measure the albumen height and the yolk mass. The shells were washed and dried overnight at 105°C, then weighed. The mass of the albumen was obtained by difference. The mass of the hens was taken at the beginning and at the end of each experiment.

Statistical analysis

The analysis of variance was performed using the GLM procedure of SAS (1985) using a model including the effects of block and treatment and their interaction. In general, neither the block nor the interaction were significant and the treatment was tested in a F test using the error term. Differences were considered significant at P<0.05. The least square means were calculated by the GLM procedure.

RESULTS

The hens' behaviors in Experiments 1, 4, and 5 were not affected by the application of chopped sinusoidal voltages. This is shown in Table I for the time spent standing, sitting, eating, or drinking and in Table II for the number of times that the hens ate or drank per hour. No differences between treatments were significant for these variables.

The production performance of hens in all experiments is presented in Table III. In Experiment 1, no significant difference between the treated hens and the control group was observed in feed intake, water consumption, or laying rate. Feed consumption of hens receiving 6 V was higher than that of hens receiving 9 V and water intake of the hens receiving 3 and 6 V was higher than that of hens receiving 9 V.

In Experiment 2, hens receiving 12 and 18 V had a lower feed intake than the control group, but the feed consumption of the control group and that of hens in the 15 V treatment were almost identical. The hens receiving 15 V had the lowest water intake while the water consumption of hens in the 12 and 18 V treatments was very close to that of the control group. There was no difference in the laying rate between treatments.

In Experiment 3, the hens receiving 6 V consumed less feed than did the control hens while in Experiments 4 and 5, there was no difference between the control group and the hens receiving 12 and 18 V. No difference was seen for water intake and laying rate in Experiments 3, 4, and 5.

The results of egg quality measurements are presented in Table IV. The only significant difference in the four experiments (data from Experiment 4 were not available) was that of egg mass between the two groups in Experiment 3.

Table V shows the initial body masses, final body masses, and mass changes of hens in all experiments. In Experiment 2, the hens in the 12 and 15 V treatments gained less mass than

Table V: Mass (g ± SEM) of hens in individual (Experiments 1 and 2) and group (Experiments 3, 4, and 5) cages[1]

	Treatment (volts)	Initial mass (g)	Final mass (g)	Mass change (g)
Experiment 1				
	0	1332 ± 22	1510 ± 30	177 ± 18
	3	1343 ± 22	1528 ± 30	185 ± 18
	6	1344 ± 22	1524 ± 30	180 ± 18
	9	1297 ± 22	1472 ± 30	175 ± 18
Experiment 2				
	0	1595 ± 28	1659 ± 30	65 ± 9[b]
	12	1527 ± 28	1556 ± 30	29 ± 9[a]
	15	1572 ± 28	1612 ± 30	39 ± 9[a]
	18	1536 ± 28	1608 ± 30	72 ± 9[b]
Experiment 3				
	0	1710 ± 30	1654 ± 34	56 ± 16
	6	1672 ± 18	1594 ± 20	77 ± 9
Experiment 4				
	0	1672 ± 9	1671 ± 4	-4 ± 4
	12	1637 ± 9	1640 ± 4	3 ± 4
Experiment 5				
	0	1713 ± 20	1757 ± 5	46 ± 14
	18	1658 ± 20	1743 ± 5	85 ± 14

[1] In Experiments 1 and 2, each number represents 30 hens. In Experiments 3, 4, and 5, each number represents 60 hens.

[a-b] The means of each column within an experiment with different letters are different at P<0.05.

Table VI: Resistance (kΩ ± standard error) of hens to AC and DC current measured between the tongue and the feet

Type of current	Age (weeks)	Number of feet	Resistance[1]
AC			
	23	1	384.4 ± 212.7
		2	415.9 ± 598.2
	40	1	430.0 ± 278.1
		2	350.0 ± 252.6
DC			
	23	2	360.5 ± 221.1
	40	2	544.0 ± 616.4

[1] Each number represents 24 hens for the AC current and 12 hens for the DC current.

those in the control group but mass gain in the control group and 18 V treatment were similar. Other differences in the five experiments were not significant.

The electrical resistance of hens to AC and DC current was observed. This varied from 18.8 to 2041 kΩ; the averages are shown in Table VI. The resistance was not greatly changed by the age of the hens or whether the current passed between the tongue and one or both feet.

DISCUSSION

The effects of stray voltage on dairy cows (Gorewit et al. 1989) and on pigs (Robert et al. 1991) have been evaluated by several researchers. In the scientific literature, only Vidali et al. (1995) has reported on the effects of electrical voltages on laying hens. In these experiments, normal sinusoidal voltages with constant amplitudes of 1 to 9 V and pulses with random amplitudes of 3 to 18 V were applied to laying hens between 23 and 48 weeks of age. Although a few differences were found between treatments, the results were notable in the absence of a clear effect of these voltages. The results presented here indicate that chopped sinusoidal voltages with continuous amplitude up to 18 V similarly had no effect on the behavior or production of laying hens.

The negative effects attributed to stray voltage in the field were not reproduced here under controlled conditions. Vidali et al. (1995) attempted to explain the difference between results obtained from experimentation and those obtained in the field by suggesting that stray voltage could be a triggering stress. In intensive management conditions, the animals undergo many stresses and the additional stress of stray voltage may elicit a negative response in an already stressed hen. In intensive production, at the end of the production period, many hens lose much of their feather cover and at this moment may be the most sensitive to voltage differences. In our experiment, the hens were caged individually for much of the experimental period and their feather cover remained good.

Gorewit et al. (1989) found that a potential of 0.5 V affected the drinking activity of dairy cows and Robert et al. (1991) observed that the sensitivity level of pigs was lower than 3 V. The absence of an effect on laying hens with voltages up to 18 V suggests that hens are less sensitive to voltage differences than are cows or pigs. The determination of the threshold sensitivity, the minimal voltage when a behavior or performance modification is measurable, was not determined.

Henke et al. (1985) observed variation in the response of dairy cows to electrical currents. They found that only one or two cows had a strong response to voltage differences and the rest of the herd was not apparently affected. Pigeon et al. (1995) also noted variability in the resistance of different pigs and considerable variability in the resistance of an individual when measured at different times. Under the good environmental conditions used in this experiment, the high resistance of hens to the passage of electrical current may explain the absence of effect. The electrical resistance of the animal determines the flow of current resulting from a given voltage differential and it is the current and not the voltage to which the animal responds (Lefcourt 1982).

The resistance varies according to the pathway followed by the current and depends on the number of contacts, the quality of the contacts between the electrodes and the animal, and probably on the materials making up the body pathway. Robert (1991) suggested that the resistance of a pig varies as a function of the body weight, the kind of animal tissue at the contact points (claw, mouth mucous, tongue), and the material (steel, plastic, concrete) of which the floor, waterers, feeders, and cage are constructed.

There was no clear difference in electrical resistance of 23 and 40 week-old hens. As was found in cattle and pigs, the resistance of individuals was quite variable. According to these results, hens have an electrical resistance that is approximately 1000 times higher than that of cows (648 ohms, Gorewit et al. 1992) or pigs (789 ohms, Gustafson et al. 1986), further explaining the total absence of response to treatments, even with voltages as high as 18 V. This high resistance can be explained in part by the insulative properties of the tongue and the epidermis of the feet.

CONCLUSIONS

Chopped sinusoidal electrical voltages with a constant amplitude had no effect on laying hens. Water and feed consumption and egg production and quality were not affected in a consistent manner by the treatments. In addition, in the year of experimentation, no behavioral or health problems were noted. This absence of effect is likely explained by the high resistance of laying hens to electrical currents.

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