Activity level and performance of weaner pigs exposed to 915 MHz microwave radiation

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Foote, K. D., Bate, L. A. and Donald, A. W. 1996. **Activity level and performance of weaner pigs exposed to 915 MHz microwave radiation**. Can. J. Anim. Sci. **76**: 183–188. Microwave radiation (MWR) (915 MHz) is considered a possible source of supplementary heat for early-weaned pigs. To determine the behavioural effect of this form of heat on weaner pigs, four trials were carried out in which 64 pigs were exposed to microwave (MW) treatment at 11.4 (MW1) or 6.1 (MW2) mW cm^{-2} or infrared (IR) radiation at 500 W (IRR), each following a 4-d adaptation period. Pigs exposed to both MW treatments displayed greater ($P < 0.05$) daily percent resting time compared with IR exposed pigs [86.0 ± 1.6 vs. 82.3 ± 2.5 vs. 79.4 ± 3.7% (mean ± SD) for MW1, MW2 and IRR, respectively]. The increase in resting time was greatest after the first day of treatment and gradually returned to pretreatment levels over the course of the 3-wk experiment. The treatment effect over time was also significant ($P < 0.05$) between IR and both MW treatments and indicated similar patterns of resting time for the MW treatments. The pattern of resting behaviour for the IR group remained relatively unchanged throughout the experiment. Microwave exposure did not have an effect ($P > 0.05$) on average daily gain [0.32 ± 0.12 vs. 0.28 ± 0.07 vs. 0.30 ± 0.13 kg day^{-1} (mean ± SD) for IRR, MW1 and MW2, respectively]. The results indicate that 915 MHz MWR causes a power-level-dependent decrease in activity in weaner pigs. However, MW exposure does not significantly affect performance in weaner pigs.

Key words: Weaner pigs, microwaves, behaviour, performance, supplementary heat

Foote, K. D., Bate, L. A. et Donald, A. W. 1996. **Niveau d'activité et croissance des porcelets sevrés exposés à des rayonnements par micro-ondes de 915 MHz**. Can. J. Anim. Sci. **76**: 183–188. Les micro-ondes (915 MHz) sont considérées comme source éventuelle de chauffage d'appoint pour les porcelets sevrés. Afin de déterminer l'efficacité de cette forme de chaleur sur le comportement des porcelets, 4 essais ont été réalisés dans lesquels 64 porcelets étaient exposés, après une période d'acclimatation de 4 jours, à 2 intensités de rayonnement par micro-ondes (MO1 ou MO2 ou au rayonnement infra-rouge RIR). Les porcs exposés aux deux traitements par micro-ondes passaient une plus grande partie ($P < 0,05$) de la journée à se reposer que les porcs chauffés par radiants infra-rouges, soit, respectivement, 86,0 ± 1,6 et 82,3 ± 2,5 contre 79,4 ± 3,7% (moyenne ± ET) pour MO1, MO2 et RIR. L'accroissement du temps de repos était plus important le premier jour, pour revenir ensuite graduellement au niveau prétraitement dans les trois semaines de l'expérience. Les effets de traitement en fonction du temps étaient également significatifs ($P < 0,05$) et révélaient des proportions de temps de repos semblables pour les deux traitements par micro-ondes. La proportion de temps de repos chez les groupes chauffés par RIR demeurait relativement stable tout au long de l'expérience. L'exposition aux micro-ondes n'avait pas d'effets significatifs au seuil de $P = 0,05$ sur le GMC, lequel était de 0,32 ± 0,28 ± 0,7 et 0,30 ± 0,13 kg par jour, respectivement, pour RIR, MO1 et MO2. Il se dégage de ces résultats qu'un rayonnement par micro-ondes de 915 MHz cause une diminution d'activité chez les porcelets sevrés, diminution liée à l'intensité du rayonnement. En revanche, il faut reconnaître que l'exposition aux micro-ondes n'abaisse pas significativement les performances de croissance des porcelets.

Mots clés: Porcelet sevré, micro-ondes, comportement, performance, chauffage d'appoint

At weaning, piglets have very little body fat (Mount 1968) or hair and, therefore, require supplemental heat for optimum performance if room temperatures are below 26°C (English et al. 1977). Conventional methods of heating weaner rooms, such as heating lamps, underfloor heating, gas heaters or radiators, although effective, are costly and present ventilation problems (Whittemore 1993).

Recently, MWR has been considered a possible source of supplementary heating for young livestock, such as pigs and chicks (Braithwaite et al. 1994). Microwaves cause polar molecules, such as water, to vibrate. The resulting friction raises the internal temperature of the animal (Copson 1975). Shanawany (1990) demonstrated that MW can increase body temperature linearly with exposure time. The penetration depth of MWR is determined by its frequency and the water content of the tissue or object irradiated. Penetration depth decreases with increasing frequency and with increasing water content. The penetration depth of 915 MHz MWR is approximately 3 cm into muscle because of the high water content, while in bone it can penetrate up to 17.7 cm (Johnson and Guy 1972). The MW method of heat transfer does not directly affect the temperature of the air or other

Abbreviations: **CT**, cage temperature; **IR**, infrared; **IRR**, infrared radiation at 500 W; **MW**, microwave; **MW1**, microwave treatment at 11.4 mW cm^{-2}; **MW2**, microwave treament at 6.1 mW cm^{-2}; **MWR**, microwave radiation; **RT**, room temperature; **RH**, relative humidity; **SD**, standard deviation; **ST**, skin temperature dry materials in the animal's environment. As a result, given the body water content, MW energy is an efficient source of heat that allows the animal to be maintained in a well-ventilated environment. The study by Braithwaite et al. (1994), involving the use of 2450 MHz MWR as a heat source, revealed that MW in newly weaned pigs did not adversely affect body weight, feed/gain ratio, or age at first estrus. However, lower activity level was observed among piglets in a MW-heated deck than among those in an IR-heated deck (Braithwaite et al. 1992). Before implementing MW technology in production units the physiological basis that triggers this type of behavioural effect should be examined. Prior to carrying out such physiological studies, however, quantification of the behavioural effect of MWR is necessary. The objective of this study, therefore, was to compare the activity level and performance of weaner pigs exposed to 915 MHz MWR or IRR.

MATERIALS AND METHODS

Treatments

The study was conducted in four replicates, each consisting of three treatments: IRR, MW1, and MW2. The specific protocol was approved by the University Animal Care Committee, and the management followed the recommendations of the Canadian Council on Animal Care (Olfert et al. 1993).

Microwave Equipment

Four cages of stainless steel (151 cm × 122 cm × 81 cm) with three wire-mesh sides (6-mm × 6-mm holes and 1-mm wire) and rubberized, expanded metal-grid flooring (Tenderfoot™) (2.5-cm × 1.0-cm holes) were used to house the piglets. All four cages were placed inside an environmentally controlled room. The floors of the cages were 47 cm above the room floor. Two cages were assigned to the IR treatment, and one was assigned to each MW treatment. The source of the MW energy was a generator with a maximum output of 4 kW of 915 MHz MWR. The generator, which had adjustable power output, was acquired from D'Ossone Canada Ltd. (Charlottetown, PE). Microwaves were delivered to the two MW cages via a stainless steel T-shaped waveguide. The stem and the top of the waveguide measured 34 and 69 cm long, respectively, and the cross section measured 25.4 cm × 12.7 cm. The waveguide was equipped with two antennae, located at opposite ends of the top portion of the waveguide. Two 300-Ω coaxial cables (2.6 and 2.3 m) were connected to the antennae and carried the MW energy to a second 28-cm-long waveguide, located on the back wall of each weaner deck. The forward power in each cage was monitored using Bird RF directional thruline wattmeters (model 43, Cleveland, OH), each placed between two segments of the coaxial cables at the entrance of each waveguide. The waveguide opening at the back wall of the cages was protected by a 4-mm-thick MW-transparent cover (33.0 cm × 20.3 cm). Each of the MW cages was equipped with two safety switches, which served to deactivate the magnetron when any of the lids were not properly closed. Microwave cages were checked frequently for leakage, using a MW survey meter, model HI 1600 (Holaday Industries Inc., Eden Prairie, MN). The IR cages were heated by two 250-W heat lamps, which were placed into 25.4-cm-diameter holes in the cage covers and guarded with a metal mesh.

Animals

For each of the four replicates, 16 piglets from four litters (two males and two females from each litter) were marked with a permanent hair dye for identification. One member of each litter was randomly allocated to each of the four cages. As a control for sex differences, two males and two females were assigned to each cage. This arrangement resulted in a total of 32 piglets for the IR treatment and 16 piglets for each MW treatment. Food and water were provided ad libitum, using commercial, galvanized steel feeders and nipple-type drinkers, which were properly grounded to the exposure cage. Pigs were fed a commercial piglet starter diet, containing 18% protein, throughout the trial. Weights of the animals were recorded at the beginning of the trial and on a weekly basis. All animals were allowed to socialize for 4 d as an adaptation period, which permitted the establishment of the social hierarchy within each cage. For environmental enrichment, each group of pigs was supplied with one quarter of a rubber tire with the wire removed.

Environmental Conditions

Room temperature was kept at 23.3 ± 0.9°C (mean ± SD) during the 4 d of adaptation and was reduced to 16.8 ± 0.6°C for the remaining 20 d. Following the adaptation period, animals had continuous exposure to MWR or IR lamps. Humidity levels were maintained at an average of 48.7 ± 0.5% throughout the experiment. Throughout the trial, animals were kept on a 12 h:12 h light/dark schedule in which the lights went on at 6:30 and off at 18:30. During the dark period, however, two fluorescent emergency lights, located in opposite corners of the room and providing a minimum illumination of 97 lx, remained on for the duration of the experiment for video-recording purposes.

Video Equipment

Pigs were videotaped continually over a 24-d period by four Panasonic video cameras (model WV-BL 200) connected to a Panasonic time-lapse video cassette recorder (model AG-6040) and a Panasonic sequential switcher (model WJ-521 altered to provide a maximum of 1.5 min switching time). Each cage was recorded for 1.5 min at a time before the recording switched to the next cage, resulting in a total of 15 min viewing time h^{-1} for each cage.

Behavioural Observations

Pig behaviour was recorded at the onset of each frame and was coded 0 for inactive, 1 for active–agonistic, and 2 for active–nonagonistic. A score of 0 was recorded when pigs were sitting or lying down. Everything else was recorded as active. Activity was recorded as agonistic if it included any one of the following behaviours: head butting, biting of the head, face or ears, and aggressive pushing. Agonistic behaviour was not observed beyond the adaptation period and, therefore, was not considered in the analysis. The total resting time was calculated and expressed for analysis as a daily percentage.

Temperature Measurements

Throughout the experimental period, ST of pigs were taken every second day with an Omega IR thermometer (model OS71) and recorded as an average of five areas: head, shoulders, middle back, lower back, and rump. Cage temperatures were measured using Luxtron fluoroptic temperature probes (model 750, Mountain View, CA), which were held in place with silly putty and protected with a wire-mesh screen. Recordings were made every 5 min with an Epson LX 800 dot-matrix portable printer (model OS71-PRT modified to a serial printer). Room temperature, RH and forward microwave power were recorded daily.

Statistical Analyses

Percent resting time was analysed using a one-way repeated measures analysis of variance. The Wilk's lambda-test statistic was generated and used to determine whether there was a MW effect on the patterns of resting behaviour. The general linear models procedure of SAS Institute, Inc. (1985) was used.

To detect MW effect on weight gain, an analysis of covariance, using initial weight as a covariate, was performed. Correlation analyses were carried out to detect any possible relationships between daily percentage resting time, microwave power level, RT, CT, ST, and humidity level.

RESULTS

Activity Level

Results of the analysis for activity level revealed that the pattern of resting behaviour displayed by IR-treated pigs was significantly different ($P < 0.05$) from that of the two MW-treated groups (Table 1). This difference was evident in both the pretreatment (adaptation) and the experimental periods. A comparison between each MW treatment, however, indicated that similar resting patterns occurred in these groups. The daily percentage resting time over the 24-d period for each treatment graphically demonstrates the similarity in patterns between the MW groups, as well as the difference between these groups and the IR-treated group (Fig. 1). The daily percentage resting times for the MW-treated pigs during the experimental period were consistently higher than those for the IR-treated pigs, although the differences were not always significant. Each MW-treated group demonstrated a sudden increase in resting behaviour on day 5, at the onset of the treatment. This peak was followed by a gradual decline in resting behaviour over the next 20 d. The IR-treated pigs, however, showed no change in resting behaviour over the entire 24-d period. By day 17, resting time for the animals in the MW2 group had returned to a level equal to that observed among animals in the IR group. Resting time for the pigs exposed to the MW1 treatment, however, remained higher for the remainder of the experiment ($P < 0.05$). The mean percentage resting time for the IR group during the experimental period was 79.4 ± 3.7% (mean ± SD); for the MW2 group, 82.3 ± 2.5%; and for the MW1 group, 86.0 ± 1.6%.

Table 1. Wilk's lambda *P* values for pretreatment and experimental analyses of variance testing pattern differences in daily percentage resting time

	P values	
Treatments	Pretreatment	Experimental
IRR vs. MW1	0.0086*	0.0009*
IRR vs. MW2	0.0105*	0.0399*
MW1 vs. MW2	0.8206	0.1226

*Significant at $P = 0.05$.

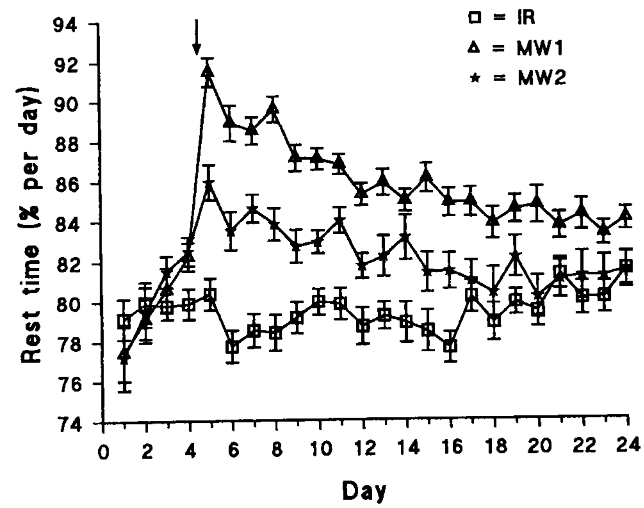

Fig. 1. Mean percentage resting times per day for IR- vs. MW-treated pigs (at two MW power levels). Arrow indicates beginning of treatments, and data points represent average over 24-h period.

Performance

The results of the analysis of covariance on average daily gain revealed that MWR at either 6.1 mW cm^{-2} or 11.4 mW cm^{-2} had no significant effect ($P > 0.05$) on weight gain in weaner pigs (Table 2). The values obtained for the average daily gain of pigs exposed to MW1, MW2 and IRR, respectively, were 0.276 ± 0.07, 0.294 ± 0.13 and 0.321 ± 0.12 kg (mean ± SD). The initial weights of pigs were significantly different ($P < 0.05$), but this variable was accounted for in the analysis as a covariate, and the values obtained were adjusted accordingly.

Correlations

There was a high positive correlation between daily power level and daily percentage resting time (Table 3). This relationship is clearly depicted in Fig. 2, which shows two distinct clusters of points: a low percentage resting time at the lower power level and a higher percentage resting time at the higher power level. A small but positive correlation was also detected between average ST and daily percentage resting time ($P < 0.05$) (Fig. 3). No relationships were observed between daily CT and percentage resting time, daily RT and daily CT, or daily humidity level and resting time ($P > 0.05$).

Table 2. Average body weights and standard deviations per treatment for weaner pigs exposed to IRR, MW1 or MW2 (n = 32; 16 and 16, respectively)

	Average body weight (kg) ± SD				
Treatment	Day 0	Day 7	Day 14	Day 21	Day 25
IRR	6.4±1.4	7.7±1.8	9.8±2.5	12.5±3.2	14.3±3.9
MW1	6.5±1.0	7.7±1.4	9.5±1.7	11.9±2.1	13.5±2.6
MW2	6.6±1.2	7.9±1.6	9.9±2.2	12.2±3.2	14.0±3.7

Table 3. Pearson-correlation coefficients and P values for comparisons between resting time, power level, RT, CT, ST and RH

Variables	Sample size (n)	Correlation coefficient	P value
Daily power level vs. daily % rest time	150	0.47	0.05
Daily power level vs. daily % rest time (MW1)	75	0.01	0.96
Daily power level vs. daily % rest time (MW2)	75	–0.11	0.35
Avg daily CT vs. daily % rest time	44	0.11	0.47
Daily RT vs. avg daily CT	44	–0.03	0.83
Daily avg ST vs. daily % rest time	156	0.18	0.03
Daily humidity vs. daily % rest time	324	–0.05	0.30

DISCUSSION

This study, in which activity level of weaner pigs exposed to 915 MHz MWR was quantified, confirms the observation by Braithwaite et al. (1992) that MW exposure results in a lower activity level in weaner pigs than IR exposure. The magnitude of this difference in activity is dependent on the MW power level, as demonstrated by the correlation between MW power level and daily percentage resting time. Pigs that were exposed to MW1 spent 3.7% more time resting than those exposed to MW2 and 6.6% more time resting than IR-exposed pigs. This suggests that the greater the power of radiation absorbed by the animal, the greater the effect on the behaviour of the animal. The maximal and minimal power levels required to trigger this response are not yet established and most likely are outside the range used in this study. These findings coincide with previous findings by Hunt et al. (1975), in which rats exposed to 2450 MHz pulsed-wave MWR at 6.3 mW g^{-1} demonstrated decreased levels of exploratory behaviour and reduced swimming speed. Swimming performance was more profoundly affected after exposure to 11 mW g^{-1} than after 6.3 mW g^{-1}.

The observed decline in percent time spent in resting behaviour over time indicates that an adaptation to the MWR is occurring. An adaptation to the radiation is the most likely explanation for this attenuated effect over time

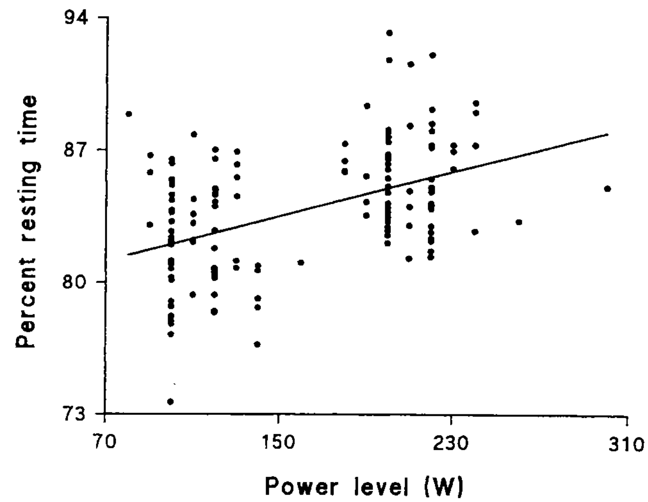

Fig. 2. Effect of MW power level (W) (x) on daily percentage resting time ($y = 79.1 + 0.03x$, $r^2 = 0.22$).

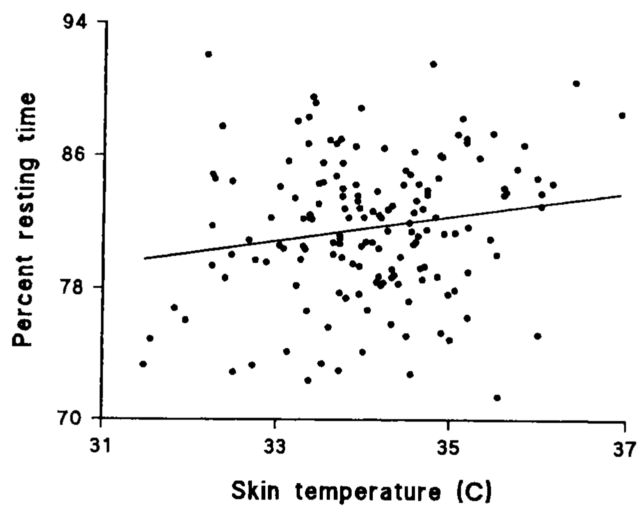

Fig. 3. The effect of daily average ST (°C) (x) on daily percentage resting time ($y = 56.8 + 0.73x$, $r^2 = 0.03$).

because the first drop in resting behaviour occurs just 24 h after the increase in resting behaviour. If the reduced effect were due to the increase in body weight with time, the reduction would not have been seen until several days had passed. Similar findings of an adaptation to MWR were reported by DeLorge (1976) in his work on behavioural effects of MWR on rhesus monkeys. On exposure to 2450 MHz MWR, the monkeys exhibited reduced lever-press responses at 72 mW cm^{-2}, and this effect declined with repeated exposures over a 5-d period. A similar adaptation was observed in rectal-temperature responses to MWR over the same period. The reduction and eventual disappearance of effect in this study suggests that in the animals' attempt to maintain homeostasis, their response to MW exposure is behavioural until the body can compensate physiologically. Further research into the physiological effects of MWR may lead to a better understanding of possible mechanisms of action. Servantie and Gillard (1983) documented a variety of behavioural changes resulting from MW exposure. Some alterations resulting from modifications in membrane permeability to calcium as a consequence of MW exposure have also been reported (Adey 1980).

The different patterns of resting behaviour among the three treatment groups during the pretreatment period are difficult to explain at this time. The sharp rise in resting time on day 5, at the onset of the treatment, in the MW-treated animals demonstrates a treatment-induced effect, rather than a continuation of the pretreatment pattern.

Pigs in a hot environment, with no place to wallow, will thermoregulate by increasing the surface area that is in contact with the cooler floor or walls, by increasing the respiration rate, and by decreasing food consumption (Mount 1968). Throughout our experiment, pigs showed no visible signs of thermoregulatory behaviour in the form of panting or rapid breathing. Pigs in the MW decks, however, sometimes slept in fully recumbent positions and were often spread around the cage. Such postures may indicate that the MW-exposed pigs were attempting to dissipate heat through conduction. On the other hand, they may simply have been adopting the relaxed postures of thermally comfortable animals (Mount 1968). The positive correlation detected between daily percentage resting time and ST also suggests that the MW effect on activity level may be temperature related. Many thermoregulatory process are triggered by thermal receptors in the skin, which results in behavioural (Corbit 1970) and physiological changes taking place before a rise in body-core temperature has occurred (Brown and Brengelmann 1970). The amount of energy absorbed by animals in the MW treatment may be more than that required to maintain homeothermic conditions, as the effective environmental temperature may be much higher than anticipated.

Pigs in the IR decks were most often observed huddling beneath the heat lamps. This huddling response may be an indication of the limited capacity of IR lamps to heat the surrounding environment, resulting in the need for the animal to be directly beneath the source to maximize its effectiveness. On the other hand, the huddling may be an attempt to minimize heat loss through conduction, thus maximizing the benefit of the IR lamps. Mount (1968) suggested that pigs will not huddle when in a thermally comfortable environment but will do so when the temperature drops below thermal neutrality. This observation indicates that the IR-exposed animals are attempting to thermoregulate behaviourally, thus reducing the thermal losses to the environment.

The behaviour of MW-treated pigs during the active periods was consistent with that of the IR-treated pigs, suggesting that such behaviour is normal under the given experimental conditions. Normal behaviour consisted of playing with the tire, investigating the surroundings, romping around, eating and drinking. No unusual or aberrant behaviour was observed in the MW-exposed animals in comparison with the IR-treated animals. Under high (>45 mW cm^{-2}) 2450 MHz MW intensity, piglets tend to shake their heads repeatedly (personal observation). Such behaviour was not observed in these studies.

Agonistic behaviours, such as head butting, ear biting, and aggressive pushing, were only observed during the adaptation period and indicate an attempt to establish a social hierarchy (Hafez and Signoret 1969). Once the social order has been determined, most disturbances of an individual by a lower ranking pig are settled by simple eye contact (McBride et al. 1964). Such subtle agonistic interactions are not distinguishable using the video-recording system, and therefore none were noted during the experimental period.

Several neurotransmitters have been studied in association with sleep. Of these, serotonin and acetylcholine have been found to play important roles in the sleep process (Webb and Dube 1981). Jouvet (1988) suggested that serotonin may act as a neurohormone, which plays a role in the onset of slow-wave sleep through its action on the anterior hypothalamus–basal forebrain. Acetylcholine has been known to induce sleep when applied to many areas of the central nervous system (Hernandez 1965). It is possible that MWR may be inducing sleep in weaner pigs via one of these neurochemicals, by affecting either its production, release or uptake.

The hypothalamus also has important implications in the sleep–wake cycle. The suprachiasmatic nucleus has been found to have many functions, including that of a timing center for the circadian rhythms of pineal serotonin N-acetyltransferase activity (Moore and Klein 1974), brain temperature (Stephan and Nuñez 1977), heart rate (Saleh and Winget 1977) and several other biological rhythms. The role of the suprachiasmatic nucleus in the circadian rhythm of serotonin N-acetyltransferase activity is important in the production of melatonin, which is also associated with sleep onset (Anton-Tay et al. 1971). Microwave radiation could be exerting its effect via direct action on the hypothalamus. There are many possibilities for the mechanism in which MWR induces sleep in weaner pigs. Further investigations are being carried out in our laboratory in an attempt to determine this mechanism's mode of action.

The performance results of MW-treated pigs were consistent with those obtained by Braithwaite et al. (1994), indicating that MWR does not affect weight gain in weaner pigs. The results obtained by Morrison et al. (1987) demonstrate that MWR reduced the feed/gain ratio of male broiler chicks. However, chicks in that study were exposed to intermittent 2450 MHz MWR, in contrast to the continuous-wave 915 MHz radiation used in this study. The absence of a MW effect on weight gain suggests that these animals were not experiencing serious thermal stress. Furthermore, the behavioural effect of MWR is insufficient to result in a change in performance. Pigs maintained in a hot environment reduce their food consumption and, therefore, would not gain as much as those that were maintained in a thermoneutral or cooler environment (Mount 1968).

Results of the correlation analyses further emphasize the power-level-dependent effect of MWR on activity in weaner pigs. The high correlation (r = 0.47) between MW power level and resting time is strong evidence that the effect of MWR on activity level is determined by the power of radiation to which the animals are exposed. The correlation between ST and resting time suggests a temperature-related effect of the MWR. However, the correlation was small (r =

0.18), indicating that the relationship is very weak and may only be coincidental. Furthermore, no relationship was detected between CT and resting time, which indicates that the ambient temperature is not interacting with the treatment to effect a change in the activity level of the pigs. Therefore, any thermal effect on activity must be the result of the MW power level. More work should be done to determine the optimal level of MWR that will result in the maximum benefit of this technology.

CONCLUSIONS

Exposure to MWR at 915 MHz causes an initial decrease in activity level among newly weaned when compared to IR exposed pigs. This effect is dependent on the MW power level inducing a greater decrease in activity at higher power densities than at lower power densities. Furthermore, the effect of MWR on activity diminishes with continued exposure in such a way that activity returns to basal levels after 3 wk of exposure. Performance of pigs exposed to MWR is similar to that of pigs exposed to IRR.

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