Effective rewarming of hypothermic piglets using 915-MHz microwaves

Bate, L. A., Crossley, J. G. and Wade, R. 1992. **Effective rewarming of hypothermic piglets using 915-MHz microwaves.** Can. J. Anim. Sci. **72**: 161–164. A prototype 915-MHz microwave unit was designed to rewarm hypothermic piglets. Initial tests indicate that it is possible to rewarm piglets successfully from deep stages of hypothermia using 915-MHz microwaves. Rewarming did not cause any significant physiological changes in blood variables, nor did the animals show any visible change while their subsequent behaviour appeared normal.

Key words: Piglets, hypothermia, microwave, rewarming

Bate, L. A., Crossley, J. G. et Wade, R. 1992. **Réchauffement de porcelets hypothermiques au moyen d'un radiateur à micro-ondes de 915 MHz.** Can. J. Anim. Sci. **72**: 161–164. Un prototype de chaufferette à micro-ondes de 915 MHz a été conçu pour le réchauffement de porcelets souffrant d'hypothermie. Les premiers essais montrent que cette fréquence de rayonnements est efficace, même dans des cas d'hypothermie avancée. Ce mode de réchauffement n'a pas entraîné de modifications physiologiques significatives dans les variables hématologiques. Les animaux ne manifestaient aucune altération corporelle visible et leur comportement ultérieur paraissait normal.

Mos clés: Porcelet, hypothermie, micro-ondes, réchauffement

The swine industry suffers large annual losses because of piglet mortality. In this respect, hypothermia is singled out by Edwards (1972) as the second most common cause of direct piglet mortality. He also observed that hypothermia additionally predisposes animals to death by starvation, crushing, and disease. Deaths from hypothermia not only result in economic losses but the condition has been recognized as a widespread, serious, welfare problem in the swine industry (Expert Committee on Farm Animal Welfare and Behaviour 1987).

Microwaves have a tremendous potential as a source of supplementary heat for many domestic animals, particularly in cold climates. The advantage of microwaves over conventional forms of energy is due to the mode of energy transfer to living tissues. Microwaves are capable of heating animal tissue without warming the air or objects other than those with a high water content (World Health Organization 1981). It has already been shown that microwaves may be used in domestic animals, such as chickens as a source of supplementary heat (Bate et al. 1986; Braithwaite et al. 1991).

Given their physical properties and mode of action, one of the obvious applications in the animal industry lies in correcting hypothermia. At a frequency of 915 MHz, microwaves have a wavelength of 32.8 cm when moving through air, and 17.7 cm when moving within low-water-content tissues such as fat and bone and 3.04 cm within high-water-content tissues such as muscle (Johnson and Guy 1972). The average penetration of 915 MHz waves should, therefore, be adequate to rewarm the core of a newborn piglet which has a cylindrical diameter of about 7–8 cm.

Successful animal rewarming experiments have been performed with other frequencies of electromagnetic radiation. Using a radio frequency of 13.46 MHz, Olsen et al. (1987) rewarmed rhesus monkeys, which, with rectal temperatures of 20°C were undergoing cardiovascular collapse. Using frequencies of 2450 MHz, Braithwaite et al. (1989) successfully rewarmed piglets having rectal temperatures of 33.7°C. Ninety percent of the rewarmed animals survived until weaning. With the same frequency Braithwaite et al. (1990) rewarmed lambs from 36 to 37°C. It is reasonable, therefore, to expect that 915 MHz radiation should be effective in rewarming piglets.

As a means of testing this hypothesis, a prototype 915-MHz Microwave rewarming unit for piglets was designed by D'Ossone Canada Ltd. (Charlottetown, PEI). The unit consists of a 500-W variable power 915-MHz generator model MPS915-500 (Choung Laboratories Inc., Baltimore, ME) connected by an 80-cm, 50-ohm coaxial cable to an antenna placed in a 28 × 14-cm stainless steel waveguide 1.31 m long. The waveguide was fitted at the opposite end of the antenna with a 1-L water load. A 16 × 64-cm oval lid was fitted with four safety switches, which turn the magnetron off if the lid is improperly closed, allowing access to the inside of the waveguide. The forward and reflected power are monitored at the connection of the coaxial cable and the antenna with two Bird RF directional thruline wattmeters (Model 43, Cleveland, OH). The total electrical consumption of the generator is constantly monitored at the power supply cable with a Hioki Digital Hi tester model 3223 and 3181-01 (Hioki E. E. Corp. Sakaky, Japan). The equipment can be also routinely checked for leaks using a Microwave Survey Meter Model 1600 (Holyday Industries, Inc., Eden Prairie, MN).

Initially, to estimate the power required for varying masses, individual 0.9% saline bags ranging from 500 to 1500 mL were rewarmed from 20 to 38°C. The initial rewarming rate was set at approximately 0.25°C min^{-1}. The power required to reach this rate of heating served as a base to start rewarming piglets. Subsequently, the power was increased to conduct rewarming of live piglets at a faster rate.

Hypothermia, as low as 20°C, was induced in 36 newborn live pigs by exposing them to a 5°C cooling unit. Hypothermic piglets were then individually wrapped in a 38 × 65-cm canvas blanket reinforced with 0.3 × 1 × 35-cm microwave transparent plastic bars placed in parallel 5 cm apart. Velcro closures were used to secure the piglet in the blanket. The piglet was then placed in a 12 × 13 × 43-cm well-ventilated microwave-transparent plastic container, and then in the waveguide. All hypothermic pigs were fitted with a Luxtron fluoroptic rectal thermometer probe (Model 750, Montain View, CA) to monitor the rewarming rate. The piglets were then exposed to a power level specific to their individual body weights in order to sustain rewarming rates between 0.5 and 1°C min^{-1}. To achieve these rewarming rates in piglets, the power level used averaged between 72 and 78 W. The rewarming process was continuously monitored and the temperature as well as the total power consumed was recorded every 30 s. Heating was stopped when the rectal temperature reached 38°C. The piglets were then visually checked for any signs of thermal damage with special attention given to thin structures as well as those areas of low circulation such as the tail, limbs, ears, eyelids and eyes. After visual inspection the rewarmed piglets were returned to the sow, which was housed in a commercial farrowing crate, and allowed to suckle. For analytical purposes, piglets were grouped in three categories: light (< 1000 g), medium (1001–1250 g), and heavy (> 1250 g) (Table 1). Analysis of variance was conducted using general linear model procedure from the Statistical Analysis System Institute, Inc. (SAS Institute, Inc. 1985).

The experimental protocol, which deviates from optimal animal care, was approved in advance by the local committee of the Canadian Council on Animal Care.

In a second trial, hypothermia was induced in 13 pigs weighing less than 1300 g from two litters, while 10 piglets heavier than 1300 g served as controls. After reaching the desired level of hypothermia (25°C rectal temperature) the piglets were allowed to rest at room temperature (20–22°C) for approximately 20–30 min prior to starting the rewarming process. A blood sample was collected from the suborbital sinus of the hypothermic piglets before cooling, after cooling and after rewarming. A single blood sample was

Table 1. Parameters observed while rewarming piglets of different weight groups to a rectal temperature of 38°C (mean ± SD)

Group	N	Piglet weight (g)	Initial temperature (°C)	Rewarming time (min)	Rewarming rate (°C min^{-1})	Generator power (W)	Rewarming power (W)
Light	7	833.7*a* ± 151.1	23.5*a* ± 1.5	17.07*a* ± 4.16	0.86*a* ± 0.13	613.9*a* ± 27.7	72.2*a* ± 8.5
Medium	12	1178.9*b* ± 71.4	27.0*b* ± 2.5	17.12*a* ± 3.76	0.64*b* ± 0.09	634.0*a* ± 23.4	78.6*a* ± 7.2
Heavy	17	1454.9*c* ± 186.0	29.4*c* ± 2.7	14.12*a* ± 3.99	0.64*b* ± 0.21	620.0*a* ± 27.0	74.1*a* ± 8.4

a-c Values with different letters within the same column are different ($P < 0.05$).

Table 2. Parameters observed when warming piglets at different rates (mean ± SD)

Parameter	Desired rewarming rate 0.5°C min^{-1} $n = 4$	0.75°C min^{-1} $n = 4$	1.0°C min^{-1} $n = 5$
Body weight at birth (g)	1007.33 ± 142.77	1061.00 ± 142.97	945.75 ± 287.56
Temp. at birth (°C)	37.86 ± 1.76	38.30 ± 1.24	38.92 ± 0.97
Temp. after cooling (°C)	24.40 ± 1.21	24.81 ± 0.98	25.12 ± 0.25
Cooling time (min)	158.66 ± 54.05	113.00 ± 30.21	175.00 ± 84.77
After cooling time (min)	30.00 ± 17.32	22.50 ± 6.12	25.00 ± 10.00
Initial rew. temp. (°C)	26.40 ± 0.17	26.16 ± 2.16	27.10 ± 0.42
Final rew. temp. (°C)	38.00 ± 0.00	38.03 ± 0.05	38.47 ± 0.44
Forward power (W)	43.20 ± 6.80	61.93 ± 15.01	64.67 ± 7.95
Reflected power (W)	17.50 ± 4.09	17.46 ± 5.28	19.40 ± 3.39
Rewarming time (min)	24.00 ± 1.32	18.08 ± 4.76	10.62 ± 2.35
Rewarming rate (°C min^{-1})	0.48 ± 0.03	0.68 ± 0.14	1.09 ± 0.17
PRT[z] 5 min	37.10 ± 0.85	36.46 ± 0.78	35.82 ± 0.89
PRT 10 min	36.80 ± 0.43	36.63 ± 0.81	35.87 ± 0.76
PRT 15 min	37.03 ± 0.46	36.76 ± 1.00	35.87 ± 0.89
PRT 25 min	37.66 ± 0.49	37.23 ± 0.54	36.32 ± 1.03
PRT 35 min	37.93 ± 0.11	37.53 ± 0.52	36.82 ± 0.89
PRT 45 min	37.63 ± 0.72	37.80 ± 0.52	37.40 ± 0.69
PRT 60 min	38.73 ± 0.32	38.33 ± 0.33	37.72 ± 0.62

[z]PRT = Post rewarming temperature.

collected from control animals. Plasma was separated by centrifugation, maintained at 4°C and used within 24 h to determine the concentrations of the following electrolytes, enzymes and other compounds: Na, K, Cl, Ca, P, urea, creatinine, cholesterol, amylase, alkaline phosphatase, total protein, albumin, globulin, and lipase. Analyses were performed using a Discrete Analyzer Continuous Optical Scanning machine (Coulter Electronic, Inc., Hialeah, FL). The piglets were rewarmed from approximately 25°C at rates of either 0.5, 0.75 or 1.0°C min^{-1}. Piglets were randomly allocated to these groups. These animals were then returned to the sow and allowed to suckle normally. The rectal temperature of all piglets was monitored for at least 1 h after rewarming. All the above-mentioned plasma variables among the groups of animals rewarmed at different rates were compared using Duncan's test using general linear models (SAS Institute, Inc. 1985).

The power required to rewarm saline bags at a rate of 0.25°C min^{-1} averaged 12.4, 23.1, 26.8, 32.7, 34.3, 41.9, 43.2, 46.8, 49.2, and 54.8 W for 500, 600, 700, 800, 900, 1000, 1200, 1300, 1400, and 1500 mL of saline, respectively. It was found that the power levels required to rewarm the live piglets deviated from that needed for equivalent weights of saline phantoms because of variable rates of reflected power. The rectal temperatures of lighter piglets dropped below those of heavier animals ($P < 0.05$)

(Table 1). Using similar rewarming powers lighter piglets were rewarmed faster than heavier ones ($P < 0.05$). The power levels required to rewarm piglets of different weights can be derived from the equation: Forward power = 26.64 W + 0.022 g body weight.

Piglets rewarmed at rates of 0.5, 0.75 or 1°C min^{-1} responded equally well to the treatment. After rewarming, the temperature of all piglets decreased approximately 2°C. The piglets recovered to euthermic levels within 60 min (Table 2). This phenomenon is virtually the same as that taking place after birth. Neonatal piglets normally experience a drop in rectal temperature of approximately 2°C within 1 h of birth (Curtis 1983). There were no differences ($P < 0.05$) in any of the blood parameters measured between the different groups of piglets.

It is concluded that 915-MHz microwave energy appears to be a viable method for rapidly rewarming hypothermic piglets. Further work should be conducted to gain a better understanding of the short- and long-term physiological and behavioural effects due to the exposure to such microwave radiation.

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