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# APPLICATIONS OF INFRARED THERMOGRAPHY IN ANIMAL PRODUCTION

**Ivana KNÍŽKOVÁ Petr KUNC**
**Research Institute of Animal Science, Prague Uhříněves, Czech Republic**

**Gürkan Alp Kağan GÜRDİL Yunus PINAR Kemal Çağatay SELVİ**
**O.M.U. Faculty of Agriculture, Dept. of Agricultural Machinery, Samsun**

**Sorumlu yazar: ggurdil@omu.edu.tr**

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**ABSTRACT:** This review presents the application and use of infrared thermography (IRT) in production animals. IRT is a non-invasive and non-contact heat detecting technology. An infrared camera measures the emitted infrared radiation from an object and then uses this information to create images (thernograms). These thermograms are evaluated by a specially analyzing software program. In live organisms, changes in vascular circulation result in an increase or decrease in tissue temperature, which is then used to evaluate the situation in that area. But there are some limitations and factors that must be considered when using IRT (sunlight, moisture, dirt, weather conditions etc). IRT has been mainly used in veterinary medicine, primarily for diagnostic purposes, especially in the diagnosis of orthopaedic diseases in horses. But IRT can be very successfully used as tool for research on livestock, pig, cattle, sheep and poultry breeding,. Areas of research include reproduction, thermoregulation, animal welfare or milking process. All of the authors using IRT recommended this method which can produce important information where conventional diagnostic techniques have exhausted their possibilities.
**Key Words:** Infrared thermography, Cattle, Pigs, Sheep, Poultry

## HAYVANSAL ÜRETİMDE KIZILÖTESİ TERMOGRAF (TERMO-KAMERA) UYGULAMALARI

**ÖZET:** Bu çalışma hayvansal üretimde kızılötesi termograf (infrared termography; IRT) uygulamalarını özetlemektedir. IRT temas ve yayılma olmaksızın ısı algılamaya dayalı bir teknolojidir. Bir kızılötesi kamera nesnelerden yayılan kızılötesi ışınımı ölçer ve bu bilgileri görüntü oluşturmada kullanır. Bu görüntüler özel bir çözümleme yazılımı ile değerlendirilir. Canlı organizmalarda kan dolaşımındaki değişmeler doku sıcaklığının artması veya azalmasına neden olur ve bu sonuçlar o bölgedeki durum değerlendirilmesinde kullanılır. IRT kullanımında güneş ışığı, nem, kir ve hava şartları gibi bası kısıtlayıcı faktörleri göz önünde bulundurmak gerekir. IRT genellikle veterinerlikte tanı amaçlı olarak kullanılmış ve özelikle atlarda ortopedik rahatsızlıkların teşhisinde kullanılmıştır. Bununla birlikte bir araç olarak IRT, büyükbaş, koyun, domuz, kanatlı gibi çiftlik hayvanları üzerinde yapılan araştırmalarda da çok başarılı bir şekilde kullanılabilir. IRT'nin kullanımı ayrıca üreme, ısısal denge, hayvan sağlığı ve süt işleme gibi alanları da kapsamaktadır. IRT yöntemini kullanan bütün araştırmacılar geleneksel teşhis yöntemlerinin yetersiz kaldığı yerlerde bu yöntemi tavsiye etmektedirler.
**Anahtar Kelimeler:** Kızılötesi termograf, Sığır, Domuz, Koyun, Kanatlı hayvanlar

## 1. INTRODUCTION

Infrared thermography (IRT) is a modern, non-invasive and safe technique of thermal profile visualisation. Every object on earth generates heat radiation in the infrared part of the light spectrum, the intensity and spectrum distribution of which depend on the mass's temperature and the radiation properties of its surface layer. Using thermographic scanning equipment (thermographic camera) able to detect this type of radiation, even minute changes in temperature can be accurately monitored. The data obtained by scanning is computer-processed and shown in the form of temperature maps that provide for a detailed analysis of the temperature field.

An infrared camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature. However, the radiation measured by the camera does not only depend upon the temperature of the object, but is also a function of the emissivity. Radiation also originates from surroundings and is reflected by the object. The radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere. To measure temperature accurately, it is therefore necessary to compensate for the effects of a number of different radiation sources. This is done on-line automatically by the camera. However, the following object parameters must be supplied for the camera: the emissivity of the object, the reflected temperature, the distance between the object and the camera and relative humidity.

Thermographic method has found numerous applications not only in industry, but also in human and veterinary medicine, primarily for diagnostic purposes (Yang and Yang, 1992; Denoix, 1994; Hilsberg et al., 1997; Harper, 2000; Embaby et al., 2005; Markel and Vainer, 2005). But IRT has been applied less frequently to research on livestock in live organisms, changes in vascular circulation result in an increase or decrease of tissue temperature, which is then used to assess the area (Harper, 2000). For example, heat generated by inflammation is transmitted to the overlying skin via increased capillary blood flow and is dissipated as infrared energy. Spruyt et al. (1995) recommended IRT as a good method in helping to study thermoregulation. A major advantage of the method is the fact that it does not require a direct physical contact with the surface monitored, thus allowing remote reading of temperature distribution (Speakman and Ward, 1998).

## 2. APPLICATIONS IN CATTLE

Hurnik et al. (1984) studied the suitability of IRT for the detection of health disorders in Holstein-Friesian dairy cattle and concluded that it was suitable for the purpose.

Schwartzkopfgenswein and Stookey (1997), using IRT, compared differences in extent and duration of inflammation observed on hot-iron and freeze brand sites as an indicator of tissue damage and the associated discomfort to the animals. The thermographic evaluation of hot-iron and freeze brand sites indicated that both methods caused tissue damage. However, hot-iron brand sites remained significantly warmer than freeze sites at 168 hours after branding. In addition, hot-iron sites were significantly warmer than control sites, while freeze sites were not warmer than control sites at 168 hours. The prolonged inflammatory response observed in hot-iron animals indicates that more tissue damage and perhaps more discomfort are associated with hot-iron branding. Spire et al. (1999) used the infrared IRT to detect inflammation caused by contaminated growth promoting ear implants in cattle. The authors found that significant differences existed between ears with contaminated implants and control ears. Cockroft et al. (2000) described the use of IRT as an aid in the diagnosis of septic arthritis of the right metatarsophalangeal joint of Friesian heifer. IRT was able to identify the focus of inflammation accurately and provide supporting evidence for more invasive diagnostic techniques and treatment therapies. Schaefer et al. (2004) used IRT for identifying calves with bovine viral diarrhoea virus. They found that increases in eye temperature were more consistent than other anatomical areas. There were also significant changes in eye temperature several days to one week before other clinical signs of infection. Nikkah et al. (2005) observed hooves of dairy cows. Images of hooves were taken using IRT to determine temperature of the coronary band, and that of a control area above the coronary band. The authors recommend IRT as tool for monitoring hoof health.

Hurnik et al. (1985) studied the relationship between differences in body surface temperatures and the oestrus in Holstein-Friesian dairy cows, and a possibility of using this technique to determine the onset of the oestrus. Because inaccuracies were encountered in determining the oestrus cycle during the experiment, the authors did not recommend IRT for routine detection of the oestrus, but it is nevertheless completely adequate in skin temperature studies, or, more precisely, in the studies of body surface temperature changes. Hellebrand et al (2003) concluded that gravidity of heifers in their usual environment (pasture or barn) cannot be determined by simple monitoring with a thermal imager, but they did find that the external pudendum temperature follows the core body temperature, and thus IRT can be utilised for oestrus climax determination.

Kozumplik et al. (1989) used IRT in the diagnosis of inflammatory processes on the sex organs of breeding bulls. The objective was to obtain an overall thermogram of the gonads of bulls with normal and disturbed fertility, and to assess the possibility of using IRT for the diagnosis of sex organ diseases accompanied with local temperature changes. Thermograms of the scrotum showed that the warmest and the coldest zones lie at the head of the epididymis and a part of the testicles adjoining the tail of the epididymis, respectively. The authors recommend thermography as a useful tool for the identification of initial stages of diseases of sex organs in breeding bulls. Kastelic et al. (1995) found that temperature gradients were most pronounced on the scrotal surface, less in the scrotal subcutaneous tissue, and slightly negative (relative to the surface) within the testicular parenchyma. Scrotal surface temperature decreased from the neck of the scrotum to the ventral aspect to scrotum. Conversely, the ventral pole of the testis was slightly warmer than the dorsal pole. The caput of the epididymis was warmer than the adjacent testicular parenchyma, while the cauda was cooler. IRT was also used by Kastelic et al. (1996a, 1996b) to study environmental factors that influence the bovine scrotal surface temperature and to study the influence of ejaculation on the scrotal surface temperature in bulls. The authors concluded that representative temperature measurements of the scrotal surface could be taken at any time of the day except at feeding and rising. Moreover, the scrotum should be dry. Measurements are independent of the ambient temperature provided it is stable. Abrupt changes in the ambient temperature may, however, result in artefacts due to overcompensations. Thermographic measurements showed that spontaneous ejaculations as well as electroejaculations increased the surface temperature of the scrotum. Further, Kastelic et al. (1996c, 1997a) found that insulation of the scrotal neck affected scrotal surface temperature, scrotal subcutaneous and intratesticular temperatures, and increasing testicular temperature results in defective spermatozoa, with recovery dependent on the nature and duration of the insult. Kastelic et al. (1997b) used IRT to study the contribution of the scrotum, testes, and testicular artery to scrotal/testicular thermoregulation in bulls at two ambient temperatures. Their results supported the hypothesis that blood within the testicular artery has a similar temperature at the top of the testis compared with the bottom, but subsequently cools before entering the testicular parenchyma. Gabor et al. (1998) determined the effect of GnRH treatment on plasma testosterone concentrations and scrotal surface temperature, the repeatability of different morphologic, thermal and endocrine measures before and after GnRH treatment. They also examined the correlation between the total number of spermatozoa and the proportion of live and motile spermatozoa, using the different morphologic, thermal and endocrine measures before and after GnRH challenge. The authors concluded that GnRH treatment significantly increased plasma testosterone concentrations and usually caused significant increases in scrotal surface temperature measured by IRT. Scrotal circumference and the total number of spermatozoa per ejaculate were highly correlated. Other measurements were less correlated, though with an apparent effect of ambient temperature on measurements of the scrotum and assessment of scrotal surface temperature. Significant regression equations were derived for the total number of spermatozoa and the percentage of motile spermatozoa; plasma testosterone concentrations and scrotal surface temperature gradients, respectively, were the significant independent variables.

In a series of experiments with beef cattle, Gerken and Barow (1998) investigated IRT as a non-invasive method of evaluating thermoregulatory responses in undisturbed animals (beef cattle) on the pasture. IRT was found to be a highly reliable tool under field conditions. Schaefer et al. (1988) studied the effect of the period of fasting and transportation of slaughter animals on, inter alia, infrared heat loss of beef cattle. In three experiments, the transportation distances were 3, 320 and 320 km, and period of fasting was 24, 48 and 72 hours, respectively. The body surface temperature was measured by IRT, and thermograms showed that the heat loss decreased with longer fasting and transportation distances, which corresponded with the darker meat colour of slaughtered animals. Similar results were obtained by Tong et al. (1995) in beef cattle and IRT was used successfully to detect to dark -firm-dry beef.

Kimmel et al. (1992) studied the effects of evaporative cooling on heat stress of Israeli-Holstein dairy cows in summer, where IRT was used to measure differences between temperature zones on their bodies. For two hours, the cows were alternatively sprinkled with water for 0.5 minutes and cooled with a flow of air ($3m.s^{-1}$) for 4.5 min. Their rectal temperature dropped from 38.2°C to 36°C and remained unchanged for another hour. Thermograms of the cows also revealed a drop of 1.5°C in body surface temperature caused by the cooling. As a part of research into the protection of cattle against high ambient temperatures, Knizkova et al. (1996) made an experiment involving thermographic monitoring of body surface temperatures immediately before and after cooling, 15, 30 and 45 minutes after cooling, and after complete drying. They also wanted to identify the warmest zones on cattle that were exposed to high ambient temperatures. Air temperatures at the time of the experiment were between 27 and 31°C. The cattle were sprinkled for 60 seconds with water by means of special nozzles mounted above. Evaluation of the thermograms showed that the warmest zones included the neck, shoulder and rib regions (Figure 1). After a 60 second period of cooling at given ambient temperatures, the mean body surface temperature dropped by 1.2°C for 45 to 60 minutes. An evaluation of naturally ventilated dairy barn management by


Fig.1 Thermal profile of dairy cow under different air temperatures (at 27 °C)

thermographic method was made by Knizkova et al. (2002). Thermal comfort of the cows in the barn was assessed by monitoring changes in their body surface temperature. Microclimatic factors in the barn were modified by opening and closing sidewall plastic curtains in the barn and doors in alleys. No changes in body surface temperature were recorded when the air temperature dropped by 3.1°C, a significant response was recorded when the air temperature dropped by 6.5°C. Significant changes in the air velocity at temperatures within the thermoneutral range influenced thermal conditions in the barn, and significant changes in body surface temperature caused by vascular responses were recorded. It is impossible to asses thermal comfort of dairy cattle housed in barns objectively only on the basis of visually detectable thermoregulatory behaviour of the cows or of microclimatic parameters measured in barns, because different combinations of air temperature and air velocities will result different intensity of body surface cooling. This is reflected the variations of the body surface temperatures, which can be reliably monitored by IRT (Figure 2). Verkerk et al. (2004) studied cold stress in dairy cattle with the use of IRT. This technology may prove to be a useful indicator of overall stress. Lendelova et al. (2005) used IRT for evaluation of the texture suitability of floors in cow resting area from the viewpoint of their thermal properties, and with a view to different sorts of top-layer structure quality. Applied data collection of temperature difference of the warmed resting areas with straw were for all significance levels of 30 minute long observations, found to correspond to the results of typical warm floors covered with mattresses filled with rubber foam and insulating mat with rubber cover. Their temperature differences were significantly higher than the results on concrete and brick floor.

## 3. APPLICATIONS IN PIGS

In their study of osteoarthrosis tarsi deformans (OATD), Sabec and Lazar (1990) found significant disease-related temperature differences when they used IRT to monitor the superficial temperature of the tarsus in Swedish Landrace boars. The boars with a positive finding had also a higher temperature of the tarsus. OATD was not ascertained in only ten boars of the entire group. Loughmiller et al. (2001) determined the relationship between ambient temperature and mean body surface temperature measured by use of IRT, and to evaluate the ability of IRT to detect febrile responses in pigs following inoculation with *Actinobacillus pleuropneumonia*. IRT can be adjusted to account for ambient temperature and used to detect changes in mean body surface temperature and radiant heat production attributable to a febrile response in pigs.

IRT was also used by Gariepy et al. (1989) to observe a correlation between incidence of meat quality defects and increasing skin surface temperature of pigs prior to stunning. The authors concluded that IRT can be a practical and rapid method of detecting which pigs will yield a significant


Fig.2 Thermal profile of dairy cow under low air temperatures (at 5 °C)

proportion of meat quality defects. Schaefer et al. (1989) studied the relationship between stress sensitivity and meat quality in pigs of known genotypes. Using a thermographic camera, the authors mapped the distribution of temperature fields on pigs immediately before slaughter and on carcasses after slaughter, and then related the temperature fields to meat quality. Although thermographic analysis failed to demonstrate in pigs of different genotypes any significant differences between mean superficial temperatures before slaughter and superficial temperature of carcasses, it was ascertained that a higher drip loss and percentage of pale, soft and exudate meat (PSE) may be expected in pigs with a lower superficial temperature.

Adamec et al. (1997) studied the possibility of reducing heat stress on fattening pigs during the summer period by means of water evaporative cooling. Changes in body surface temperature were measured by IRT. The authors concluded that evaporative cooling decreased heat stress on pigs, and improved growth and feed conversion.

Loughmiller et al. (2005) determined the relationships among feed intake or diet composition and mean body surface temperature. The results indicate that IRT can detect mean body surface temperature changes in pigs caused by changes in dietary intake or energy level. These changes can be detected under more variable environmental conditions than those used with a calorimeter and may be adapted as a low cost non – invasive tool to categorize factors impacting swine thermoenergetics.

Using a thermographic system, Kotrbacek and Nau (1984) studied the temperature of the mammary gland skin in twenty Large White sows. The evaluation of their body surface thermograms from the last days of pregnancy showed that the area of the mammary glands was the warmest zone of the body. On the first day of lactation, the temperature in some limited areas was 39°C, and average skin temperatures in the following days of lactation ranged from 37 to 38°C. Similar temperatures were ascertained on the skin of sucking piglets or those resting close to the sows. Using IRT, the authors were able to show that the mammary gland and the piglets make up a single isothermic complex supporting the integrity of the mother-offspring biological unit. Xin (1999) tested the thermal comfort of group-housed 4 – 5 week old pigs exposed 20, 24, 28, 32 and 36°C with air velocity at 0.1, 0.5, 1.0 and 1,5 m.s$^{-1}$. The thermal profiles of pigs were obtained by IRT. His research may further elucidate the thermoregulatory responsiveness of the pigs to environmental modifications.

**4. OTHER APPLICATIONS**

Chepete and Xin (2000) investigated the efficacy of intermittent partial surface sprinkling to cool caged hens at 20, 38 and 56 week of age. The body surface temperature of the hens was measured by IRT. The authors found that sprinkling once every 5 to 6 min provides adequate cooling to prevent the surface temperature from rising.

Mala et al. (2004) and Knizkova et al. (2005) observed and compared thermal insulation of birthcoat in 3-days-old lambs in two then four genetics types exposed to cold environment and to rain simulation. Body surface temperature of body was measured by

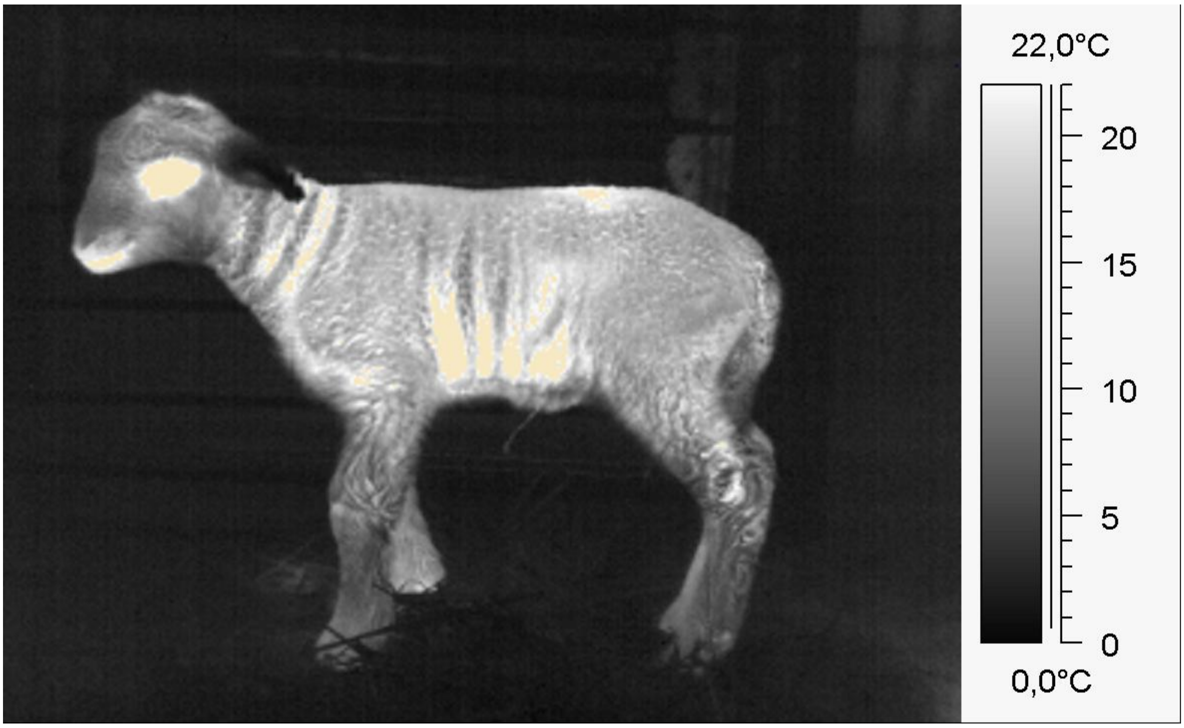


Fig.3 Bad thermal insulation of birthcoat in postnatal lambs (at 5 °C)

Fig.4 Good thermal insulation of birthcoat in postnatal lambs (at 5 °C)

IRT. The lowest heat losses were recorded in the Šumavská breed. The results showed that cold resistance of postnatal lambs is influenced by breed and by birthcoat character and that the Šumavská breed is better adapted to cold and rainy conditions than the Merinolandchaf breed and the crossbreeds Suffolk x Merinolandschaf and Suffolk x Šumavská (Figure 3 and 4). The results obtained by IRT were confirmed by biochemical and haematic analysis.

Stewart et al. (2005) recommended IRT as a non-invasive tool to study animal welfare. Reliable, non-invasive tools that can be used to measure acute and chronic stress during commercial practises and pre-slaughter are required. IRT fits these criteria and has great potential as a way to assess animal welfare.

## 5. CONCLUSION

The above examples prove conclusively that IRT can produce important information where conventional diagnostic techniques have exhausted their possibilities. But there are some limitations and factors that need to be considered when using IRT. Thermograms must be collected out of direct sunlight and wind drafts. Hair coats should be free of dirt, moisture or foreign material. The effect of weather conditions, circadian and ultradian rhythms, time of feeding, milking, laying and rumination etc. are also factors that need to be considered and require further investigation as a part validating IRT. Then infrared thermal measurements can be used very successfully in prediction, detection and diagnosis of diseases, and others applications in livestock science.

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