Anadolu Tarım Bilimleri Dergisi
Anadolu Journal of Agricultural Sciences
http://dergipark.gov.tr/omuanajas

Araştırma/Research

Anadolu Tarım Bilim. Derg./Anadolu J Agr Sci, 35 (2020)
ISSN: 1308-8750 (Print) 1308-8769 (Online)
doi: 10.7161/omuanajas.758342

Monitoring poultry barns thermal problems using thermal cameras

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Geliş/Received 26/06/2020 Kabul/Accepted 05/08/2020

ABSTRACT
Buildings consume approximately 36% of the total energy overall in Turkey. Further, space heating and cooling in buildings accounts for more than one-third of the total energy consumed. Therefore, undesirable heat losses are one of the most significant problems in enhancing buildings' energy efficiency. The most important issue in preventing heat losses in buildings is determining the areas that cause loss, which can be detected with high-tech thermal cameras. The application of thermal imaging in poultry barns is an innovative new technology that can help determine the performance of insulation applications. This study focused on applicability of thermal imaging to detect heat losses and gains occurred because of structural problems in a poultry barn. The findings indicate that thermal imaging technique can identify structural problems which cause heat losses or gains and that these problems mostly arise from holes in windows and doors, insufficient insulation of windows and doors frame, and cracks in sandwich panel structures.

Keywords:
Energy
Heat loss
Poultry barn
Thermal imaging

Kümeslerdeki ısı kayıplarının termal kamerayla izlenmesi

ÖZET
Türkiye'de toplam enerjinin yaklaşık yüzde %36'sı binalarda tüketilmektedir. Binalarda ise tüketilen toplam enerjinin üçte birinden fazlasını ısıtma ve soğutma oluşturmaktadır. Bu nedenle, istenmeyen ısı kayıpları binaların enerji verimliliğini arttırmada en önemli sorunlardan biri olarak görülmektedir. Binalarda ısı kayıplarını önlemede en önemli konu, ısı kaybına yol açan alanların yüksek teknolojili termal kameralarla belirlenmesidir. Kümeslerde termal görüntüleme teknikleri, yalıtım uygulamalarının performansını belirlemeye yardımcı olabilecek yeni bir teknolojidir. Bu çalışmada, kümesteki yapısal problemlerin neden olduğu ısı kayıplarını ve kazançlarını tespit etmek için termal görüntülemenin uygulanabilirliği araştırılmıştır. Elde edilen bulgular, termal görüntüleme tekniğinin ısı kayıp ve kazançlarına yol açan yapısal sorunları tespit edebildiğini ve bu yapısal sorunların çoğunlukla pencere ve kapılardaki boşluklardan, kapı ve pencerelerdeki yetersiz yalıtımlardan ve sandviç paneldeki çatlaklardan kaynaklandığını göstermektedir.

Anahtar Sözcükler:
Enerji
Isı kaybı
Kümes
Termal görüntüleme

1. Introduction

Energy conservation is a critical issue for all countries, but it is prominent for Turkey, which fulfills most of its energy requirements through import. The energy consumption has risen quickly as a result of climate change, industrialization, population growth and improved living standards. The energy consumption is globally divided to four sectors: residential, commercial, industrial and transport (Mares, 2018). In particular, the building sector, consisting of residential and commercial end users, accounts for 20% of the total energy consumption (Sieminski, 2014). Buildings consume approximately 36% of the energy consumption overall in Turkey. Further, more than one-third of the total energy

consumed is used space heating and cooling for buildings (Mangan and Oral, 2016). Therefore, undesirable heat losses and the related energy losses are one of the most significant problems in enhancing buildings' energy efficiency. The most important issue in preventing heat losses in buildings is determining the areas that cause loss, which can be detected with high-tech, heat sensitive thermal cameras.

Infrared thermography has been widely used throughout the world in recent years. This technique is used to measure surface properties for a variety of research studies involving all possible heat transfer phenomena. The use of thermal camera to detect radiation can precisely monitor even minute based temperature changes. The data acquired through scanning are processed by computer and shown as temperature maps for a comprehensive temperature-field assessment (Knizkova et al., 2007).

Infrared inspection is a powerful and non-destructive way to monitor and diagnose building conditions. Using infrared thermography, we can detect heat loss/gain, air leakages, missing or damaged thermal insulation in walls and roofs, moisture accumulation in building materials, and many other applications directly related to the building envelope (Balaras and Argiriou, 2002; Kylili et al., 2014; Ljungberg, 1994). Infrared thermographic method has been performed by different authors in civil engineering applications (Baldinelli et al., 2018; Grinzato et al., 1998; Lo and Choi, 2004; Lucchi, 2018; Plesu et al., 2012; Snell et al., 2002; Wiggenhauser, 2002); however, there is no comprehensive study for monitoring thermal conditions in a poultry barn.

Poultry buildings are designed to meet specific requirements for birds during different growth stages. The ideal indoor environmental requirements of birds are highly important in the design and planning of poultry barns. Environmental conditions within poultry buildings have a major impact on the productivity of the poultry farm. If the ideal environment is not provided during the brooding time, profitability will decline because of slow growth, decreased feeding intake, poor conversion of feed, and enhanced rates of mortality (Daghir, 2008). Therefore, it is crucial that a poultry barn provides an ideal indoor environment for birds (Küçüktopcu and Cemek, 2018). The ideal inside temperature of broiler building should be 32-33 °C in 1-2 weeks and 21-24 °C in 3-7 weeks (Lindley and Whitaker, 1996; Reece and Lott, 1982).

In poultry buildings heating and cooling costs are among the highest expenditures for producers. Therefore, determination of heat loss and gains is a vital importance in poultry production.

Based on above mentioned, this study aimed to use thermal camera to capture thermal images of a poultry barn for different rearing seasons and, to determine the heat loss and gains through structural members.

2. Theoretical Background

2.1 Thermal imaging: theory and measurement

Particles of matter are random motion, which produces internal energy known as "thermal energy". The average thermal energy of the particles in an object is measured by its temperature. The transfer of thermal energy from one system to another in a process simply referred to as "heat". There are three different ways for heat transfer including convection, conduction and radiation. Radiation is the transfer of energy through electromagnetic waves (Brewster, 1992; Howell et al., 2015). Infrared is a part of the electromagnetic spectrum that covers from the long wavelength, or red, end of the visible-light range to the microwave range. Infrared wavelengths ranged between 700 nm and 1 mm, is particularly related to thermal imaging, since objects close to room temperature emit most of their thermal radiation in this range (Haynes, 2014). The function of a thermographic camera is to remotely detect infrared radiation, convert it to an electronic signal, and then create an image representing the radiation intensity. Although heat is transferred through conduction, convection and radiation, thermal cameras are only capable of directly measuring radiated heat (Miller, 2012). However, this does not mean that conductive heat loss or air currents cannot be located. Conduction and convection change the temperature of a building's elements, which in turn effects the level of heat that they radiate. Unusual thermal radiation concentrations can therefore be indications of problematic regions. These devices can also detect the accumulation of moisture in building materials (Barreira and Almeida, 2019; Barreira et al., 2016; Grinzato et al., 2002; Lerma et al., 2011). Thermal cameras cannot directly measure water content; however, its existence can often be inferred from thermal images. Evaporating water cools moist surfaces so that thermal cameras locate moisture which would be unseen to the naked eye. Condensation takes place in cool and moist areas of a structure. By locating regions below dew point temperatures, inspectors can find regions that are at risk of moisture accumulation.

A thermal camera generates a gray or colored pixel picture that represents different temperatures. Most systems offer a choice of color palette. Some palettes only are for appropriate display and printing of colors, while proportional intensity palettes may be used for greyscale and color printing. The selection of thermal camera depends on measurement requirements. The main options are whether the investigator wants to measure the temperature or just detect the difference from hot to cold areas, what temperature and spatial resolution is necessary, how long distance the measurement is , and whether the researcher interested in recording still or moving images. For further evaluation, it is suggested that visual pictures and heat pictures are recorded together. Image analysis can be utilized by appropriate

software to obtain summary statistics from various areas of image. Statistical information (e.g. mean, minimum, maximum) can be quickly collected by using appropriate polygons from regions of concern in the image (Vollmer and Möllmann, 2017).

3. Materials and Methods

3.1 Description of poultry building

Thermal measurements were conducted at a commercial broiler barn located in Samsun, Turkey. In terms of basic geometric dimensions building had a length of 90 m, width of 14 m, sidewall height of 2.40 m and a maximum height of 3.80 m (Figure 1). Sawdust is used as a litter material. Feeding, watering, lighting, heating and ventilation are controlled automatically. The barn has a negative forced-air ventilation system, comprising five side-wall fans (diameter 0.92 m) and eleven frontal fans (diameter 1.38 m). Also, 66 air inlets measuring 0.40×0.60 m are situated along the building's side walls. The walls and roof made of sandwich panels with expanded polystyrene insulation material.

3.2 Thermal image measurements

A thermal survey was undertaken in different seasons of production. The internal and external temperatures of these measurement periods are given in Table 1. Thermal measurements were conducted by using a non-contact infrared technology of the thermal camera (Testo 875-2i, Testo AG, Lenzkirch, Germany).

Table 1. The seasons of thermal image measurements
Çizelge 1. Termal ölçümlerin dönemleri

Seasons	Dates	Internal temperature (°C)	Outdoor temperature (°C)
Winter	23.02.2018	25.50	7.50
Spring	22.03.2019	28.60	5.60
Summer	24.07.2019	30.80	27.70
Autumn	01.10.2019	27.30	26.40

4. Results and Discussion

Thermal imaging technique can be utilized to detect heat losses or gains through the building envelopes. The resulting accurate and comprehensive information can reveal the location of a problem, thereby avoiding extensive and costly maintenance operations (Balaras and Argiriou, 2002). To determine the location of problematic areas of a poultry barn, thermal camera images acquired in different rearing seasons were used. Some problems including insulation defects, thermal bridges, air leakage around openings, and cracks in sandwich panels were detected.

Insulation minimizes winter heat losses and summer heat gains and thus, it reduces heating and cooling costs (Barreira et al., 2013). Cold and hot surfaces have a direct negative impact on birds' thermal comfort and despite that the air temperature is at the appropriate levels it will cause thermal discomfort. Temperature distributions of inside the poultry barn for winter season are presented in Figure 2. As seen in the figure, the door frames are particularly not insulated appropriately, resulting in a temperature difference of about 9 °C between the internal and external surface.

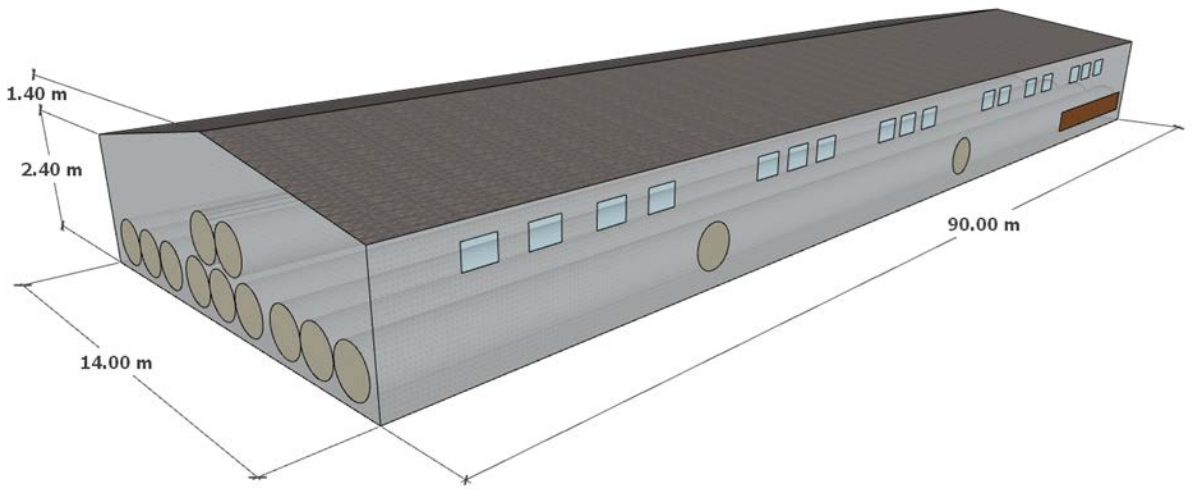

Figure 1. The dimensions of poultry barn
Şekil 1. Kümesin boyutları

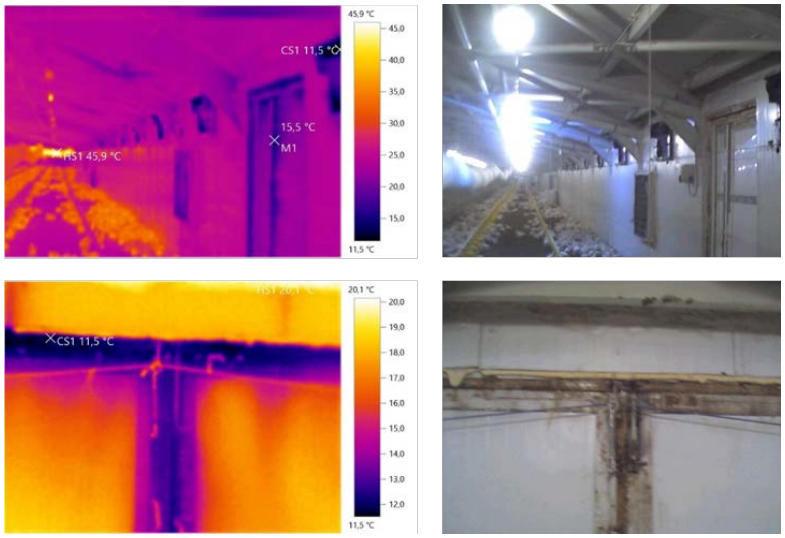

Figure 2. Thermal images of winter season
Şekil 2. Kış dönemi termal görüntüler

Air inlets and outlets play an important role in adjusting environmental conditions in a poultry barn. Air leaking from around the inlet and/or outlet can further increase heating or cooling costs. Visualizing leakage pathway could be extremely difficult without thermal imaging. During the heating season, the resulting areas of air infiltration tend to appear cooler. In Figure 3, the dark blue color around the air inlet indicates cold air entering the building, resulting in inappropriate thermal conditions within the barn. In addition, the insulation on the evaporative cooling pad covers on the side wall is insufficient.

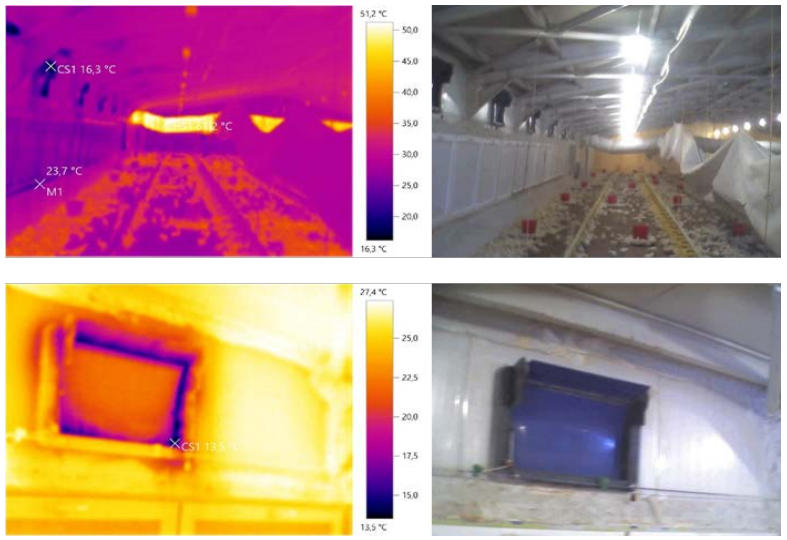

Figure 3. Thermal images of spring season
Şekil 3. İlkbahar dönemi termal görüntüler

In winter, cold air drafts near the openings may be the main cause of thermal discomfort for the birds. It is clearly seen Figure 4, too much cool air is coming from bottom of door, which contributes to moisture problems in litter. Litter conditions significantly influence broiler performance and, ultimately, the profits of producers. The quality of indoor environment depends on litter quality. Excessive moisture in the litter is also one of the main reason of ammonia emissions, which may affect production (Ritz et al., 2009).

In warmer areas, producers sometimes feel insulation to be unnecessary and uneconomical. However, Figure 5 confirms that how important the insulation is to provide ideal indoor environmental conditions. As can be seen in the figure, warm air entering the building from the door frame, causing higher building temperatures and consequently lower broiler performance.

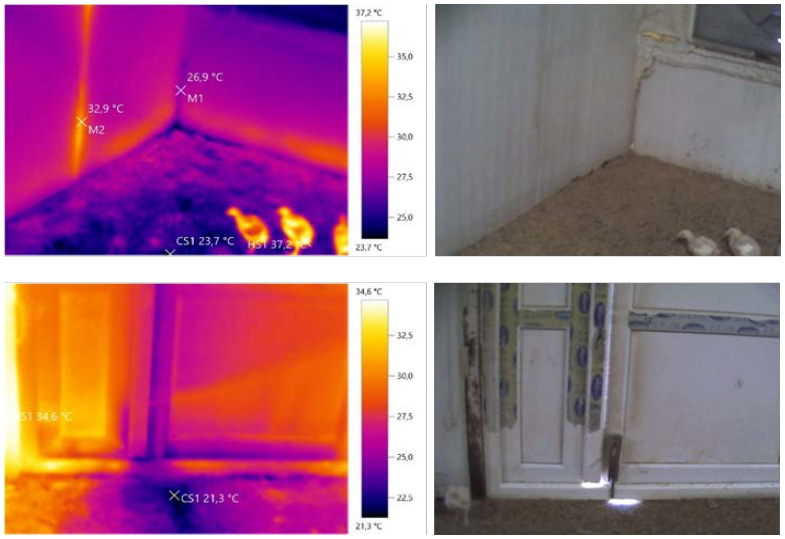

Figure 4. Thermal images of autumn season
Şekil 4. Sonbahar dönemi termal görüntüler

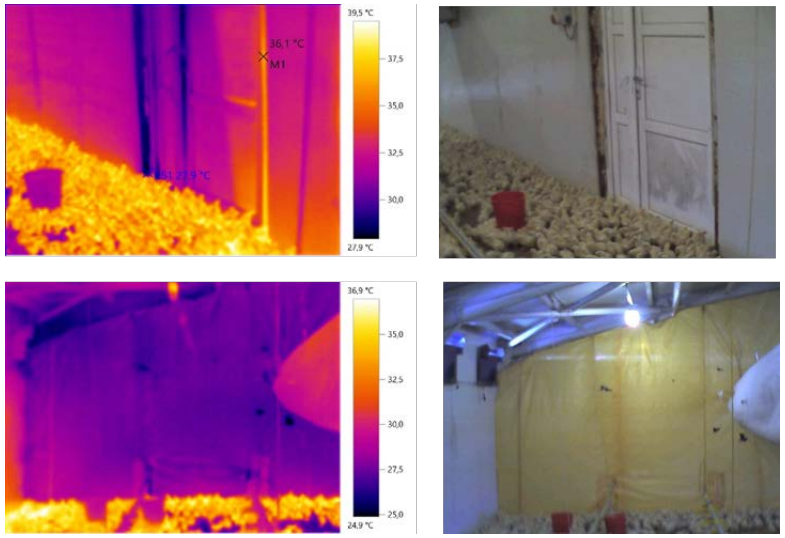

Figure 5. Thermal images of summer season
Şekil 5. Yaz dönemi termal görüntüler

5. Conclusions

Infrared thermography as a non-destructive method has the main purpose to offer information by analyzing the real features of the existing buildings in order to identify surface anomalies (cracks, insulation defects, air leakage etc.). The high variations of temperature on the thermal images often indicates structural changes or problems, insufficient insulation, air leakage, cracks, heat losses or gains.

In this study, a thermal camera was used to capture thermal images of a poultry barn during different rearing seasons and the heat loss or gains due to structural problems were identified. The findings show that thermal image may indicate a problem within building elements that could not be seen with the naked eye, and also particularly useful for investigating thermal bridging, air leakage and cracks, as these will cause temperature variations that are visible when viewed with a thermal camera. Making local repairs and applying insulation materials in location of problematic areas will prevent energy losses and cause suitable indoor environment for birds.

Acknowledgements

This project was supported by the Ondokuz Mayıs University Scientific Research Projects Department (PYO.ZRT.1901.18.018). The authors would also like to thank the help and contributions of Prof. Dr. Mehmet KURAN.

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