Effect of ambient temperature on growth performances, carcass traits and meat quality of pigs

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ABSTRACT

Pigs are sensitive to high environmental temperature due to difficulties in eliminating excess body heat. The present study was undertaken to evaluate the effects of ambient temperature on growth performances, carcass traits and meat quality of pigs. This trial was carried out at the Experimental Center of Livestock at Sunchon National University, South Korea. A total of 40 three-way crossbred pigs (initial body weight 38.50 ± 0.55 kg) were assigned into four groups: group 1 (12°C to 19°C), group 2 (19°C to 25°C), group 3 (25°C to 31°C) and group 4 (31°C to 37°C). Pigs were offered ad libitum diet and free access to drinking water. Weight gain and feed intake were significantly enhanced in groups 1 and 2, respectively. The lowest weight gain, feed intake, back-fat thickness and cholesterol content was observed in group 4 (P < 0.05). Temperature variation exerted no significant effect on TBARS, pH during the storage period and water holding capacity, shear force and meat colour. The total microbial content was significantly enhanced in group 1 compared to other groups (P < 0.05). We therefore conclude that pigs respond differently to environmental temperature variations, with respect to growth performances, carcass traits and meat quality.

Introduction

Thermal environment has a significant negative impact on animal production and performance in the global livestock sector (Baumgard et al. 2012). Myer and Bucklin (2001) reported that the optimum temperature for growing-finishing pigs ranged between 10°C and 23.9°C, with a gradual decrease in voluntary feed intake at temperatures above 23.9°C (Kouba et al. 1999). Pig production losses occur when animals are exposed to elevated temperature for a significant duration and intensity (Lucas et al. 2000). Owing to inefficient thermoregulation, pigs are reported to be more sensitive to hot environmental conditions (Nardone et al. 2010).

According to Fagundes et al. (2009), imbalanced temperature and humidity levels impair the metabolic activities and final carcass quality. Pigs develop paler meat when reared under alternating high and low temperature levels, as compared with a constant temperature (Gregory 2010). The prevalence of pale-soft exudative (PSE) meat was significantly lower with higher pH values observed during summer, as compared with autumn or spring (Van de Perre et al. 2010). However, Guàrdia et al. (2004) stated that the occurrence of PSE meat during summer season is expected to be high owing to temperature fluctuations, thereby resulting in stress, higher post-mortem muscle temperature and impaired meat quality.

Higher pH value and low moisture losses in meat were observed in large white pigs reared under tropical climatic conditions (Nardone et al. 2010). Pigs exposed to 12°C showed lower moisture loss in the semispinalis muscle, as compared with animals reared at 28°C (Lefaucheur et al. 1991). A significant decline of back-fat percentage and increment of leaf fat was also reported when pigs were exposed to warm season (Rinaldo et al. 2000). According to Rinaldo and Mourot (2001), as compared with temperate climatic conditions, tropical climatic conditions increase the incidence of higher pH in both the longissimus dorsi and biceps dorsi muscles.

Considering the above literature, this study was undertaken to evaluate the impact of ambient temperature variation on growth performances, carcass traits and meat quality characteristics of pigs.

Materials and methods

Animals and experimental design

The experimental procedures involving the management and care of animals were reviewed and approved by the Animal Care and Use Committee at the Sunchon National University. A total of 40 crossbred (Duroc × Landrace × Yorkshire) barrow pigs with a mean weight of 38.50 ± 0.55 kg were randomly allocated to four treatment groups (T1, T2, T3 and T4) consisting of 10 pigs per treatment. The four temperature ranges evaluated for each treatment were 12°C to 19°C, 19°C to 25°C, 25°C to 31°C and 31°C to 37°C, respectively. Dunging space and feeding-
Table 1. Ingredient composition and nutrient content of diets (%).

| Ingredients               | Piglet | Growing | Finishing |
|---------------------------|--------|---------|-----------|
| Yellow corn               | 47.80  | 51.36   | 55.00     |
| Rice bran                 | 14.00  | 7.00    | 8.00      |
| Rapeseed oil meal         | –      | 1.72    | 3.00      |
| DDGS                      | –      | 6.00    | 6.00      |
| Soybean meal              | 22.10  | 21.80   | 18.16     |
| Limestone                 | 0.70   | 0.84    | 1.00      |
| Calcium phosphate         | 0.70   | 0.10    | 0.20      |
| Salt                      | 0.15   | 0.30    | 0.30      |
| Vitamin Premixa           | 0.50   | 0.45    | 0.20      |
| Animal fat                | 7.0    | 6.78    | 4.76      |
| Molasses                  | 2.00   | 2.50    | 2.50      |
| Amino acid additive       | 5.05   | 1.15    | 0.88      |
| Sum                       | 100.00 | 100.00  | 100.00    |

| Chemical composition     |        |         |           |
|---------------------------|--------|---------|-----------|
| ME (kcal/kg)              | 3350.00| 3265.00 | 3265.00   |
| Crude protein (%)         | 19.00  | 18.00   | 17.00     |
| Ca (%)                    | 0.70   | 0.80    | 0.80      |
| Available, P (%)          | 0.44   | 0.34    | 0.34      |
| Lysine (%)                | 1.35   | 1.20    | 1.10      |
| Methionine (%)            | 0.53   | 0.37    | 0.31      |

| Vitamin. Premix provided following nutrients per kg of premix: |        |         |           |
| vitamin A, 6000IU; vitamin D₃, 800IU; vitamin E, 20IU; |        |         |           |
| vitamin K₃, 2 mg; thiamin, 2 mg; riboflavin, 4 mg; |        |         |           |
| vitamin B₆, 2 mg; vitamin B₁₂, 1 mg; pantothenic |        |         |           |
| acid, 11 mg; niacin, 10 mg; biotin, 0.02 mg; Cu |        |         |           |
| (copper sulfate), 21 mg; Fe (ferrous sulfate), |        |         |           |
| 100 mg; Mn (manganese sul fate), 90 mg; I |        |         |           |
| (calcium iodate), 1.0 mg; Co (cobalt nitrate), 0.3 mg; |        |         |           |
| Se (sodium selenite), 0.3 mg. |        |         |           |

**Carass traits**

At the end of the experimental period, all pigs were transferred to an abattoir and slaughtered by exsanguination after being electrically stunned. The meat grade was determined by applying the Korea Institute for Animal Products Quality Evaluation (KAPE 2010) method. Based on the lean colour and marbling of meat, the meat quality was graded as A grade = 3, B grade = 2, C grade = 1 and non-descript = 0. Back fat thickness was measured using the A-mode ultrasound, (Lean-Meat, Renco Corporation, Minneapolis, MN).

For evaluating meat quality traits, meat sirloin was obtained from the pig carcasses. At approximately 24 h post-mortem, meat samples were vacuum packed and stored at 4°C.

**Chemical composition and cholesterol analysis**

The crude protein (CP), crude fat (CF), moisture and crude ash contents of sirloin samples were analyzed according to the method described by AOAC (2012).

Analysis of cholesterol content in meat (fillet) of the sample was carried out according to the method proposed by King et al. (1998). Briefly, for homogenizing 5a-cholesterol, 5 mL of 50% KOH (aq) and 22 mL of ethanol were added to the 1 g of ground meat; the sample was saponified at 23°C for 6 h and repeatedly extracted and analyzed by gas chromatography (Agilent, 7890B series, USA).

**Thiobarbituric acid reactive substances (TBARS), microbial count and pH value**

After preservation of meat samples at 4°C, the TBARS values of meat samples were determined at 0, 1, 2 and 3 weeks after storage, using the method described by Ahmed et al. (2015). Briefly, 4 g of meat were homogenized using a homogenizer (Ultra-Turrax T-25 Basic, IKA Werke, GMBH & CO. KG, Stefan, Germany) at full speed for 1.5 min, with 10 mL of solution containing 20% trichloroacetic acid in 2 M phosphoric acid and 10 mL distilled water. The homogenate was then filtered through Hyundai Micro No. 60 (Hyundai Micro Co., Ltd.) filter paper. Equal amounts (2 mL) of the filtrate and 2-thiobarbituric acid (98% 4, 6 dihydroxy-2- mercaptopurinimidine, 0.005 M in DW) were heated in a shaking water bath at 80°C for 30 min. After cooling, the absorbance was measured at 530 nm using a VIS-spectrophotometer (Libra S22, Biochrom Ltd. Cambridge, England). The amount of TBARS is expressed as micromoles of malondialdehyde (MDA) per 100 g meat.

For assessing the total microbial count, 1 g of sample was taken from the torso of each test shaft, diluted stepwise with sterile physiological saline to 10⁶ and inoculated onto TSA (trypetase soy agar). Colony counts were determined after incubation at 35°C for 24-48 h.

Analytical samples were collected from the sirloin area, and pH was measured as follows: 2 g of the sample was mixed with 18 mL of distilled water and homogenized at 15,000 rpm for 30 s using a homogenizer (Polytron PT 10–35 GT, Kinematica, Switzerland); the pH of each sample filtrate was subsequently measured using a pH meter (Orion 2 star, Thermo Scientific, Beverly, MA, USA).

**Water holding capacity, shearing force and meat colour**

To assess water-holding capacity, 5 g of the sample was centrifuged at 5°C for 10 min at 1000 rpm using a centrifuge (Combi 514-R, HANIL, Korea), and subsequent weight of the meat was measured. For measuring shear force value, each meat sample (cooked meat sample) was prepared in cubic form (40 × 50 × 10 mm) and subsequently cut perpendicular to the longitudinal orientation of the muscle fibre using a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2, Stable Micro System Ltd., Surrey, U.K.). The maximum shear force value (kgf) was recorded for each sample. Test and pre-test speeds were set at 2.0 mm/sec, and post-test speeds were set at 5.0 mm/sec.

The lightness (L*), redness (a*) and yellowness (b*) of the cut meat samples were measured by using a Minolta colorimeter (CR-410, Minolta Co. Ltd., Japan). The standard average of the values was obtained by repeating the experiment 3 times: L* value 89.2, a* value 0.921 and b* value 0.783.

**Statistical analysis**

Statistical analysis of the data obtained was analyzed by applying the SAS Statistical Package Program (SAS®9.4 Package/PC). Significance of the mean value of the treatment interval was evaluated by Duncan’s multiple test method.
Table 2. Effect of pig house inside temperature on growth performances.

| Treatment | Setting temp. (°C) | T1 | T2 | T3 | T4 | SEM | p-value |
|-----------|-------------------|----|----|----|----|-----|--------|
| 0–2 weeks |                   |    |    |    |    |     |        |
| Initial weight (kg) | 38.50 | 38.50 | 38.50 | 38.50 | 0.55 | 1.0000 |
| Final weight (kg) | 52.70a | 54.65ab | 55.60a | 51.95b | 1.09 | 0.0932 |
| Weight gain (kg) | 14.20b | 16.15ab | 17.10a | 13.45b | 0.91 | 0.0292 |
| Feed intake (kg) | 30.81 | 31.05 | 32.08 | 29.92 | 1.69 | 0.8857 |
| FCR (feed/gain) | 2.17 | 1.92 | 1.89 | 2.22 | 0.11 | 0.0859 |
| 2–6 weeks |                   |    |    |    |    |     |        |
| Initial weight (kg) | 52.70ab | 54.65ab | 55.60a | 51.95b | 1.09 | 0.0932 |
| Final weight (kg) | 83.60a | 82.60a | 81.75a | 75.95b | 1.58 | 0.0079 |
| Weight gain (kg) | 30.90a | 27.95b | 26.15ab | 24.00c | 0.89 | <0.0001 |
| Feed intake (kg) | 71.37a | 64.13a | 67.23a | 55.07b | 2.88 | 0.0032 |
| FCR (feed/gain) | 2.32 | 2.29 | 2.57 | 2.29 | 0.10 | 0.1976 |
| 6 to 10 weeks |                   |    |    |    |    |     |        |
| Initial weight (kg) | 83.60a | 82.60a | 81.75a | 75.95b | 1.58 | 0.0079 |
| Final weight (kg) | 115.75a | 113.85a | 106.35b | 97.20c | 2.19 | <0.0001 |
| Weight gain (kg) | 32.15a | 31.25a | 24.60b | 21.25c | 1.08 | <0.0001 |
| Feed intake (kg) | 95.14a | 86.99ab | 79.62c | 67.94c | 4.15 | 0.0005 |
| FCR (feed/gain) | 2.96 | 2.78 | 3.24 | 3.20 | 0.14 | 0.1280 |
| 0–10 weeks |                   |    |    |    |    |     |        |
| Initial weight (kg) | 38.50 | 38.50 | 38.50 | 38.50 | 0.55 | 1.0000 |
| Final weight (kg) | 115.75a | 113.85a | 106.35b | 97.20c | 2.19 | <0.0001 |
| Weight gain (kg) | 77.25a | 75.35a | 67.85b | 58.70c | 1.98 | <0.0001 |
| Feed intake (kg) | 197.32a | 182.17a | 178.93a | 152.93b | 7.45 | 0.0022 |
| FCR (feed/gain) | 2.32 | 2.29 | 2.57 | 2.29 | 0.10 | 0.1976 |

FCR = feed conversion ratio.

*Means with different superscripts differ significantly.

Results and discussion

Growth performances

Growth performance of animals with respect to various temperature are presented in Table 2. These results indicate lower weight gain (P < 0.05) during the first two weeks in T4 treatment, with decreased feed intake, although not significantly different. Moreover, at the end of 10th week, T4 treatment showed lowest weight gain and feed intake as compared with other treatment groups. The weight gain in T1 and T2, and feed intake in T1, T2 and T3 treatments, were markedly enhanced as compared with T4 treatment (P < 0.05).

In this study, temperature ranges between 12°C to 19°C and 19°C to 25°C showed highest weight gain, whereas poorer weight gain and feed intake was determined in the temperature range 29°C to 33°C. According to Le Bellego et al. (2002), the reduction of feed intake is a mechanism to minimize the amount of heat production from various metabolic and digestive activities. As a pig becomes heavier, the susceptibility to stress gradually decreases. Oliveira et al. (2018) reported that temperatures around 34°C are able to reduce the average daily gain and average daily feed intake of growing-finish pigs. Despite varying temperature ranges, we observed no significant difference in the FCR in all four treatment groups.

Table 3 shows the proximate composition and cholesterol content in T4 treatment. The results reveal higher CF content and cholesterol value of sirloin.

Carcass traits

The effect of temperature on carcass weight, back-fat thickness and carcass grade are presented in Table 3. Carcass yield and back-fat thickness were higher in T1 treatment than other treatments (P < 0.05). As expected, the lower carcass yield and back-fat thickness in T4 treatment was significantly influenced by higher temperatures. The high environmental temperature stimulates heat stress in pigs due to their poor thermoregulation process. Moreover, T1 treatment resulted in numerically higher carcass grade but was not significant.

Table 4 shows the proximate composition and cholesterol content of meat. The results reveal higher CF and crude ash content in T2 treatment (P < 0.05). Furthermore, CP content

Table 4. Effect of pig house inside temperature on the proximate composition and cholesterol value of sirloin.

| Treatment | T1 | T2 | T3 | T4 | SEM | p-value |
|-----------|----|----|----|----|-----|--------|
| Carcass weight (kg) | 92.20a | 89.50ab | 86.00b | 79.70c | 1.69 | <0.0001 |
| Back-fat thickness (mm) | 22.30a | 21.30ab | 17.30b | 15.90b | 1.94 | 0.0803 |
| Meat point | 2.10 | 1.70 | 1.90 | 1.40 | 0.26 | 0.2826 |

*Means with different superscripts differ significantly.
was also increased in T2 treatment but was not significant. A significantly lower (P < 0.05) cholesterol level was observed in T4 treatment and highest cholesterol level in T2 treatment. Carcass weight, fat firmness, weight of the cuts and amount of fat deposited are significant factors that determine the carcass quality. The belly, ham and loin parts of the carcass contribute to the maximum economy. Thus, good quality of these components is essential to get high economic benefits (Marcoux et al. 2007).

According to Fernandez et al. (1999), the intramuscular fat content in pork enhances the juiciness, tenderness and flavour. Similar to our results, Lefaucheur et al. (1991) had earlier reported that pigs housed at lower temperature (12°C) exhibit increased ham fat content than pigs exposed to elevated temperature (28°C); the lean:fat ratio was reduced when the animals were reared under lower environmental temperature. Similarly, in the present study, both T1 and T2 treatments had the highest final body weight and carcass yield at termination of the experiment. Decreased metabolic activities in T4 treatment resulted in lower weight gain, and consequently reduced carcass yield.

Pigs slaughtered during winter had the highest slaughter weight and back-fat thickness, whereas summers saw lower slaughter weight, lower hot carcass weight and depleted cold carcass weight. This could be owed to the tendency of increased voluntary feed intake in winter caused higher live weight and thicker back-fat (Čobanović et al. 2016). Rinaldo and Mourot (2001) also reported reduced back-fat thickness in pigs reared in tropical climate than in a controlled environment (20°C). When evaluating carcass grade, marbling is the most important trait for determining meat quality. Since consumer’s appraisal is most important in the meat industry, marbling pork has higher palatability among consumers (Brewer et al. 2001).

Cholesterol acts as a biologically important compound; however, oxidation of compounds is known to contribute to mutagenic, carcinogenic and cytotoxic effects (Ryan et al. 2005). Migdal et al. (1999) and Jacyno et al. (2002) reported that the cholesterol content in fresh musculus longissimus tissue of pig ranges from 58 to 73 mg/100 g. The cholesterol content in meat is determined by breed, age and diet of the animal. Moreover, Chizzolini et al. (1999) found clear dissimilarities in the cholesterol content among certain muscles part, such as m. longissimus dorsi (45.3 mg/100 g), m. semimembranosus (49.9 mg/100 g) and m. biceps femoris (48.6 mg/100 g).

**Thiobarbituric acid reactive substances, microbial count and pH of meat**

Table 5 shows the TBARS values of meat analyzed at 0, 1st, 2nd and 3rd weeks of storage. The TBARS value was initially higher in T4 treatment (0.08 MDA µmol/100 g) and lower in the T2 and T3 treatments. However, at the end of the 3rd week, the average TBARS values were not significantly different among all four treatments, although numerically lower values were obtained in T2 treatment.

Data on microbial count in all four treatments over the three weeks of storage period are presented in Table 6. Pigs exposed to temperature range 20°C to 24°C had a lower microbial count until end of the 2nd week as compared to other treatments, but not significantly different. Considering the average microbial count, T3 treatment had lowest count (P < 0.05), whereas T1 treatment had the highest microbial count (P < 0.05).

The effects of temperature on pH values of meat are presented in Table 7. No significant difference was initially observed between the treatment groups. Moreover, the ultimate average pH value was also not significantly different among treatments. The shelf life of meat is determined by the oxidation of lipid and protein compounds. TBARS evaluation determines the level of thiobarbituric acid reactive substances and is an indicator of the lipid peroxidation process. TBARS is the most important method used to quantify malonaldehyde (MDA). Various studies have found that values between 2 and 2.5 mg/MDA/kg do not impart any rancidity to meat and meat products (Campo et al. 2006; Zhang et al. 2019). Owing to the various nutrient compounds, fresh pork is a good medium for microbes, resulting in quality deterioration, as well as production of numerous health hazards (Raeisi et al. 2016). According to the Ministry of Food and Drug Safety in Korea, the recommended aerobic plate count (APC) of distributed meat is <1 × 10⁷ CFU/g. Some studies have further confirmed that the above value is the beginning of spoilage. Pork loin APC increased with the storage period and was determined to be 7.45 log CFU/cm² on day 13, which exceeds the recommended microbiological guidelines set up in Korea (Kim and Jang 2018). Lee et al. (2004) reported that the initial APC value of pork loin (5.50 log CFU/cm²) remains constant until the 7th day of storage but increased to 7.79 log CFU/cm² on the 14th day, which is similar to our results. Furthermore, all treatments in the current study showed increased microbial counts at the end of day 14.

The muscle pH of living pigs is between 7.0 and 7.2. During meat processing, lactic acid accumulation occurs in the muscle tissues due to incomplete oxidation (Pearce et al. 2011). According to Klont et al. (1999), the initial pH of fresh pork ranges between 5.4 and 5.8. Microbial spoilage in meat is also enhanced by elevated pH values (Borch et al. 1996), due to the formation of various peptides, amino acids and ammonia compounds which are related to proteolytic activities (Demeyer et al. 1979). However, previous researches on the

### Table 5. Effect of pig house inside temperature on the oxidative stability (TBARS) of sirloin (MDA µmol/100 g).

| Treatment | T1     | T2     | T3     | T4     | SEM    | p-value |
|-----------|--------|--------|--------|--------|--------|---------|
| 0 weeks   | 0.04<sup>a,b</sup> | 0.03<sup>b</sup> | 0.02<sup>b</sup> | 0.08<sup>a</sup> | 0.01    | 0.0647  |
| 1 weeks   | 0.09<sup>ab</sup>  | 0.09<sup>b</sup>  | 0.13<sup>a</sup>  | 0.09<sup>b</sup>  | 0.01    | 0.0333  |
| 2 weeks   | 0.29   | 0.21   | 0.27   | 0.30   | 0.08    | 0.8894  |
| 3 weeks   | 0.41   | 0.29   | 0.28   | 0.37   | 0.05    | 0.3632  |
| Average   | 0.21   | 0.15   | 0.18   | 0.21   | 0.02    | 0.4074  |

<sup>a,b</sup>Means with different superscripts differ significantly.

### Table 6. Effect of pig house inside temperature on total microbial count of sirloin (log<sub>10</sub> cfu/g).

| Treatment | T1     | T2     | T3     | T4     | SEM    | p-value |
|-----------|--------|--------|--------|--------|--------|---------|
| 0 weeks   | 1.56   | 1.38   | 1.66   | 1.67   | 0.17   | 0.6546  |
| 1 weeks   | 5.89   | 5.62   | 5.77   | 5.79   | 0.20   | 0.8314  |
| 2 weeks   | 6.31   | 5.75   | 5.85   | 5.99   | 0.22   | 0.4514  |
| 3 weeks   | 6.69<sup>a</sup> | 6.26<sup>b</sup> | 6.00<sup>b</sup> | 6.26<sup>a</sup> | 0.17   | 0.0813  |
| Average   | 6.32<sup>a</sup> | 5.96<sup>b</sup> | 5.83<sup>b</sup> | 6.08<sup>a</sup> | 0.13   | 0.0980  |

<sup>a,b</sup>Means with different superscripts differ significantly.
effect of ambient temperature on pH are somewhat controversial. Mota-Rojas et al. (2006) reported lower pH values in longissimus dorsi and biceps femoris muscles during the hot season as compared with cool season. This finding is consistent with the present data, which indicates reduction of pH at elevated temperatures. Lefaucheur et al. (1991) have reported higher pH of longissimus dorsi muscle at an ambient temperature of 28°C, as compared with 12°C.

**Water holding capacity, shearing force and meat colour**

As shown in Table 8, no significant differences were observed in WHC, shear force and meat colour among all four treatments (P > 0.05). The numerically highest WHC, lowest shear force and enhanced meat colour was observed in T2 treatment.

The water content in meat products is considered as one of the important quality parameters that relates to the ultimate yield (Bertram et al. 2003; Rosenvold and Andersen 2003). The moisture content in muscle is entrapped within the muscle structures and various muscle cells (Offer and Cousins 1992). It is well known that excessive drip loss is unacceptable and leads to poor water holding capacity (WHC). Lehotayová et al. (2012) reported that pigs reared under higher temperature conditions exhibited higher drip loss in the musculus semimembranosus muscle and musculus longissimus thoracis muscle. Furthermore, they also reported numerically higher, though not significant, shear force value at elevated temperature. The lower shear force during aging of beef extended muscles was lower than when aged at the elevated temperature (Bruce and Ball 1990).

Pigs reared under alternating high and low temperatures possessed paler meat as compared with pigs housed at constant 18°C or 29°C with 30% relative humidity. This occurs due to less myoglobin content in muscle fibres when the animal is exposed to alternating temperatures and moderate humidity levels (Gregory 2010). According to Guàrdia et al. (2005) and Santos et al. (1997), temperature fluctuations and elevated temperature in summer impairs the thermoregulation process of the animal, thereby resulting in stress and inferior meat quality. Higher light reflectance value in the longissimus and semi membranous muscle has been reported in animals during summer, as compared with winter season (Dalla Costa et al. 2007). Nevertheless, in our study, we found no significant difference among the four treatments.

**Conclusions**

Environmental temperature influences the growth performances, carcass characteristic and meat quality of pigs. High ambient temperature adversely affects growth performances and carcass characteristics. Consequently, there is diminishment in the ultimate meat quality parameters. Considering the results obtained, we conclude that the temperature range from 12°C to 19°C imparts optimum growth performances, carcass traits parameters.

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**Disclosure statement**

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**References**

Ahmed ST, Islam MM, Bostami ABMR, Mun HS, Kim YJ, Yang CJ. 2015. Meat composition, fatty acid profile and oxidative stability of meat from broilers supplemented with pomegranate (Punica granatum L) by-products. Food Chem. 188:481–488.

AOAC [Association of Official Analytical Chemists]. 2012. Official methods of analysis. 19th ed. Gaithersburg (MD): AOAC.

Baumgard LH, Rhodos RP, Rhodos ML, Gabler NK, Ross JW, Keating AF, Boddicker RL, Lenka S, Seijan V. 2012. Impact of climate change on livestock production. In: Seijan V, Naqvi SMK, Ezeji T, Lakritz J, Lal R, editors. Environmental stress and amelioration in livestock production. Berlin: Springer; p. 413–468.

Bertram HC, Andersen HJ, Karlsson AH, Horn P, Hedegaard J, Nørgaard L, Engelsen SB. 2003. Prediction of technological quality (cooking loss and napole yield) of pork based on fresh meat characteristics. Meat Sci. 65:707–712.

Borch E, Kant-Muermans ML, Blixt Y. 1996. Bacterial spoilage of meat and cured meat products. Int J Food Microbiol. 33:103–120.

| Table 7. Effect of pig house inside temperature on pH of sirloin. |
|---|
| Treatment | T1 | T2 | T3 | T4 | SEM | p-value |
| 0 weeks | 6.08 | 5.88 | 5.92 | 5.88 | 0.08 | 0.3308 |
| 1 weeks | 6.06a | 5.79b | 5.80b | 5.75b | 0.07 | 0.0696 |
| 2 weeks | 5.92 | 5.77 | 5.70 | 5.82 | 0.10 | 0.5651 |
| 3 weeks | 6.27 | 5.95 | 5.85 | 5.90 | 0.17 | 0.3610 |
| Average | 6.08 | 5.85 | 5.82 | 5.84 | 0.10 | 0.3239 |

Table 8. Effect of pig house inside temperature on the meat quality parameters.

| Treatment | T1 | T2 | T3 | T4 | SEM | p-value |
|---|---|---|---|---|---|---|
| WHC (%) | 80.33 | 80.93 | 75.93 | 81.60 | 1.79 | 0.3302 |
| Shear force (kg) | 3.85 | 2.49 | 3.77 | 2.65 | 0.48 | 0.3150 |
| Meat colour | | | | | | |
| L* | 45.39 | 46.83 | 45.09 | 42.66 | 1.15 | 0.2078 |
| a* | 14.20 | 13.86 | 14.50 | 14.63 | 0.78 | 0.4831 |
| b* | 5.68 | 5.81 | 5.79 | 4.79 | 0.63 | 0.6505 |
Brewer MS, Zhu LG, McKeith FK. 2001. Marbling effects on quality characteristics of pork loin chops: consumer purchase intent, visual and sensory characteristics. Meat Sci. 59:153–163.

Bruce HL, Ball RO. 1990. Postmortem interaction of muscle temperature, pH and extension on beef quality. J Anim Sci. 68:4167–4175.

Campos MM, Nute GR, Hughes SI, Enser M, Wood JD, Richardson RI. 2006. Flavour perception of oxidation in beef. Meat Sci. 72:303–311.

Chizzolini R, Zanardi E, Dorigoni V, Ghidini S. 1999. Caloric value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci Technol. 10:119–128.

Čobanović N, Bošković M, Vasilev D, Dimitrijević M, Parunović N, Djordjević J, Karabasil N. 2016. Effects of various pre-slaughter conditions on pork carcases and meat quality in a low-input slaughter facility. S Afr J Anim Sci. 46:380–390.

Collin A, van Milgen J, Le Dividich J. 2001. Modelling the effect of high, constant temperature on food intake in young growing pigs. Anim Sci. 72:519–527.

Dalla Costa OA, Fucitano L, Coldebelia A, Ludke JV, Peloso JV, Dalla Roza D, da Costa MP. 2007. Effects of the season of the year, truck type and location on truck on skin bruises and meat quality in pigs. Livest Sci. 107:29–36.

Demeyer DJ, Vandeckerkhove P, Moerans R. 1979. Compounds determining pH in dry sausage. Meat Sci. 3:161–167.

Fagundes AC, Da Silva RG, Gomes JD, De Oliveira Souza LW, Fukushima RS. 2009. Influence of environmental temperature, dietary energy level and sex on performance and carcass characteristics of pigs. Braz J Vet Res Anim Sci. 46:32–39.

Fernandez X, Monin G, Talgaft A, Mourot J, Lebret B. 1999. Influence of intra-muscular fat content on the quality of pig meat - 1. Composition of the lipid fraction and sensory characteristics of m. longissimus lumborum. Meat Sci. 53:59–65.

Gregory NG. 2010. How climatic changes could affect meat quality. Food Res Int. 43:1866–1873.

Guárdia MD, Estany J, Balasch S, Oliver MA, Gispert M, Driestre A. 2005. Risk assessment of FSE condition due to pre-slaughter conditions in pigs. Meat Sci. 70:709–716.

Guárdia MD, Estany J, Balasch S, Oliver MA, Gispert M, Driestre A. 2004. Risk assessment of FSE condition due to pre-slaughter conditions and RYR1 gene in pigs. Meat Sci. 67:471–478.

Jacyno EUGENIA, Pietruszka ARKAUDUSZ, Kolodziej ANITA, Czarnecki ROMAN. 2002. Content of lipid components in m. longissimus dorsi of progeny of the boars descending from reciprocal crossing of the Pietrain and Duroc breeds. Archiv Anim Breed. 45:237–245.

KAPE [Korean Institute for Animal Products Quality Evaluation]. 2010. Korean beef carcass grading standard; [Accessed 2019 Sept 1]. http://www.ekape.or.kr/view/eng/system/beef.asp.

Kim HJ, Jang A. 2018. Evaluation of the microbiological status of raw pork meat in Korea: modification of the microbial guideline levels for meat. Food Sci Biotechnol. 27:1219–1225.

King AJ, Paniangvait P, Jones AD, German JB. 1998. Rapid method for quantification of cholesterol in turkey meat and products. J Food Sci. 63:382–385.

Klont RE, Barnier VMH, Smulders FJM, Van Dijk A, HovingBolink AH, Eikelenboom G. 1999. Post-mortem variation in pH, temperature, and colour profiles of veal carcases in relation to breed, blood haemoglobin content, and carcass characteristics. Meat Sci. 53:195–202.

Kouba M, Hermier D, Le Dividich J. 1999. Influence of a high ambient temperature on stearyl-CoA-desaturase activity in the growing pig. Comp Biochem Physiol B Biochem Mol Biol. 124:7–13.

Le Bellego L, Van Milgen J, Noblet J. 2002. Effect of high temperature and low-protein diets on the performance of growing-finishing pigs. J Anim Sci. 80:691–701.

Lee KT, Choi WS, Yoon CS. 2004. Effects of micro-perforated film on the quality and shelf life improvements of pork loins during chilled storage. Meat Sci. 66:77–82.

Lefaucheur L, Le Dividich J, Mourot J, Monin G, Ecolan P, Krauss D. 1991. Influence of environmental temperature on growth, muscle and adipose tissue metabolism, and meat quality in swine. J Anim Sci. 69:2844–2854.

Lehotayová A, Bajo O, Petrák J, Mrázová J, Debrecení O. 2012. Effect of high ambient temperature on meat quality of pigs. Res Pig Breed. 6:37–40.

Lucas EM, Randall JM, Menezes JF. 2000. Potential for evaporative cooling during heat stress periods in pig production in Portugal (Alentejo). J Agric Eng Res. 76:363–371.

Marcoux M, Pomar C, Fucitano L, Brodeur C. 2007. The relationship between different pork carcass lean yield definitions and the market carcass value. Meat Sci. 75:94–102.

Migdal W, Koziczk K, Koczanowski J, Tuz R, Borowicz F, Furgal K, Gardzińska A. 1999. Tissue traits of cross-breed fatteners. Med Weter. 55:403–407.

Mota-Rojas D, Becerril M, Lemus C, Sánchez P, González M, Olmos SA, Alonso-Spilsbury M. 2006. Effects of mid-summer transport duration on pre-and post-slaughter performance and pork quality in Mexico. Meat Sci. 73:404–412.

Myer RO, Bucklin RA. 2001. Influence of hot-humid environment on growth performance and reproduction of swine. AN107. Gainesville (FL): University of Florida, Institute of Food and Agricultural Sciences Extension.

Myer RO, Bucklin RA. 2002. Effect of season (summer vs. fall) and diet nutrient density on performance and carcass characteristics of growing finishing swine. Trans ASAE. 45:807–811.

Nardone A, Ronchi B, Laceterna N, Ranieri MS, Bernabucci U. 2010. Effects of climate changes on animal production and sustainability of livestock systems. Livest Sci. 130:57–69.

Nienaber JA, Hahn GL, Eigenberg RA. 1999. Quantifying livestock responses for heat stress management. Int J Biometeorol. 42:183–188.

Offer G, Cousins T. 1992. The mechanism of drip production: formation of two compartments of extracellular-space in muscle post mortem. J Sci Food Agric. 58:107–116.

Olivera RF, Moreira RHR, Abreu MLT, Gionbelli MP, Teixeira AO, Cantarelli VS, Ferreira RA. 2018. Effects of air temperature on physiology and productive performance of pigs during growing and finishing phases. SAfJ Anim Sci. 48:627–635.

Pearce KL, Rosenfeld K, Andersen HJ, Hopkins DL. 2011. Water distribution and mobility in meat during the conversion of muscle to meat and ageing and the impacts on fresh meat quality attributes-a review. Meat Sci. 89:111–124.

Raeisi M, Tabaraei A, Hashemi M, Behnampour N. 2016. Effect of sodium alginate coating incorporated with nisin, Cinnamomum zeylanicum, and rosemary essential oils on microbial quality of chicken meat and fate of Listeria monocytogenes during refrigeration. Int J Food Microbiol. 238:139–145.

Renaudeau D, Gourdon JL, St-Pierre NR. 2011. A meta-analysis of the effect of high ambient temperature on growing-finishing pigs. J Anim Sci. 89:2220–2230.

Rinaldo D, Le Dividich J, Noblet J. 2000. Adverse effects of tropical climate on voluntary feed intake and performance of growing pigs. Livest Prod Sci. 66:223–234.

Rinaldo D, Mourot J. 2001. Effects of tropical climate and season on growth, chemical composition of muscle and adipose tissue and meat quality in pigs. Anim Res. 50:507–521.

Rodrigues NEB, Fialho ET, Zanggeronomo MG, Cantarelli VS, Rodrigues PB, Rodrigues Filho M, Gomide EM, Betarelli RP. 2012. Reduction in the protein level and addition of oil in diets for finishing pigs under different temperatures. Rev Bras Zootec. 41:1878–1883.

Rosenfeld K, Andersen HJ. 2003. Factors of significance for pork quality – a review. Meat Sci. 64:219–237.

Ryan E, Chopra J, McCarthy F, Maguire AR, O’Brien NM. 2005. Qualitative and quantitative comparison of the cytotoxic and apoptotic potential of phytosterol oxidation products with their corresponding cholesterol oxidation products. Br J Nutr. 94:443–451.

Santos C, Almeida JM, Matias C, Frequeza MJ, Roseiro C, Sardina L. 1997. Influence of environment factors on meat quality in pigs. Meat Sci. 45:263–262.

Van de Perre V, Permentier L, De Bie S, Verbeke G, Geers R. 2010. Effect of unloading, lairage, pig handling, stunning and searing on pH of pork. Meat Sci. 86:921–937.

Zhang Y, Holman BWB, Ponnampalam EN, Kerr MG, Bailes KL, Kilgannon AK, Collins D, Hopkins DL. 2019. Understanding beef flavour and overall liking traits using two different methods for determination of thiobarbituric acid reactive substance (TBARS). Meat Sci. 149:114–119.