Postprint: Energy Metabolism and Deposition Patterns in 20-50 kg Chuan-Zang Black Pigs

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Abstract

This study aimed to investigate the energy metabolism and deposition patterns in Tibetan black pigs from 20 to 50 kg body weight. Experiment 1: Sixty-four commercial crossbred Tibetan black pigs with similar body weight [(20.17$±3.46)*kg*]*wereselected*.*Aftera*7−*daypreliminaryperiod*, 4*pigswereslaughteredtodeterminecarcassco* *Fifteenbarrowswithsimilarbodyweight*[(48.34±$4.07) kg] from Experiment 1 were selected and randomly divided into 5 groups, with 3 replicates per group and 1 pig per replicate. They were individually housed in metabolism cages and fed the above 5 DE-level diets to conduct a digestion and metabolism trial. The preliminary period lasted 3 days, and the formal experimental period lasted 4 days. A factorial method was used to establish an energy requirement prediction model. The results showed that dietary DE level affected the average daily feed intake, average daily gain, and feed conversion ratio of Tibetan black pigs from 20 to 50 kg. The efficiency of dietary DE conversion to metabolizable energy (ME) (ME/DE) was 97.26%~98.10%, and the average efficiency of ME utilization for product energy deposition (DED/ME) was 41.71%. The average ME requirement for maintenance in Tibetan black pigs at this stage was 0.49 MJ/W0.75 or 0.85 MJ/W0.60 (equivalent to 0.50 MJ/W0.75 or 0.87 MJ/W0.60 in DE terms), and the average requirements for weight gain were 18.91 MJ/kg for DE and 18.47 MJ/kg for ME. Therefore, the energy requirement models for Tibetan black pigs at the 20-50 kg stage were established as: DE (MJ/d) = 0.504 W0.75 + 18.91ΔW or DE (MJ/d) = 0.867 W0.60 + 18.91ΔW; ME (MJ/d) = 0.492 W0.75 + 18.47ΔW or ME (MJ/d) = 0.847 W0.60 + 18.47ΔW.

Full Text

Study on Regularity of Energy Metabolism and Deposition in 20 to 50 kg Chuanzang Black Pigs

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Abstract

This study investigated the regularity of energy metabolism and deposition in 20 to 50 kg Chuanzang black pigs. In Experiment 1, 64 Chuanzang black pigs with an average body weight of (20.17$±$3.46) kg were selected. After a 7-day preliminary period, 4 pigs were slaughtered to determine carcass composition. The remaining 60 pigs were randomly divided into 5 groups based on sex, with 4 replicates per group and 3 pigs per replicate, housed individually per replicate. Each group was fed ad libitum diets with digestible energy (DE) levels of 13.79, 13.37, 12.96, 12.54, and 12.12 MJ/kg, respectively, and average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio were measured. When pigs reached approximately 50 kg body weight, Experiment 1 was terminated and one pig per group was selected for slaughter to determine carcass composition.

In Experiment 2, 15 barrows from Experiment 1 with a body weight of (48.34$±$4.07) kg were randomly divided into 5 groups, with 3 replicates per group and 1 pig per replicate, housed individually in metabolic cages. The 5 groups were fed the same 5 DE-level diets as in Experiment 1 for a digestion-metabolism trial consisting of a 3-day preliminary period and a 4-day collection period. An energy requirement prediction model was established using the factorial method. Results showed that dietary DE level significantly affected ADFI, ADG, and feed-to-gain ratio in 20 to 50 kg Chuanzang black pigs. The conversion efficiency of DE to metabolizable energy (ME) (ME/DE) ranged from 97.26% to 98.10%, and the average deposition efficiency of ME (DED/ME) was 41.71%. The average ME requirement for maintenance was 0.49 MJ/W^0.75 or 0.85 MJ/W^0.60 (equivalent to 0.50 MJ/W^0.75 or 0.87 MJ/W^0.60 as DE). The average DE and ME requirements for weight gain were 18.91 and 18.47 MJ/kg, respectively. The resulting energy requirement models for the 20 to 50 kg stage of Chuanzang black pigs are:

DE (MJ/d) = 0.504 W^0.75 + 18.91ΔW or DE (MJ/d) = 0.867 W^0.60 + 18.91ΔW
ME (MJ/d) = 0.492 W^0.75 + 18.47ΔW or ME (MJ/d) = 0.847 W^0.60 + 18.47ΔW

Keywords: Chuanzang black pig; energy requirement; energy metabolism; energy deposition

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Introduction

Energy is fundamental to all metabolic and productive activities in animals. Energy requirements vary among pig breeds and physiological stages due to influences from genotype, diet type, nutrient interactions, and environmental conditions. In recent years, researchers including Yang et al. [1], Li et al. [2], Liu et al. [3], Zhang et al. [4], and Jiang et al. [5] have investigated energy metabolism and deposition in Guizhou Xiang pigs, exotic crossbred growing-finishing pigs, binary (Landrace × Yorkshire) gilts, binary (Landrace × Yorkshire) growing-finishing pigs, and 10 to 20 kg Xiangcun black pigs using comparative slaughter or gradient feeding trials (linear regression method).

Chuanzang black pig is a new strain developed by the Sichuan Animal Science Academy through introducing exotic pig bloodlines into local Sichuan breeds. This strain maintains the meat quality characteristics of local breeds while substantially improving growth performance [6]. Consequently, its energy requirements differ from both exotic and local breeds. Accurate assessment of its energy requirements enables precise formulation of dietary energy levels to maximize economic benefits. With numerous local pig breeds in China showing substantial inter-breed variation, few in-depth studies on energy transformation, metabolism, and feeding standards have been reported in recent years. This study determined nutrient deposition in 20 to 50 kg Chuanzang black pigs and investigated energy metabolism and deposition patterns using the factorial method to establish energy requirement models and provide parameters for formulating feeding standards, which is crucial for promoting the rapid dissemination of this superior breed and improving production efficiency.

1.1 Experimental Design

Experiment 1 (Feeding Trial): Sixty-four Chuanzang black pigs with similar genetic background, typical breed characteristics, and an average body weight of (20.17$±$3.46) kg were selected from the breeding farm of Sichuan Animal Science Academy. After a 7-day preliminary period, 4 pigs (half barrows, half gilts) with body weight closest to the group average were slaughtered as blank controls. The remaining 60 pigs were randomly divided into 5 groups with 4 replicates per group and 3 pigs per replicate, housed one replicate per pen. Two replicates contained 2 barrows and 1 gilt, while the other two replicates contained 1 barrow and 2 gilts, ensuring equal sex distribution (6 barrows and 6 gilts per group). The five groups were fed ad libitum diets with DE levels of 13.79, 13.37, 12.96, 12.54, and 12.12 MJ/kg, respectively. Dietary DE values of feed ingredients were obtained from the Chinese Feed Database (2011 edition), while other nutrient levels were formulated according to NRC (1998) [7], NRC (2012) [8], and Chinese Feeding Standard for Swine [9]. The feeding trial ended when pigs reached approximately 50 kg body weight, at which point one pig per group (with body weight closest to the group mean) was selected for slaughter and comparative carcass analysis. Dietary composition and nutrient levels are presented in Table 1 .

Experiment 2 (Digestion-Metabolism Trial): Following Experiment 1, 15 barrows with a body weight of (48.34$±$4.07) kg were selected and randomly divided into 5 groups with 3 replicates per group and 1 pig per replicate, housed individually in metabolic cages. The five groups were fed the same five DE-level diets as in Experiment 1. The trial consisted of a 3-day preliminary period and a 4-day collection period.

1.2.1 Body Weight and Feed Intake

Experiment 1: Pigs were weighed after 12-hour fasting at the end of the preliminary period and at the conclusion of the formal trial. Feed was provided three times daily with accurate recording of feed allowance to ensure ad libitum access, with free access to water. Daily feed intake, pig health status, and average pen temperature were recorded per replicate. At trial completion, body weight was measured and average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio were calculated.

Experiment 2: A 3-day preliminary period was implemented where feed was provided based on average intake from the previous period, gradually increasing to ad libitum intake with continuous recording. During the 4-day collection period, feed was provided at 85% of ad libitum intake three times daily.

1.2.2 Carcass Sample Preparation

After slaughter, the left carcass was obtained after removing gastrointestinal and bladder contents. Muscle, fat, and viscera were minced using a meat grinder 2-3 times to ensure uniformity. Bone samples were crushed using a blender and thoroughly mixed. Blood volume was measured, and hair was cut with scissors. All components were thoroughly mixed according to the weight ratio of carcass, viscera, hair, and blood for sample preparation. The 4 pigs slaughtered at the end of the preliminary period consisted of 2 barrows and 2 gilts with body weight closest to the trial average, while the 5 pigs slaughtered at trial completion comprised 3 barrows and 2 gilts with body weight closest to their respective group means.

1.2.3 Fecal and Urine Sample Preparation in Digestion-Metabolism Trial

The total feces collection method was employed. Daily fecal output (24 h) was accurately collected during the collection period, with the time boundary between days defined as 1-1.5 hours after morning feeding when pigs were in their most resting state. For each pig, 10% hydrochloric acid (5 mL per 100 g fresh sample) and several drops of toluene were added to daily fecal collections for preservation. After thorough mixing, 10% of the fresh weight was sampled.

Daily urine was filtered, measured, and preserved by adding 10 mL of 10% hydrochloric acid per 100 mL urine in sealed containers stored at -20°C. After the trial, fecal samples from the same group over 4 days were mixed uniformly to prepare air-dried samples, ground to pass a 40-mesh screen, and stored refrigerated for analysis. Urine samples were mixed uniformly and stored at -20°C for analysis.

1.2.4 Analytical Methods

Feed and carcass samples were analyzed for moisture, crude protein, and fat content according to GB/T 6435—2014 [10], GB/T 6432—1994 [11], and GB/T 6433—2006 [12] methods, respectively. Gross energy in feed, carcass, feces, and urine was determined using an automatic oxygen bomb calorimeter (Changsha Youxin YX-ZR9302).

1.2.5 Calculation Formulas

Nutrient (energy, crude protein, fat) intake and deposition were calculated as follows:

Nutrient intake (g/d) = Feed intake (g/d) × Nutrient content in feed (%)

Nutrient deposition (g/d) = [Final body weight (g) × Final carcass nutrient content (%) - Initial body weight (g) × Initial carcass nutrient content (%)] / Trial days (d)

Apparent digestible energy of diet (MJ/kg) = [Total feed intake (kg) × Gross energy of feed (MJ/kg) - Dry fecal excretion (kg) × Gross energy of dry feces (MJ/kg)] / [Dry matter intake (kg) × Dry matter content of air-dried feed sample (%)]

Apparent metabolizable energy of diet (MJ/kg) = [Total feed intake (kg) × Gross energy of feed (MJ/kg) - Dry fecal excretion (kg) × Gross energy of dry feces (MJ/kg) - Urine excretion (kg) × Gross energy of urine (MJ/kg)] / [Dry matter intake (kg) × Dry matter content of air-dried feed sample (%)]

Surface nitrogen energy = 0.018 × W^0.75 × 6.25 × 23.64 kJ [13]

Maintenance heat production = Metabolizable energy intake - (Energy deposition + Surface nitrogen energy loss + Heat production from protein and fat deposition)

1.3 Data Processing

Experimental data were organized using Excel and analyzed using one-way ANOVA in SPSS 18.0. Significance was tested using F-test at $P < 0.05$ and $P < 0.01$ levels. Results are expressed as "mean ± standard deviation."

2.1 Feeding Trial Results

The feeding trial lasted 45 days, with results presented in Table 2 . Growth performance of 20 to 50 kg Chuanzang black pigs differed significantly among dietary DE levels. Final body weight of Group 4 was extremely significantly lower than Group 1 ($P < 0.01$) and significantly lower than Group 3 ($P < 0.05$). Final body weight of Group 5 was significantly lower than Group 1 ($P < 0.05$). For average daily feed intake, only Groups 2 and 3 differed significantly ($P < 0.05$), with no significant differences among other groups ($P > 0.05$). For average daily gain, Group 1 differed significantly from Groups 2 and 5 ($P < 0.05$), with no significant differences among other groups ($P > 0.05$). For feed-to-gain ratio, Group 1 was extremely significantly lower than Groups 4 and 5 ($P < 0.01$) and significantly lower than Group 3 ($P < 0.05$), with no significant differences among Groups 2, 3, 4, and 5 ($P > 0.05$).

In the same row, values with different small letter superscripts indicate significant difference ($P < 0.05$), different capital letter superscripts indicate extremely significant difference ($P < 0.01$), and same or no letter superscripts indicate no significant difference ($P > 0.05$). The same applies below.

2.2 Dietary Digestible and Metabolizable Energy

Through measurement and calculation, dietary energy intake, digestion, and metabolism for each group are presented in Table 3 .

2.3 Digestion-Metabolism Trial Results

Daily energy deposition was calculated from the difference in gross energy of carcass samples obtained from two slaughter trials. Daily protein and fat deposition were calculated from measured protein and fat content in carcass samples and average daily gain. Heat production from daily protein and fat deposition was calculated assuming 20 kJ per gram of protein deposited and 14 kJ per gram of fat deposited. Energy requirement per kilogram of gain comprised deposited energy, heat production from protein and fat deposition, and surface nitrogen energy loss per kilogram of gain [14].

Results of ME deposition and distribution in the body (Table 4) showed that maintenance ME requirement for Chuanzang black pigs at 20 to 50 kg stage, calculated using the widely accepted metabolic body weight exponent of 0.75 (W^0.75), ranged from 0.41 to 0.54 MJ/W^0.75 with a mean of 0.49 MJ/W^0.75. ME requirement for gain ranged from 17.41 to 19.95 MJ/kg with a mean of 18.47 MJ/kg. According to NRC (2012), W^0.75 is used to measure fasting heat production (FHP) and maintenance metabolizable energy (MEm) in sows, while W^0.60 is generally used for growing-finishing pigs. Calculated using W^0.60, maintenance ME requirement ranged from 0.71 to 0.92 MJ/W^0.60 with a mean of 0.85 MJ/W^0.60.

3.1.1 Efficiency of DE to ME Conversion

The digestion-metabolism trial determined that the average efficiency of DE conversion to ME in 20 to 50 kg Chuanzang black pigs was 97.66%. This value is higher than the 96% recommended in Chinese Feeding Standards for Swine [12] and the 95.23% reported by Li et al. [2] in exotic crossbred growing-finishing pigs, as well as the 94.22% reported by Jiang et al. [5] in 10 to 20 kg Xiangcun black pigs. NRC (2012) [13] considers that ME and DE have an important proportional relationship (92%-98%). Our measured value falls within the NRC (2012) recommended range and is slightly higher than the Chinese standard.

3.1.2 Energy and Nutrient Deposition

Animal growth energy deposition is primarily manifested as protein and fat deposition. In the 20 to 50 kg stage of Chuanzang black pigs, each kilogram of body weight gain corresponded to average net deposition of 180.03 g protein, 148.24 g fat, and 12,689.67 kJ energy. The efficiency of ME utilization for deposited product energy in this pig strain at 20 to 50 kg stage ranged from 38.32% to 44.82% with a mean of 41.71%, which is slightly lower than the 43.50% reported by Li et al. [2] in exotic crossbred pigs at 50 to 80 kg stage, possibly due to differences in breed and physiological stage.

3.2.1 Maintenance Energy Requirement

The MEm requirement for Chuanzang black pigs at 20 to 50 kg stage was 0.847 MJ/W^0.60 (0.492 MJ/W^0.75). With an average DE to ME conversion efficiency of 97.66%, the maintenance DE (DEm) requirement was 0.867 MJ/W^0.60 (0.504 MJ/W^0.75). The measured average maintenance ME requirement (0.49 MJ/W^0.75) is slightly higher than the 0.444 kJ/W^0.75 recommended by NRC (1998) [13]. Calculated using W^0.60, the value of 0.87 MJ/W^0.60 falls within the MEm range for growing-finishing pigs recommended by NRC (2012) (0.799-0.903 MJ/W^0.60). Published reports indicate minimal differences in FHP and MEm among barrows, gilts, and boars. However, breeds with different lean growth rates show varying FHP and MEm. Based on this, it can be inferred that within the same breed, barrows and gilts may also differ significantly in FHP and MEm due to differential lean tissue deposition.

3.2.2 Growth Energy Requirement

The ME requirement for weight gain measured in this trial ranged from 17.41 to 19.95 MJ/kg with a mean of 18.47 MJ/kg. Based on the average DE to ME conversion efficiency of 97.66%, the DE requirement for weight gain was 18.91 MJ/kg. Energy requirements for pig growth are closely related to breed, body weight, and environmental factors. Yang et al. [1] reported that in Guizhou Xiang pigs, ME requirement per kilogram gain was 20.29 MJ/kg at 7–16 kg body weight and 21.66 MJ/kg at 1–25 kg body weight, with an average of 21.89 MJ/kg across both stages. Jiang et al. [5] determined using comparative slaughter that the DE requirement per kilogram gain in 10 to 20 kg Xiangcun black pigs was 13.79 MJ/kg.

3.2.3 Total Energy Requirement

Energy requirements for growing-finishing pigs are primarily determined by two factors: body weight and average daily gain, i.e., total energy requirement = maintenance requirement + growth requirement. Based on the above results, the energy requirement models for Chuanzang black pigs at 20 to 50 kg stage under our experimental conditions are:

DE (MJ/d) = 0.504 W^0.75 + 18.91ΔW or DE (MJ/d) = 0.867 W^0.60 + 18.91ΔW
ME (MJ/d) = 0.492 W^0.75 + 18.47ΔW or ME (MJ/d) = 0.847 W^0.60 + 18.47ΔW

According to these formulas, assuming a potential average daily gain of 0.7 kg and using W^0.75, the daily DE requirement for Chuanzang black pigs at 20 to 50 kg stage ranges from 18.00 to 22.71 MJ. Based on an average daily feed intake of 1.5 kg, the dietary DE level is estimated at 13.66 MJ/kg. Using W^0.60, the daily DE requirement ranges from 18.46 to 22.30 MJ, corresponding to a dietary DE level of 13.72 MJ/kg based on 1.5 kg daily feed intake.

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Note: Figure translations are in progress. See original paper for figures.