

# 猪舍环境温湿度对育成猪的生理及生产指标的影响

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**摘要:** 试验采用美国 DSI 公司生产的动物生理参数无线遥测系统与猪舍环境参数及动物行为自动检测系统研究了长白猪在夏季湿热环境下的行为生理反应。结果表明猪舍高温将导致猪的体温升高、心率加快, 猪的生产性能降低等热应激反应, 高温高湿环境下猪的热应激反应更为严重, 高温时环境湿度增大 10%, 相当于环境温度升高 1 对猪的影响。环境温度对猪的体温和心率影响极显著; 环境湿度对猪的体温影响显著, 对心率有影响但不显著。

**关键词:** 环境温度; 相对湿度; 生理指标; 育成猪

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猪是恒温动物, 其平均直肠温度为 39.2, 但由于受诸多因素的影响, 其体温可在狭小的范围内波动, 变动范围在 38.7 ~ 39.8<sup>[1]</sup>。热环境与猪体生理恒定性密切相关, 而体温恒定是机体进行正常生命活动和生产的基础。猪在呼吸、循环、肌肉活动、采食、消化等过程中不断产生热量, 并通过传导、对流、辐射、蒸发等途径向周围环境散发。环境温度和湿度是猪与其生存环境保持平衡的重要因素, 猪在适宜环境范围中, 能借助物理调节维持正常体温。当环境温度逐渐升高或环境温度与湿度都较高时, 猪体就开始通过加速血液循环, 加快皮肤与呼吸蒸发散热调节体温。温度继续升高, 猪就表现出活动量和采食量减少, 饮水增加, 生长缓慢, 甚至出现负增重等热应激反应。有关猪舍温度对猪生产性能和行为表现方面的影响, 国内外许多学者做了各自感兴趣的研究。据 NRC(1988)<sup>[2]</sup>测定, 气温升高 1, 猪采食量减少 40 g; 若环境温度超出最佳温度 5~10, 则每天采食量下降 200~400 g。艾地云(1996)<sup>[3]</sup>报道: 在持续高温环境下(28~35), 30~60 kg 的猪日采食量较常温下降了 14%, 日增重下降了 21%, 料肉比增加了 0.23。国内外有关猪舍湿热环境对育成猪的生产性能、热调节行为生理反应的影响的研究, 一般应用较传统的方法和技术手段在各种试验猪舍或试验猪场里取一定品种、日龄的猪来完成的。传统的检测手段如检测猪的肛温、心率等生理参数一般需用夹套、系链、绳索等器械将动物的活动限制或将其麻醉, 这样所测得的生理参数值

必然会受到动物因遭受行为或精神限制而产生的应激反应的影响, 因而影响所测值的精确性和可靠性。美国 DSI(Data Sciences International) 公司生产的动物生理参数无线遥测系统最早被用于测量鼠、松鼠、兔、狗、灵长类等小型试验动物的体温、心率、血压及动态心电图等生理参数, 后来也用于对母牛、绵羊、山羊、蜥蜴、熊、雪豹等大型动物的试验研究, 近年来该系统已成功应用于猪、鸡等饲养动物的相关研究。I. C. de Jong 等(1999)<sup>[4]</sup>应用 DSI 动物生理参数无线遥测系统研究了育成猪混群前后的体温、心率的变化, 结果表明深部的体温能充分反映猪的生理应激反应; B. Lacey 等(2000)<sup>[5]</sup>用 DSI 动物生理参数无线遥测系统对不同环境温度和湿度下鸡的体温变化进行了研究, 结果表明该系统能较好地说明各种环境因素对鸡的生理影响作用。DSI 动物生理参数无线遥测系统是在动物处于自由活动、神志清醒、无愤怒状况下进行生理参数的采集和实时显示, 因而能真实反映动物的生理变化情况。

本试验研究采用美国 DSI 公司生产的动物生理参数无线遥测系统测试了中国东南地区夏季湿热的猪舍环境下育成猪的行为生理反应, 探讨湿热环境对育成猪生产性能、体温和心率、行为等的影响, 并探讨育成猪生产环境控制要求, 为养猪业生产中的环境调控及夏季降温实施提供理论依据。

## 1 材料与方法

试验在编号为 104 和 103 两猪舍内进行。两猪舍大小、结构完全相同, 在试验前均采用调温器进行控温(温度为 25, 相对湿度为 60%, 猪的平均体温为 39.2), 且试验用猪在试验前的体质量相近(104 舍猪的体质量为 41.5 kg, 103 舍猪的体质量为 41 kg), 以确保两猪在相同的状态下进入试验。

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热应激试验期(2000 年 8 月 9 日~ 8 月 14 日)两猪舍温度变化控制如表 1。

表 1 试验期猪舍温度设定条件

	控温组(104 舍)	试验组(103 舍)
8: 30~ 10: 30	23	猪舍内不采取任何
10: 30~ 15: 30	25	降温措施, 猪舍温
15: 30~ 20: 30	23	度随外界气候条件
20: 30~ 8: 30	20	的变化而变化

## 2 测定指标及仪器设备

### 2.1 猪舍环境参数

猪舍内环境温度、湿度由比利时鲁汶大学提供的动物环境检测系统(由猪舍内外温湿度传感器、数据采集及转换器和电脑组成)实时自动采集、存贮和处理, 舍内温湿度传感器安装在距地 1.8 m 高处, 猪舍外环境温湿度传感器安置在舍外距地面 3 m 高的小气候箱内。系统数据采集时间间隔为 5 min, 温湿度传感器的温度和湿度检测精度分别为  $\pm 0.7$  和  $\pm 5\%$ 。

### 2.2 猪的行为和生理参数

猪的体温、心率、呼吸次数由美国 DSI 公司(Data Sciences International, St Paul, MN, USA)生产的动物生理参数无线遥测系统(Physio Telemetry System, 由 DSI 植入片、信号接收器、数据转换器及电脑组成)实时采集、存贮和处理。生理参数感应元件 DSI 植入片埋植在猪腹部肌肉组织内。猪的行为幅度由动物行为检测系统自动检测。其中猪体温的检测精度为 0.1, 行为幅度检测精度为 0.01 V。与猪舍环境参数检测系统同步, 猪的行为和生理参数的数据采集时间间隔均为 5 min。猪的行为幅度由动物行为检测系统自动检测, 用于测定猪的行为的红外传感器是根据焦热电原理工作的(S. Pederson, 1995)<sup>[6]</sup>, 即温度变化引起传感器的输出电压信号的变化。在该系统中的热源是猪体, 辐射热与猪相对传感器的位置有关, 猪体相对于传感器的位置变化引起传感器的温度变化, 进而传感器输出电压信号发生变化, 猪的行为幅度检测精度为 0.01 V。

### 2.3 猪的生产性能

猪的生产性能通过人工办法进行采集, 采集的指标包括猪的日采食量、日增重、饮水量、料肉比等。其中日增重为周增重的平均值。

## 3 试验结果与分析

### 3.1 猪舍湿热环境与猪的行为生理分析

用 SAS (Statistics Analysis System, Version

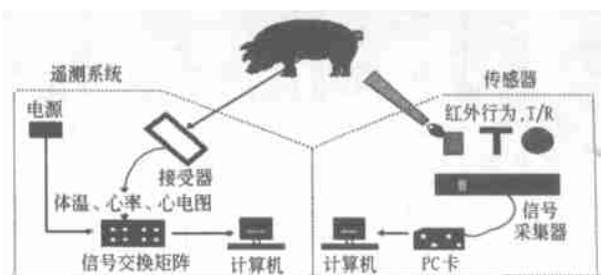


图 1 猪舍环境参数及动物行为检测与生理参数遥测系统

Fig 1 Detection system of environment, swine activity and physiological parameters

6.12) 数据统计分析软件对试验数据进行相关分析, 环境温度、湿度与猪的体温、心率及行为活动的综合因素分析结果如下。

1) 控温组 104 舍的日平均温度为 24.6, 相对湿度为 75%, 舍内猪的体温基本保持在 39.2 (39.2 ± 0.16), 心率(132 ± 16)次; 试验组 103 舍的日平均温度为 28.4, 最高温度达 36.9, 相对湿度为 76%, 最高达 90%, 舍内猪的体温高于其正常体温 39.2 [(39.68 ± 0.29)], 最高达 40.6, 心率(160 ± 22)次。

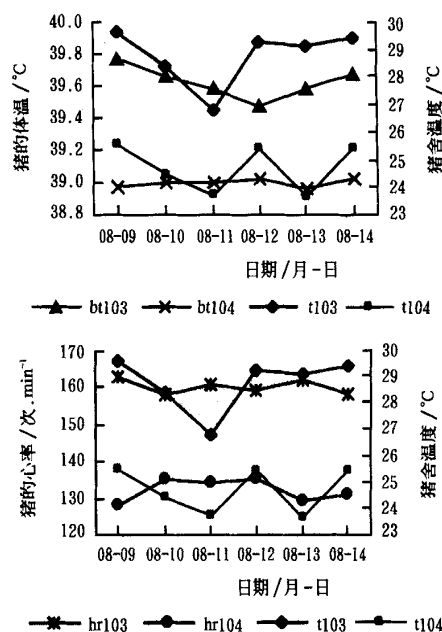


图 2 猪的体温和心率与猪舍温度关系曲线

Fig 2 The relationship between body temperature and heart rate of pig and environmental temperature

2) 高温使猪的体温、心率及其昼夜行为活动发生变化, 猪表现出体温升高、心率加快(如图 2、图 3 所示, 图中 t103öt104、bt103öbt104、hr103öhr104、Dact103öDact104 分别代表 103 舍和 104 舍环境温度、猪舍内猪的体温、心率及其白天行为活动), 白天活动减少而夜晚活动增加(白天和夜晚猪的活动最

小平方差  $t$  检验:  $t = 3, P = 0.0029$ ); 环境温度对猪的体温影响极显著 ( $F = 22.54, P = 0.0001$ ); 环境温度对猪的心率变化影响极显著 ( $F = 60.22, P = 0.0001$ ); 环境温度对猪的行为影响极显著 ( $F = 254.96, P = 0.0001$ ); 环境湿度对猪的体温变化影响显著 ( $F = 4.96, P = 0.0264$ ).

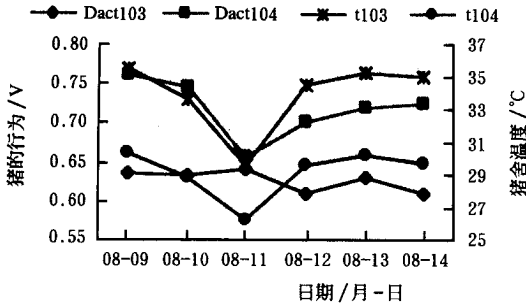


图 3 猪的行为与猪舍温度关系曲线(高温时段)

Fig 3 The relationship between activity of pig and environmental temperature

表 2 为试验期内每天高温时段(11:00~16:00)猪舍内温热指标与猪的行为生理表现。从表 2 中可看出, 103 舍的猪的活动行为比环境适宜的 104 舍减少 ( $F = 4.26, P = 0.0028$ ), 说明在热应激猪舍

表 2 猪舍温热指标与猪的行为生理表现(高温时段)

Table 2 Thermal indexes of room environment and body temperature and activity of pigs (high temperature period)

试验日期 ø月ø日	控温组猪舍 温度ø	试验组猪舍 温度ø	控温组猪舍 湿度ø%	试验组猪舍 湿度ø%	控温组猪的 体温ø	试验组猪的 体温ø	控温组猪的 行为øV	试验组猪的 行为øV
08209	30.4	35.5	65	55	39.19	39.86	0.74	0.64
08210	28.8	33.7	74	66	39.04	39.69	0.74	0.63
08211	26.3	29.7	85	74	39.00	39.53	0.67	0.66
08212	29.7	34.5	75	65	39.08	39.87	0.69	0.61
08213	30.1	35.3	68	60	39.00	39.91	0.72	0.62
08214	29.8	35.0	66	52	39.07	39.83	0.74	0.63

### 3.2 猪舍湿热因子对猪的生产性能的影响

从表 3 中可看出, 104 舍的各项生产性能优于 103 舍。受热应激影响, 103 舍猪饮水量约为 104 舍的 3 倍, 而同时食欲下降, 日采食量比 104 舍下降 12%。高温引起采食量下降, 导致养分摄入量不足, 结果猪体增重减缓, 日增重比 104 舍降低 20%。最终使料肉比增大, 生产成本提高而效益下降。这说明热应激会降低育成猪的生产性能, 进而使生产成本升高, 养猪业的生产水平降低。

表 3 猪的生长性能

Table 3 Growing indexes of pigs

猪舍号	始重 økg	末重 økg	日增重 øg	日采食量 økg · d <sup>-1</sup>	料肉比 økg · kg <sup>-1</sup>	日饮水量 øL · d <sup>-1</sup>
104	41.5	46.5	714	1.78	2.48	4.5
103	41	45	571	1.57	2.75	12.5

环境中猪为减少产热而减少了活动。

3) 环境湿度对猪的心率及其行为变化影响不显著; 104 舍日平均温度控制在 25 以下, 相对湿度随舍外空气湿度的变化而变化(平均相对湿度变化范围 65%~85%)时, 育成猪的体温、心率等生理参数及行为活动正常。这说明在适宜温度区内湿度对猪的行为生理几乎没有影响。

当 103 舍湿度较低(52%~55%), 而环境温度高于 35 时, 猪的体温比正常值高出 0.6, 当环境湿度相等时(65%左右), 环境温度高的猪的体温也高。这说明高温高湿比仅仅高温对猪的影响更大, 因为高温高湿时, 猪的蒸发散热过程受到了抑制, 而使有机体的散热受阻, 以致形成热在体内的积累。从表中还可看出, 当环境温度 35.5, 相对湿度 55%时, 猪的体温与环境温度 34.5, 相对湿度为 65%时猪的体温一样都超出了其正常调节上限 39.8。这说明高温时增大 10% 的环境湿度相当于环境温度升高 1, 同时说明此时猪的体内热量聚积, 自身热平衡受到破坏, 表明猪处于严重的热应激之中, 在生产中应及时对猪舍进行降温, 以减轻猪的热应激反应。

### 4 结论与讨论

1) 传统的检测手段如检测猪的肛温、心率等生理参数一般需用夹套、系链、绳索等器械将动物的活动限制或将其麻醉, 这样所测得的生理参数值必然会受到动物因遭受行为或精神限制而产生的应激反应的影响, 因而影响所测值的精确性和可靠性。DSI 动物生理参数无线遥测系统是在猪处于自由活动、神志清醒、无愤怒状况下进行生理参数的采集和实时显示, 研究表明用该系统结合动物环境参数检测系统可准确、实时在线检测动物的生理对环境因子的反应。

2) 环境温度是影响猪的体温、心率和行为变化的主要原因, 随着环境温度升高超出等热区, 猪表现出体温升高、心率加快、呼吸次数增多及白天活动减

少、夜晚活动增加等行为生理热应激反应,同时采食量减少,日增重减缓,饮水增加。高温高湿环境下,猪的行为生理反应和生产性能的热应激反应更严重。

3) 当环境温度为 35.5,相对湿度为 55% 时,猪的体温与环境温度为 34.5,相对湿度为 65% 时猪的体温一样都超出了其正常调节范围的上限 39.8。结果表明高温时环境湿度增大 10% 相当于温度升高 1,同时说明夏季高温时环境湿度对猪的行为生理及生产性能有明显的影响,对养猪生产极为不利。因而,夏季高温高湿的中国东南地区猪舍在实施降温措施时必须考虑控制猪舍的湿度。

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**Abstract** Heat preservation and energy saving experiment using aluminumized thermal screens in greenhouse was conducted. The temperatures inside greenhouse both with and without thermal screens were measured based on experiment. The experimental result showed that air temperature inside greenhouse under aluminumized thermal screens can be improved by 3~5 °C, and the air temperature at 40 cm above the screen was 8.8 °C higher than that at 40 cm under the screen. According to calculated results of the heating load of the greenhouse and the overall heat transfer coefficient of the roof with and without thermal screens, the average energy saving efficiency reached about 37%, which reveals excellent thermal performance of aluminumized thermal screens.

**Key words:** greenhouse; aluminumized film; thermal screen; energy saving

### Preliminary Study on Calculating Dynamic Wind Pressure for Multi-span Greenhouse Structural Design ..... (93)

Sun Defa, Miao Xiangwen, Cui Shaorong (Institute of Agricultural Bioenvironmental Engineering, Zhejiang University, Hangzhou 310029, China)

**Abstract** Based on the contrast analysis of loads provided in foreign and Chinese standards, analysis and discussion are mentioned about the definition and estimation of dynamic wind pressures for multi-span greenhouse structural design in details. Meanwhile, taking advantage of past experience in greenhouse structural design a practical method which can be used in greenhouse design was given for wind load. Under the present conditions, it is unnecessary to make modification of statistical reappearing factor in calculation wind load dynamic pressure when considering the coefficients of wind pressure depending on height and the gust factor according to Chinese architectural structure load standards (GBJ9287).

**Key words:** greenhouse; dynamic pressure; structural design

### Design and Experiment of CO<sub>2</sub> Enrichment and Real-time Control System for Tissue Culture ..... (96)

Ding Yongqian, Ding Weimin, Cui Jin, Li Shijun, Xu Zhigang, Wang Xiaohan (College of Agricultural Engineering, Nanjing Agricultural University, Nanjing 210032, China)

**Abstract** In order to improve the environmental conditions of tissue culture in vitro and to investigate the function of CO<sub>2</sub> in the culture, a CO<sub>2</sub> enrichment and real-time control system was developed. Using this system, the growth experiment of subcultured grape (cabernet sauvignon) plantlets was carried out as compared with the traditional tissue culture method (non-CO<sub>2</sub> enrichment). The results indicated that the system worked well, the required ranges of CO<sub>2</sub> concentration [(800~1200) μL/L] could be obtained; and the CO<sub>2</sub> enrichment environment could promote the growth and photoautotrophic capability of the plantlets in vitro.

**Key words:** CO<sub>2</sub> enrichment; real-time control; biological environment; tissue culture; sucrose-free culture

### Effects of Ambient Temperature and Relative Humidity on Physiological Parameters and Performance of Growing Pigs ..... (99)

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**Abstract** Responses of physiological parameters and activity to humidity and temperature were studied using DSI animal physiological parameters online telemetry system and environmental condition and animal activity detecting system. The results show that body temperature, heart rate of pigs raised under high room temperature in summer, and swine growing performance decreased, especially, under high humidity and temperature. A 10% increase in relative humidity was offset by 1 °C decrease in ambient

temperature Effects of environmental temperature on body temperature and heart rate are very significant, effect of environmental humidity on body temperature is significant, environmental humidity makes little effect on heart rate of pig

**Key words:** ambient temperature; relative humidity; physiological parameters; growing pigs

**· Rural Energy, Agricultural Waste Treatment and Environmental Protection Engineering ·**

**Fuzzy Hierarchy Comprehensive Evaluation of Energy-saving Projects of Township Enterprises With Computer** ..... (103)

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**Abstract:** Using the method of multi aim fuzzy analytical hierarchy process, the indexes system and the judgement model of comprehensive evaluation of the energy saving projects of township enterprise were established. The author studied the subordinate function, the numerical method to conform the subordinate degree of the judgement indexes and the method of combination operation. The evaluation software system on computer was designed by using Visual Basic (6.0). Through the typical cases, the method and the system were verified in application. The result indicated the established indexes system reflected the integrated effect of energy saving project in impersonality and reality through three aspects of technology, economy and social environment. The established judgement model reflected the characteristics of fuzzy, integration and multi hierarchy in comprehensive evaluation to energy saving project, also offered the scientific basis for evaluating the overall excellence or badness of the project and investment decision making.

**Key words:** energy saving project; fuzzy comprehensive evaluation; township enterprise

**Pyrolysis Kinetics of Rice Straw** ..... (107)

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**Abstract:** The pyrolysis of biomass is one of the most promising renewable forms of future energy. The optimal parameters of pyrolysis and the proper equipment design require the knowledge of kinetics. In this paper, Thermogravimetric Analysis (TGA) was used to study the thermal degradation of rice straw at different heating rates (10, 15, 20, 30 °C/min) under a nitrogen atmosphere. The kinetic model for first order paralld linear reaction is provided and details are presented such as weight loss, temperature and kinetic data obtained during the pyrolysis of rice straw.

**Key words:** biomass; rice straw pyrolysis; kinetic model; Thermogravimetric Analysis (TGA)

**Characteristics of Bioreactor Landfill Technology and Its Future Application** ..... (111)

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**Abstract:** The disadvantages of conventional Sanitary Landfill (CL) were analyzed, and the structural characteristics of Bioreactor Landfill (BL) were described, and the biodegrading characteristics of BL technology was introduced by taking a BL research project conducted in California as an example. The preliminary experimental results showed that the biodegradation capability of BL was strongly enhanced due to the leachate recirculation and moisture content adjustment. As compared with CL, BL could increase 75% landfill gas amount and approximately 42fold landfill volume reduction, and faster leachate stabilization. Finally, the current status of refuse treatment technologies in China was analyzed, and the potential application of BL technology in China was investigated as well.

**Key words:** refuse; sanitary landfill; bioreactor; landfill gas; leachate

**K Cycle of Rubber-Tea-Chicken Agro-Forestry Model in Tropical Areas of China** ..... (115)