Comparison of Slaughter Performance, Complex Stomach Development, and Histomorphological Structure between Calm-type and Nervous-type Hu Sheep

Authors: Mao Jianyu, Li Hao, Wang Mengzhi, Ding Luoyang, BLACHE Dominique

Date: 2018-12-20T17:08:57+00:00

Abstract

This study aimed to compare the slaughter performance, compound stomach development, and histomorphological structure of calm-type and nervous-type Hu sheep. Ten calm-type and ten nervous-type Hu sheep were selected using temperament comparison methods, with each type constituting one group, and both groups were maintained under identical feeding conditions. The pre-trial period lasted 7 d, and the formal trial period lasted 60 d. Upon completion of the experiment, the compound stomach was dissected following slaughter, weighed, and tissue sections were prepared. The results indicated that dry matter intake, pre-slaughter live weight, carcass weight, and various organ indices did not differ significantly between temperament types ($P>0.05$); however, the dressing percentage of calm-type Hu sheep was significantly higher than that of nervous-type Hu sheep ($P<0.05$). The compound stomach index showed no significant inter-group difference ($P>0.05$), whereas the stratum corneum thickness of the rumen epithelium in calm-type Hu sheep was significantly lower than in nervous-type Hu sheep ($P<0.05$), and both the basal layer thickness and rumen papilla width were significantly greater in calm-type Hu sheep ($P<0.05$). In summary, calm-type Hu sheep exhibited a higher dressing percentage than nervous-type Hu sheep. Although compound stomach development did not differ significantly, calm-type Hu sheep possessed wider rumen epithelial papillae and a thinner stratum corneum, which would facilitate nutrient absorption.

Full Text

Comparison of Slaughter Performance, Complex Stomach Development, and Tissue Morphological Structure in Quiet- versus Excited-Temperament Hu Sheep

MAO Jianyu[1], LI Hao[1], WANG Mengzhi[1]*, DING Luoyang[2], BLACHE Dominique[2]

[1]College of Animal Science and Technology, Yangzhou University, Yangzhou 225009, China
[2]Department of Animal Physiology, The University of Western Australia, Perth 6009, Australia

Abstract

This study compared the slaughter performance, complex stomach development, and tissue morphological structure of Hu sheep with quiet versus excited temperaments. Twenty Hu sheep were selected using temperament assessment methods, with ten quiet-type and ten excited-type sheep constituting two separate groups under identical feeding conditions. Following a 7-day pre-experimental period, the formal experiment lasted 60 days. Upon completion, all sheep were slaughtered to isolate the complex stomach, which was weighed and processed for histological sectioning. The results indicated no significant differences in dry matter intake, pre-slaughter live weight, carcass weight, or organ indices between temperament groups ($P>0.05$). However, the dressing percentage was significantly higher in quiet-type sheep compared to excited-type sheep ($P<0.05$). While the complex stomach index did not differ significantly between groups ($P>0.05$), quiet-type sheep exhibited significantly lower stratum corneum thickness in the rumen epithelium ($P<0.05$) alongside significantly greater stratum basale thickness and rumen papillae width ($P<0.05$). In conclusion, quiet-type Hu sheep demonstrated superior dressing percentage compared to excited-type sheep. Although complex stomach development showed no significant differences, quiet-type sheep possessed wider rumen papillae and a thinner stratum corneum, which may facilitate enhanced nutrient absorption.

Keywords: temperament; quiet temperament; excited temperament; slaughter performance; complex stomach development; tissue morphology

Introduction

Zhou Zhanqin et al. [?] found that temperament affects growth rate and reproductive performance in Boer goats. Excited male goats exhibited earlier sexual maturity but lower yearling weight, reduced semen volume, and decreased sperm density compared to their calm counterparts. While international research has extensively investigated the genetic basis of temperament and its regulation of brain activity and hormone synthesis, Qui [?] identified candidate genes controlling temperament in Australian Merino sheep, and Brown et al. [?] demonstrated that selective improvement of temperament type and maternal behavior in Australian ewes enhanced lamb growth performance and produced additional beneficial traits. Similarly, Cooke et al. [?] reported that conception rates in beef cattle were negatively correlated with temperament scores, where higher scores indicated more excitable temperaments. These findings underscore that genetic factors play crucial roles in shaping sheep temperament and behavior, which in turn affect individual reproductive capacity, productivity, and overall herd profitability. However, the mechanisms through which temperament influences production performance remain unclear, and research on the relationship between temperament and behavior in sheep is limited.

Sheep of different temperaments exhibit variations in behavioral patterns, environmental responsiveness, and endocrine profiles, leading to differences in digestion, growth, and production performance [?]. Previous studies have shown that temperament influences growth rate and meat quality [?], though the underlying mechanisms remain insufficiently understood. This experiment aimed to compare differences in gastrointestinal development and tissue morphology between quiet-type and excited-type Hu sheep, providing foundational data for investigating the mechanisms through which temperament affects the digestive tract.

1.1 Experimental Animals and Feeding Management

The experiment was conducted at a Hu sheep farm in Xuyi County, Huai'an City, Jiangsu Province. Experimental animals were approximately 5-month-old Hu sheep with similar body weights [(30$±$2) kg], selected as quiet-type or excited-type using the Pen Score method developed by Hammond et al. [?]. Ten sheep of each temperament type were allocated to separate groups. All sheep were fed a total mixed ration (TMR) with a concentrate-to-forage ratio of 40:60, consisting primarily of corn-based concentrate and roughage composed of Chinese wildrye and corn silage. The basal diet composition and nutrient levels are presented in Table 1 . The pre-experimental period lasted 7 days, followed by a 60-day formal experimental period. During the formal period, feed was provided twice daily at 06:00 and 18:00, with each sheep fed individually.

Nutrient composition of the basal diet was analyzed according to *Feed Detection and Analysis Experimental Techniques* [?]. Crude protein content was determined using the Kjeldahl method, neutral detergent fiber (NDF) and acid detergent fiber (ADF) using the Van Soest detergent fiber analysis method, ether extract using Soxhlet extraction, calcium using the potassium permanganate method, and total phosphorus using the vanadium molybdate yellow colorimetric method.

1.2 Selection of Hu Sheep with Different Temperaments

Following the Pen Score method of Hammond et al. [?], sheep were scored based on their reactions to an approaching evaluator. The procedure was as follows: Sheep were housed in a pen, and an observer approached the flock to assess individual responses. Sheep that remained docile without reaction and allowed approach received a score of 1; those showing slight aggression and retreating to corners received 2 points; sheep that immediately fled along the pen edge while clearly identifying the observer' s position received 3 points; those displaying strong aggression and fleeing toward the pen door received 4 points; and sheep that became agitated and attempted to escape through doors or fences received 5 points.

Three observers conducted the scoring, with each observer performing two independent assessments. Final temperament classification was based on the combined scores: sheep with scores $ $2 were classified as quiet-type, while those with scores $ $4 were classified as excited-type. Using this method, ten sheep of each temperament type were selected for the experiment.

1.3 Sample Collection and Measurements

1.3.1 Dry Matter Intake Daily feed intake was recorded throughout the formal experimental period to calculate dry matter intake (DMI).

1.3.2 Slaughter Performance Slaughter performance was measured according to methods described by Zhao Youzhang et al. [?]. Sheep were fasted for 24 hours before slaughter at the end of the experimental period. After weighing, sheep were slaughtered, and the head, hooves, and internal organs were removed. The carcass was skinned, and weights of the carcass, heart, liver, kidneys, lungs, and spleen were recorded. The rumen, reticulum, omasum, and abomasum were separated, emptied of digesta, and weighed fresh. Calculations were performed as follows:

- Dressing percentage (%) = (carcass weight / pre-slaughter live weight) × 100
- Organ index (%) = (organ weight / pre-slaughter live weight) × 100
- Complex stomach index (%) = (complex stomach weight / pre-slaughter live weight) × 100

1.3.3 Complex Stomach Tissue Morphology Immediately after slaughter, the gastrointestinal tract was isolated, emptied, washed, and weighed. Tissue samples (2 cm × 2 cm) were collected from the middle portion of each stomach compartment (rumen, reticulum, omasum, and abomasum). Samples were fixed in tissue fixative (120 mL of 40% paraformaldehyde, 880 mL distilled water, 4 g $NaH_2PO_4 \cdot H_2O$, and 13 g Na_2HPO_4), then processed routinely through paraffin dehydration, xylene clearing, and paraffin embedding. Sections were cut at 6 m thickness and stained with hematoxylin-eosin (HE) for microscopic examination of rumen papillae and small intestinal mucosal morphology. Using Image-Pro Express image analysis software, three non-consecutive sections were examined per sample. For the rumen, papilla length, width, mucosal layer thickness, and muscular layer thickness were measured. For small intestine sections, villus height and crypt depth were measured. At least five fields of view were evaluated for mucosal and muscular layers, with mean values calculated from these measurements.

1.4 Statistical Analysis

Experimental data were compiled using Excel 2003 and analyzed using SPSS 22.0. Independent t-tests were performed with significance declared at $P<0.05$.

2.1 Dry Matter Intake and Slaughter Performance

As shown in Table 2 , no significant differences were observed between quiet-type and excited-type Hu sheep in dry matter intake, pre-slaughter live weight, or carcass weight ($P>0.05$). However, dressing percentage was significantly higher in quiet-type sheep compared to excited-type sheep ($P<0.05$). No significant differences were detected between groups for organ indices of heart, liver, spleen, lungs, and kidneys, or for loin muscle area ($P>0.05$).

2.2 Complex Stomach Development and Tissue Morphology

Table 3 shows that no significant differences existed between quiet-type and excited-type sheep in complex stomach weight or complex stomach index ($P>0.05$). Additionally, the proportional weights of rumen, reticulum, omasum, and abomasum relative to total complex stomach weight did not differ significantly between groups ($P>0.05$). However, quiet-type sheep exhibited significantly thinner stratum corneum in the rumen epithelium compared to excited-type sheep ($P<0.05$), while stratum basale thickness and rumen papillae width were significantly greater ($P<0.05$) (Table 3 and Figure 1 [Figure 1: see original paper]).

3 Discussion

Dry matter intake represents one of the most critical indicators of ruminant nutrition, fundamentally determining whether animal production proceeds in a healthy and efficient manner. While physical and chemical factors such as dietary energy levels and environmental conditions interactively affect DMI, psychological and sensory factors also influence feed intake [?]. Nkrumah et al. [?] reported that excited-type beef cattle had higher DMI than quiet-type cattle, whereas Francisco et al. [?] found no differences in DMI among Nellore cattle of different temperaments. In the present study, no significant difference in DMI was observed between temperament groups in Hu sheep. Slaughter performance serves as a key metric for evaluating animal production efficiency. Numerous studies have demonstrated that differences in pre-slaughter live weight ultimately lead to variations in slaughter performance, with sheep dressing percentage increasing with greater live weight [?]. In this experiment, although pre-slaughter live weight did not differ significantly between quiet-type and excited-type sheep, carcass weight tended to be higher in quiet-type sheep, resulting in a significantly greater dressing percentage. Additionally, some reports suggest that lamb metabolic activity can be indirectly reflected by metabolic rate and volume of visceral organs [?], with higher metabolic rates and larger organ volumes increasing protein synthesis and nutrient absorption for normal metabolic maintenance [?]. However, this study found no significant differences between temperament groups in organ indices for heart, liver, spleen, lungs, and kidneys, or in loin muscle area.

The ruminant forestomach comprises the rumen, reticulum, omasum, and abomasum. At birth, the rumen constitutes approximately 30% of the complex stomach, but in adulthood, it accounts for 60-80% of total complex stomach weight [?]. Ruminant fiber degradation depends on the rumen, where digesta forms three layers: gas, dense, and liquid phases. Effective utilization of fibrous materials in roughage relies primarily on rumination, during which digesta is regurgitated through the esophagus to the mouth for re-mastication [?]. The rumen occupies nearly the entire left abdominal cavity, with digesta passing through the cardia and entering the reticulum via the rumino-reticular orifice after initial processing. Beyond mechanical degradation, the rumen performs crucial fermentative digestion through microorganisms including bacteria, methanogens, fungi, protozoa, and a few bacteriophages [?]. Rumen development is reflected by both increased capacity and rumen epithelial development. Under healthy conditions, rumen weight increases with animal growth, enhancing capacity and facilitating feed utilization in adult ruminants [?]. In this study, no obvious differences were observed in complex stomach development between temperament groups, and the proportional weights of rumen, reticulum, omasum, and abomasum also did not differ significantly.

Beyond volumetric changes, rumen mucosal development plays a vital role in ruminant digestion and utilization of feed, particularly roughage. Rumen mucosal differentiation begins during embryonic development, with epithelial and lamina propria protrusions forming mobile rumen papillae that perform mechanical digestion through kneading and grinding. Approximately 250,000 papillae project from the rumen wall, increasing mucosal surface area by approximately six-fold and significantly enhancing digestive and absorptive capacity [?]. Consequently, papilla size serves as an important criterion for evaluating rumen and mucosal digestive and absorptive function [?]. This study found that quiet-type Hu sheep had higher dressing percentage than excited-type sheep. Further investigation of complex stomach development and tissue structure revealed that quiet-type sheep had significantly wider rumen papillae, which increased contact between rumen epithelium and feed, promoted nutrient digestion and absorption, and consequently improved meat production performance.

The rumen papilla surface consists of stratified squamous epithelial cells. Rumen epithelial tissue comprises four layers from outer to inner: stratum corneum, stratum granulosum, stratum spinosum, and stratum basale. Incomplete keratinization of the rumen occurs when squamous epithelial cells produce a rigid keratin layer, which serves as a physical barrier but can coat papilla surfaces, reducing blood flow and causing papilla degeneration, necrosis at margins, and eventual clumping [?]. Keratin layer formation primarily results from insufficient dietary particle size, which fails to mechanically remove aging epithelial cells. While once considered detrimental to absorption, subsequent research has shown that under normal conditions, continuous abrasion from rumen contents maintains the keratinized cell layer at only 3-4 cells thick, having minimal impact on nutrient absorption while providing significant papilla protection. This study found that quiet-type sheep had thinner rumen papilla stratum corneum than excited-type sheep, potentially offering less protective function. However, other researchers have demonstrated that high-concentrate diets can increase stratum corneum thickness to 15 cell layers, whereas high-roughage diets maintain only 4 cell layers, with excessive thickness clearly impairing nutrient absorption [?]. In this experiment, the thinner stratum corneum in quiet-type sheep likely facilitated nutrient absorption by rumen papillae. The stratum basale, which forms the foundation of rumen papillae, contains fully functional mitochondria and other organelles. The greater thickness observed in quiet-type sheep in this study would benefit rumen epithelial renewal and damage repair. The stratum granulosum features tight junctions but is discontinuous and lacks sebaceous glands, allowing free water passage, while the stratum spinosum serves as the site for short-chain fatty acid metabolism in rumen epithelial tissue. Thus, both the stratum granulosum and stratum spinosum are important for nutrient transport across rumen epithelium [?], though no significant differences in these layers were observed between temperament groups in this study.

4 Conclusion

Quiet-type Hu sheep exhibited higher dressing percentage than excited-type sheep. Although complex stomach development showed no significant differences, quiet-type sheep possessed wider rumen papillae and a thinner stratum corneum, which may facilitate enhanced nutrient absorption.

References

[1] Zhou Zhanqin, Wu Heping, Chen Xiaoqiang, et al. Behavioral characteristics of Boer goats[J]. Acta Agriculturae Boreali-occidentalis Sinica, 2008, 17(4): 10–13.

[2] QUI X Y. Gene polymorphisms associated with temperament in Merino sheep[D]. Ph.D. Thesis. Perth: The University of Western Australia, 2015.

[3] BROWN D J, FOGARTY N M, IKER C L, et al. Genetic evaluation of maternal behaviour and temperament in Australian sheep[J]. Animal Production Science, 2016, 56(4): 767–774.

[4] COOKE R F, BOHNERT D W, MENEGHETTI M, et al. Effects of temperament on pregnancy rates fixed-timed indicus cows[J]. Livestock Science, 2011, 142(1/2/3): 108-113.

[5] Ma Yanfen, Du Ruiping, Gao Min. Effects of heat stress on production performance and morphological structure of rumen epithelial cells in dairy goats[J]. Scientia Agricultura Sinica, 2013, 46(21): 4486-4495.

[6] BLACHE D, BICKELL S L. Temperament and reproductive biology: emotional reactivity and reproduction in sheep[J]. Revista Brasileira de Zootecnia, 2010, 39: 401-408.

[7] CAVIGELLI S A, BENNETT J M, MICHAEL K C, et al. Female temperament, tumor development and life span: relation to glucocorticoid and tumor necrosis factor α levels in rats[J]. Brain, Behavior, and Immunity, 2008, 22(5): 727-735.

[8] MÜLLER R, VON KEYSERLINGK M A G. Consistency of flight speed and its correlation to productivity and to personality in Bos taurus beef cattle[J]. Applied Animal Behaviour Science, 2006, 99(3): 193-204.

[9] CAFE L M, ROBINSON D L, FERGUSON D M, et al. Cattle temperament: persistence of assessments and associations with productivity, efficiency, carcass and meat quality traits[J]. Journal of Animal Science, 2011, 89(5): 1452-1465.

[10] NJISANE Y Z, MUCHENJE V. Farm to abattoir conditions, animal factors and their subsequent effects cattle behavioural responses quality—A review[J]. Asian-Australasian Journal of Animal Sciences, 2017, 30(6): 755-764.

[11] HAMMOND A C, OLSON T A, CHASE C C, Jr., et al. Heat tolerance in two tropically adapted Bos taurus breeds, Senepol and Romosinuano, compared with Brahman, Angus, and Hereford cattle in Florida[J]. Journal of Animal Science, 1996, 74(2): 295-303.

[12] Wang Hongrong. Feed Detection and Analysis Experimental Techniques[M]. Nanjing: Southeast University Press, 2014.

[13] Xiong Benhai. International Ruminant Feed Composition and Nutritional Value Tables[M]. Beijing: China Agricultural Science and Technology Press, 2013.

[14] Zhao Youzhang, Wang Yuqin. Modern Sheep Farming in China[M]. Beijing: Jindun Publishing House, 2005.

[15] Subcommittee on dairy cattle nutrition. Nutrient requirements of dairy cattle[M]. 7th ed. Washington, D.C.: National Academies Press, 2001.

[16] NKRUMAH J D, CREWS D H, BASARAB J A, et al. Genetic and phenotypic relationships of feeding behavior and temperament with performance, feed efficiency, ultrasound, and carcass merit of beef cattle[J]. Journal of Animal Science, 2007, 85(10): 2382-2390.

[17] FRANCISCO C L, RESENDE F D, BENATTI J M B, et al. Impacts of temperament on Nellore cattle: physiological responses, feedlot performance, and carcass characteristics[J]. Journal of Animal Science, 2015, 93(11): 5419–5429.

[18] DHANDA J S. Evaluation crossbred sheep production typics[M]. London: Long Man Group Ltd., 2001: 56–59.

[19] PRIOLO A, MICOL D, AGABRIEL J, et al. Effect of grass or concentrate feeding systems on lamb carcass and meat quality[J]. Meat Science, 2002, 62(2): 179–185.

[20] Zhao Yanguang, Hong Qionghua, Xie Ping, et al. Effects of concentrate nutrition on slaughter performance and meat quality of Yunnan semi-fine wool sheep[J]. Acta Prataculturae Sinica, 2014, 23(2): 277–286.

[21] Yue Xixin. Effects of protein level and feeding amount on growth performance and digestion metabolism of early-weaned lambs[D]. Master' s Thesis. Ala' er: Tarim University, 2011.

[22] Feng Yanglian. Ruminant Nutrition[M]. Beijing: Science Press, 2004.

[23] LEE H J, JUNG J Y, OH Y K, et al. Comparative survey of rumen microbial communities and metabolites across one caprine and three bovine groups, using bar-coded pyrosequencing and nuclear magnetic resonance spectroscopy[J]. Applied Environmental Microbiology, 2012, 78(17): 5983–5993.

[24] Li Hui. Effects of protein level and source on digestion metabolism and gastrointestinal structure of early-weaned calves[D]. Ph.D. Thesis. Beijing: Chinese Academy of Agricultural Sciences, 2008.

[25] LESMEISTER K E, TOZER P R, HEINRICHS A J. Development and analysis of a rumen tissue sampling procedure[J]. Journal of Dairy Science, 2004, 87(5): 1336–1344.

[26] Gao Yanxia, Wang Jiaqi. Development of digestive function in newborn calves and influencing factors[J]. China Dairy Cattle, 2006(8): 6–9.

[27] BALDWIN R L, JESSE B W. Isolation and characterisation of sheep ruminal epithelial cells[J]. Journal of Animal Science, 1991, 69(9): 3603–3609.

[28] BEHARKA A A, NAGARAJA T G, MORRILL J L, et al. Effects of form of the diet on anatomical, microbial, and fermentative development rumen neonatal calves1[J]. Journal of Dairy Science, 1998, 81(7): 1946–1955.

[29] HUYEN N T, WANAPAT M, NAVANUKRAW C. Effect of mulberry leaf pellet (MUP) supplementation on rumen fermentation and nutrient digestibility in beef cattle fed on rice straw-based diets[J]. Animal Feed Science and Technology, 2012, 175(1/2): 8–15.

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