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Sexual Maturity in Male Guinea Pigs: A Review of Normal Development and Factors Causing Delayed Maturation

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ABSTRACT

Sexual maturity in male guinea pigs (Cavia porcellus) is a critical biological milestone marking the onset of reproductive capability, generally occurring between 45 to 55 days of age under optimal conditions. This review synthesizes current scientific knowledge on the normal developmental trajectory of sexual maturity in male guinea pigs, focusing on the physiological, hormonal, and morphological changes involved. The process is characterized by the activation of the hypothalamic-pituitary-gonadal axis, leading to increased testosterone secretion, spermatogenesis initiation, and the development of secondary sexual characteristics such as testicular growth and penile spicules. However, this tightly regulated process is highly sensitive to a range of intrinsic and extrinsic factors that can delay maturation with significant implications for animal breeding, research validity, and welfare. Key factors influencing the timing of sexual maturity include nutritional status, environmental conditions, genetic background, and health status. Severe nutritional deficiencies, particularly in protein and vitamin C, can substantially retard sexual development by disrupting hormonal balance and limiting energy resources necessary for growth. Environmental factors such as photoperiod, temperature, and social stress also modulate maturation timing, with males exhibiting greater sensitivity than females. Genetic and strain-specific differences contribute to individual variability in developmental rates. Furthermore, infectious diseases and metabolic disorders during juvenile stages adversely affect reproductive development by diverting physiological resources to immune responses. Understanding these factors is essential for optimizing guinea pig husbandry practices in laboratory and domestic settings, enhancing breeding program outcomes, and ensuring the welfare of these animals. This review highlights the importance of integrated management approaches encompassing nutrition, environment, health monitoring, and genetic considerations. Future research directions include exploring epigenetic regulation, nutritional genomics, and advanced reproductive technologies to further unravel the complex mechanisms controlling sexual maturation and to improve breeding efficiency and animal welfare.

Keywords: *Guinea pig, sexual maturity, puberty, reproduction, nutrition, environmental factors*

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INTRODUCTION

The domestic guinea pig (*Cavia porcellus*) serves as an important animal model in biomedical research and has become increasingly popular as a companion animal (Shomer *et al*., 2015). Understanding the normal parameters of sexual development and the factors that can disrupt this process is essential for successful breeding programs, research protocols, and animal welfare considerations. Unlike many other laboratory rodents, guinea pigs are born as precocial young with advanced developmental status, yet their sexual maturation follows a complex pattern influenced by multiple environmental and physiological factors (Bauer *et al*. 2008; Genzer *et al*., 2023). Sexual maturity in male guinea pigs represents a critical developmental milestone that determines reproductive capacity and influences long-term health outcomes. The process involves coordinated changes in the hypothalamic-pituitary-gonadal (HPG) axis, resulting in increased testosterone production, spermatogenesis initiation, and the development of secondary sexual characteristics. However, this developmental process is remarkably sensitive to external influences, making guinea pigs an excellent model for studying environmental and nutritional effects on reproductive development (Slob *et al*. 1979; Zheng *et al*., 2015). Recent research has revealed significant variability in the timing of sexual maturation among male guinea pigs, with some animals achieving fertility as early as 17 days while others may not reach full sexual maturity until 70 days of age or later (de Matos *et al*. 2022; Quispe-Ccasa *et al*., 2023). This variability appears to be largely attributable to modifiable factors, suggesting that understanding and controlling these influences could optimize reproductive outcomes and animal welfare (Balzani & Hanlon, 2020; Emokpae & Brown, 2021).

Normal Sexual Maturation Development in Male Guinea Pigs

Timeline of Sexual Development

Sexual maturity in male guinea pigs follows a predictable developmental sequence, though the timing can vary considerably based on multiple factors. Research utilizing light and electron microscopy has provided detailed insights into the cellular changes occurring during sexual development (de Matos *et al*., 2022). The earliest signs of sexual development typically appear around 14 days of age (Figure 1), when some males begin to exhibit mounting behavior, though this behavior is not indicative of fertility (Young & Grunt, 1951).

At 30 days of age, microscopic examination reveals the differentiation of spermatocytes only through transmission electron microscopy in the leptotene, zygotene and pachytene phases of meiosis (Holstein *et al*. 2003; Han *et al*., 2021). During the pubertal period around 45 days, there is differentiation of the germinative epithelium and formation of the acrosome, however spermatozoa are not yet detected, indicating that the onset of puberty occurs after 45 days of age (Simões et al., 2016). True sexual maturity, defined as the capacity for successful reproduction with spermatozoa present in the epididymis, generally occurs between 45-55 days of age under optimal conditions (Bork *et al*., 1998).

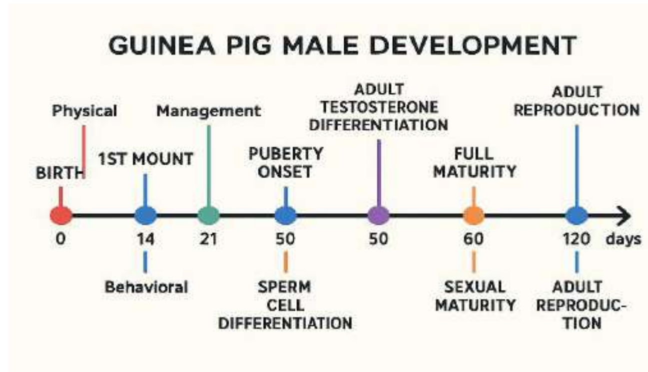

Figure 1: Timeline of sexual development in male guinea pigs from birth to 120 days of age, showing key developmental milestones in behavioral, hormonal, cellular, and functional categories.

Hormonal Changes during Sexual Maturation

The hormonal changes underlying sexual maturation begin early in postnatal development. Research has demonstrated that plasma testosterone concentrations reach adult levels by approximately 50 days of age and remain relatively stable throughout the pubertal period (Arnold *et al*., 1996). This early testosterone elevation is crucial for initiating spermatogenesis and the development of accessory sex organs. The development of both Leydig and Sertoli cells characterizes the phase of puberty and sexual maturity (Zheng *et al*., 2022). Hormonal activity of the testes appears to mature well before the first spermatozoa are found, with testosterone levels similar to those found in adult male guinea pigs observed at 35 days of age. Peak testosterone levels typically occur around 70 days of age followed by a gradual decline to adult maintenance levels (Slob *et al*., 1979).

Studies on testosterone secretion capacity show that guinea pig testes have substantial steroidogenic capacity, with perfused testes releasing 9.76 ± 2.05 micrograms testosterone per hour when stimulated with luteinizing hormone (Zirkin *et al*., 1980; Mendis-Handagama *et al*., 1988). This represents one of the highest testosterone secretion rates among laboratory rodent species (Ewing *et al*., 1979).

Markers of Sexual Maturity

The primary indicator of sexual maturity in male guinea pigs is the presence of spermatozoa in the epididymis, which typically occurs between 45-55 days of age under normal conditions (Quispe-Ccasa *et al*., 2023). This milestone represents functional fertility, as males become capable of successful mating and reproduction. Concurrent with sperm production, the testes undergo rapid growth and descent, with testicular volume increasing significantly during the 4-8 week period (Benavides *et al*., 2020).

Secondary sexual characteristics also develop during this period, including the growth of seminal vesicles, which can be quite large in guinea pigs and are sometimes mistaken for uterine horns during necropsy (Ventura et al., 1968). The development of penile spicules, specialized keratinized structures on the penis, also occurs during puberty and is testosterone-dependent (Ayala Guanga *et al*., 2020). Recent morphometric studies of guinea pig spermatozoa have revealed detailed characteristics that can be used to assess reproductive maturity. Normal spermatozoa have a nucleus length of approximately 8.25 μm, width of 7.34-7.37 μm, and total sperm length including the tail of approximately 89-90 μm (Quispe-Ccasa *et al*., 2023).

Individual Variation and Influencing Factors

Even under optimal conditions, considerable individual variation exists in the timing of sexual maturity. Birth weight appears to be a significant predictor of sexual maturity timing, with high birth-weight animals showing a higher incidence of advanced stages of spermatogenesis compared to low birth-weight littermates at various ages studied (Rubim Sacramento *et al*., 2022). This relationship suggests that prenatal factors affecting fetal growth also influence postnatal reproductive development. The timing of testicular development appears to be determined by the time the animals are born and seems to be largely unaffected by severe under nutrition from 21 days of age, though the progression of spermatogenesis can be delayed (Glass *et al*., 1986). This indicates that while the initiation of sexual development may be programmed, the completion of the process is highly dependent on environmental conditions. Research on wild guinea pig species has shown that age at first conception in *Cavia aperea* can vary dramatically with season of birth, from 28 days in animals born during favorable seasons to 255 days in those born during unfavorable periods (Rübensam *et al*., 2015). However, in laboratory conditions with controlled environment and nutrition, females paired with males from birth showed a mean age at conception of 60.6 days (range 17 to 152 days), with twenty-one animals conceiving at their first estrus (Fitria *et al*., 2022).

Nutritional Factors Affecting Sexual Maturity

Severe Under nutrition

Severe under nutrition represents one of the most significant factors capable of delaying sexual maturity in male guinea pigs (Slob *et al*., 1979).

Research has demonstrated that males subjected to severe nutritional restriction from 21 days of age show dramatically delayed spermatogenesis compared to normally fed counterparts (Slob *et al*., 1979; Quispe-Ccasa *et al*., 2023). In severely undernourished animals with weight gains of only 1.2 g/day compared to 10 g/day in controls, spermatogenesis was clearly delayed (Genovese *et al*., 2010).

The undernourished animals had very low plasma testosterone levels with no overlap with normally fed groups of the same age (Santos *et al*., 2004). Despite these low testosterone levels, maintenance of spermatogenesis seemed compatible with low plasma levels of testosterone, suggesting that testicular testosterone concentration rather than peripheral blood concentration is important for spermatogenesis (Santos *et al*., 2004). Historical observations documented that guinea pigs on poor quality diets reached sexual maturity at 75-100 days after birth, compared to 45-60 days on rich diets and 55-70 days on usual diets. The quality of food affected not only the timing of sexual maturity but also the physical condition and size of the animals (de Figueiredo *et al*., 2020)

Protein Deficiency during Early Development

Dietary protein content during early development has been identified as particularly important for normal sexual maturation. Research examining the effects of low-protein diets (14%) versus high-protein diets (23%) during gestation and lactation found significant effects on offspring development (Jang *et al*., 2014). Protein restriction during gestation and/or lactation resulted in decreased body and reproductive organ weight, delayed puberty onset, and reduced reproductive performance (Pinheiro *et al*., 2008).

Recent studies on lysine requirements in breeding guinea pigs have shown that optimal lysine levels (1.18% of diet) improve reproductive performance compared to lower levels (Typpo *et al*., 1985; Vargas-Jauja *et al*., 2025). Guinea pigs receiving 1.18% lysine had offspring with the highest birth weight (206±4.4 g) and weight gain at weaning (197.7±8.9 g), while excessive lysine (1.34%) caused increased young mortality (18.2%) during lactation (Vargas-Jauja *et al*., 2025). In guinea pigs, growth is sensitive to the quality of the maternal and early postnatal diet, and reproductive maturation is more sensitive in females than males (Bauer *et al*., 2009). However, body weight of offspring was significantly affected by dietary treatment in both sexes, indicating the importance of adequate protein intake during critical developmental periods (Le *et al*., 2023. The challenges of guinea pig nutrition remain focused on efficiently satisfying protein needs. Studies comparing different protein sources have shown that diets containing *Stylosanthes guianensis* meal achieved higher fertility rates (76.92%) and litter sizes compared to control diets, highlighting the importance of protein quality in addition to quantity (Ntsafack *et al*. 2021).

Vitamin C Deficiency and Its Impact on Reproduction

Guinea pigs, like humans, cannot synthesize vitamin C and are therefore dependent on dietary sources of this essential nutrient. Recent comprehensive research has demonstrated that vitamin C deficiency has significant impacts on reproductive health and fertility (Chambial *et al*., 2013). Animals receiving a low vitamin C diet (100 mg/kg feed) compared to optimal intake (900 mg/kg feed) had an increased number of unsuccessful matings, higher incidence of fetal reabsorption, and among pregnancies resulting in delivery at term, produced fewer offspring (Coker *et al*., 2023; Coker *et al*., 2024). A study concluded that a diet low in vitamin C induces a state of subfertility, reduces overall fecundity, and adversely impacts both pregnancy outcomes and growth in offspring (Shukla & Shrivastava, 2024).

Coker *et al*., 2023 noted that poor-quality diets deficient in vitamin C could delay sexual maturity by 15-40 days compared to animals receiving adequate nutrition. The mechanism involves the role of vitamin C as a cofactor for various enzymatic processes, including collagen synthesis and hormone production. Vitamin C also plays a crucial role in maintaining the integrity of blood vessels and supporting immune function, both of which are important for normal reproductive development (Alberts, *et al*., 2025). Other studies have shown that vitamin C deficiency can lead to impaired sperm production and function, potentially affecting male fertility. Reduced levels of ascorbic acid in the testes can result in oxidative damage to sperm cells and alterations in sperm motility and morphology (Fernandes *et al*., 2011). These effects can hamper the ability to fertilize ova and contribute to sub fertility in males.

Environmental Factors and Sexual Maturity

Photoperiod and Temperature Effects

Environmental conditions during prenatal and early postnatal development have been shown to significantly influence sexual maturation in male guinea pigs (Figure 2). Research examining the effects of different photoperiod and temperature combinations found that males exposed to short photoperiod (8L:16D) and cold temperature (15°C) conditions showed delayed pubertal testosterone increases compared to those in long photoperiod (16L:8D) and warm temperature (25°C) conditions (Quispe-Ccasa, *et al*., 2023).

Mean body weight of males from long photoperiod/warm temperature conditions was higher than that of short photoperiod/cold temperature males during the whole pubertal period, although the difference was significant only during the early growth phase (Bauer *et al*., 2008). Testosterone concentrations also differed significantly between the two treatment groups, pointing to an earlier pubertal onset in long photoperiod/warm temperature than short photoperiod/cold temperature males (Bauer *et al*., 2008). The somatic and reproductive development is more sensitive to early photoperiod and temperature conditions in male than female guinea pigs, indicating sex-specific sensitivity to environmental factors during the critical period of sexual development (Bauer *et al*., 2008). This finding has important implications for laboratory animal facilities and breeding programs, as seasonal variations in lighting and temperature could inadvertently affect reproductive outcomes. Recent studies on photoperiodic effects on sperm morphology have shown that LED light photoperiods (10L/14D) can improve sperm quality and accelerate reproductive maturity compared to natural sunlight exposure (Quispe-Ccasa, *et al*., 2023). Guinea pigs exposed to LED photoperiods showed earlier mating age (61.5 ± 0.5 days) compared to animals without direct light stimulation (84.5 ± 0.6 days), though pregnancy rates were higher in the non-stimulated group (100% vs 50%). Interestingly, exposure to natural sunlight with high temperature resulted in complete reproductive failure, with no pregnancies achieved, likely due to heat stress effects on spermatogenesis (Quispe-Ccasa, *et al*., 2023). This emphasizes the importance of controlled environmental conditions for optimal reproductive development.

Social Housing and Stress Effects

Social housing conditions have been shown to influence sexual maturity timing through their effects on stress hormone production. Research on guinea pigs housed in same-sex groups revealed that cortisol concentrations increase during adolescence in males but remain stable in females (Kaiser *et al*., 2007). This pattern was suggested to be related to different social and energetic demands by age and sex.

During the teenage months (4-15 months of age), males housed in same-sex groups show characteristic increases in cortisol, which can negatively impact growth and reproductive development (Nemeth *et al*., 2024). The mechanism involves social competition and hierarchy establishment, which triggers stress responses that can suppress the hypothalamic-pituitary-gonadal axis.

Studies throughout the guinea pig lifespan have revealed age-specific changes in social buffering patterns (Nemeth *et al*., 2024). In peri-adolescent individuals aged 49-61 days, exposure to unfamiliar females demonstrated a protective effect against cortisol elevation in response to novel environments. This buffering effect was not observed when the subjects were in the presence of favored females. The findings suggest that interactions with unfamiliar females may play a unique role in modulating stress responses during this developmental stage, potentially influencing how peri-adolescents adapt to new situations (Hennessy *et al*., 2008). At the sexually but not socially mature stage (114-126 days), cortisol responses to novelty were depressed in all conditions, representing a previously undescribed period of cortisol response suppression in maturing male guinea pigs (Hennessy *et al*., 2006).

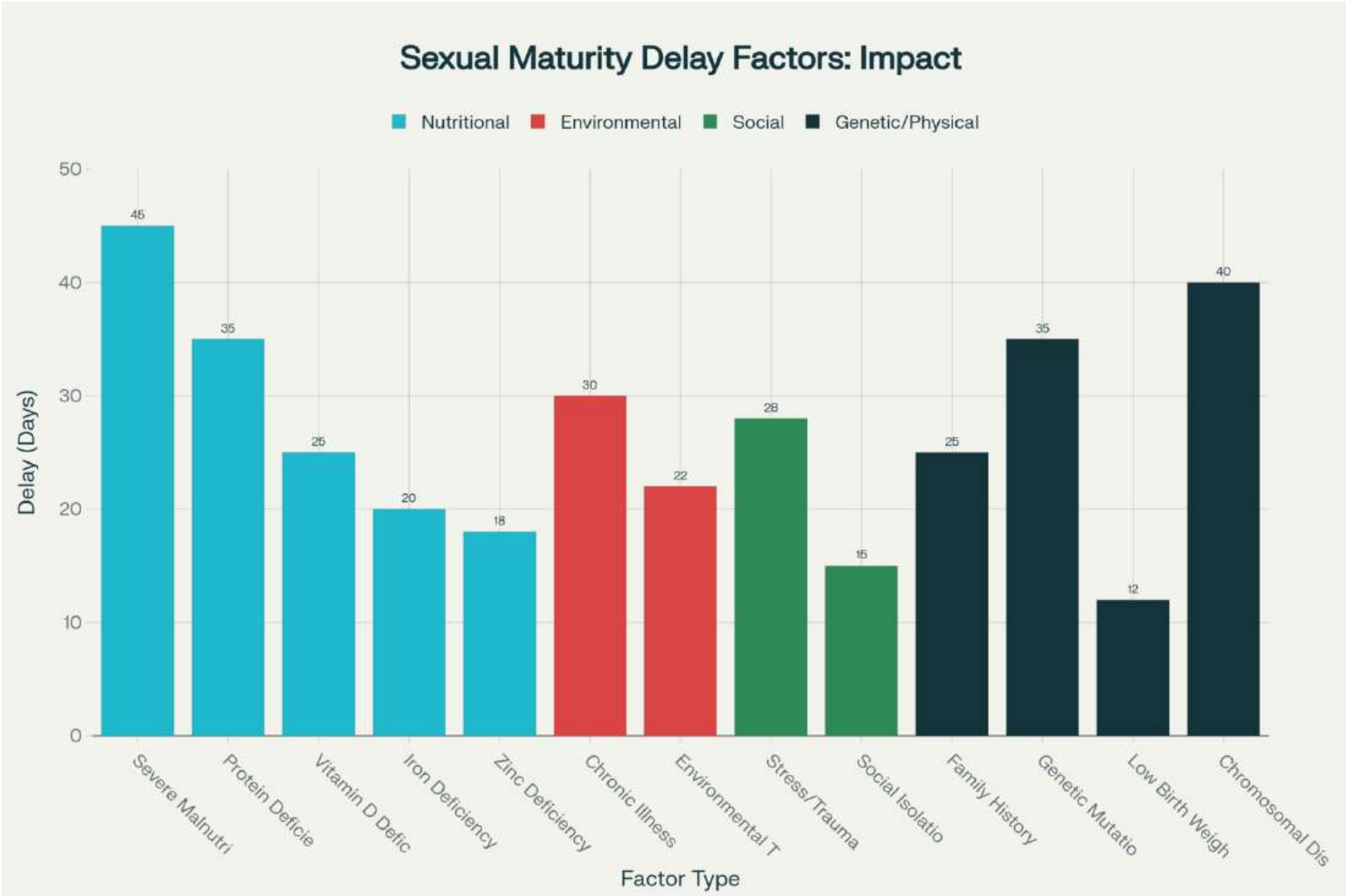

Figure 2: Comprehensive analysis of factors that can delay sexual maturity, organized by category and showing relative impact in days.

Research on dietary fatty acids has shown that stress-induced cortisol elevation can negatively affect body mass and potentially delay sexual maturation, with sex-specific effects more pronounced in males (Nemeth *et al*., 2016). Male guinea pigs showed a U-shaped pattern in cortisol secretion with age, while females showed decreasing levels, indicating different stress response patterns between sexes during development (Nemeth *et al*., 2025) The importance of social housing is emphasized by welfare guidelines stating that guinea pigs are social animals and should never be housed singly without compelling veterinary or scientific justification (Elsbacher *et al*., 2025). Individual housing not only compromises welfare but may also delay normal social and sexual development (Elsbacher *et al*., 2025).

Genetic and Strain Differences

Breed and Strain Variations

While environmental factors play the predominant role in determining sexual maturity timing, genetic factors also contribute to individual variation. Different guinea pig strains show characteristic differences in reproductive development, with some inbred lines consistently maturing earlier or later than others. Research has documented behavioral and physiological differences between guinea pig strains, including variations in growth patterns and maturation rates (Rosero *et al*., 2024).The differences in body weight at birth foreshadow those in adulthood, with animals small at birth becoming small adults and animals large at birth becoming large adults (Sarr *et al*., 2014). This suggests that the mechanisms controlling adult body weight and sexual maturation timing in guinea pigs become set sometime before birth, emphasizing the importance of prenatal factors (Schöpper *et al*., 2012).

Studies on inbred guinea pig lines have shown that inbreeding can affect various reproductive parameters, though the effects on sexual maturity timing are relatively modest (Wang *et al*., 2020). Each percent increase in inbreeding resulted in decreased litter size and weaning weight, but had minimal effects on age at puberty. However, birth weight remained an important predictor, with heavier animals reaching puberty earlier regardless of inbreeding status (Kraus *et al*., 2024).

Research on specialized guinea pig strains, such as those bred for bronchial hypersensitivity studies, has demonstrated that selective breeding can alter physiological characteristics that may indirectly affect reproductive development (Mikami *et al*., 1991). These findings suggest that genetic selection for specific traits should consider potential impacts on reproductive parameters.

Sex-Specific Genetic Programming

Recent research has revealed important sex-specific differences in the genetic control of reproductive development. Studies examining testosterone effects during fetal development found that prenatal androgen exposure significantly affects postnatal growth patterns and sexual maturation timing (Roy, 1992). Male guinea pigs from testosterone propionate-treated mothers were heavier at birth and showed altered growth curves compared to controls. The capacity for testosterone biosynthesis is present in fetal guinea pig testes as early as 25 days of gestation and increases during subsequent development (Roy, 1992). This early testosterone production is crucial for sexual differentiation and may influence later reproductive maturation patterns. Studies on castration and sterilization effects have shown that testosterone experienced during adolescence can shape long-term cortisol responsiveness and stress sensitivity (Kaiser *et al*., 2023). Males with high testosterone exposure during development showed different cortisol response patterns, which could influence the timing of sexual maturation and adult reproductive capacity (Kapoor & Matthews, 2011).

Health Factors and Pathological Conditions

Infectious Diseases and Immune System Activation

Infections and illnesses during the critical juvenile period can significantly delay sexual maturity through multiple mechanisms. Acute or chronic infections divert energy resources toward immune system activation and away from growth and reproductive development. Additionally, inflammatory responses associated with infections can disrupt normal hormonal signaling pathways (Trillmich *et al*., 2020).

Common respiratory infections, such as those caused by *Chlamydia caviae*, typically affect young animals between 4-8 weeks of age, coinciding with the critical period for sexual development (Ciuria *et al*., 2021). Predisposing factors for bacterial pneumonia include changes in environmental temperature, humidity, or ventilation, which often occur during winter housing transitions (Harkness *et al*., 2002).

The clinical implication is that maintaining optimal health during the juvenile period is crucial for normal sexual development. Prevention of infectious diseases through appropriate vaccination, quarantine procedures, and environmental management should be prioritized in breeding programs (Fitria *et al*., 2022).

Metabolic Disorders and Their Impact

Metabolic disorders affecting energy balance can significantly impact sexual maturity timing. Conditions that interfere with normal metabolism, such as diabetes or thyroid disorders, can delay reproductive development by affecting the energy available for growth and hormonal processes essential for sexual maturation (Mazza *et al*., 2024). Recent studies on metabolic rate and cortisol concentrations in adolescent guinea pigs have revealed complex interactions between energy metabolism and stress hormone production during development. Animals with elevated cortisol showed altered metabolic patterns that could potentially delay sexual maturation (Nemeth *et al*., 2024). Guinea pig pregnancy toxemia, characterized by metabolic dysfunction during late pregnancy, can also indirectly affect male offspring development by compromising prenatal nutrition and development. This condition can result in smaller, weaker offspring with delayed developmental milestones (Pedersen *et al*., 2025).

Clinical Implications and Management Strategies

Breeding Program Optimization

Understanding the factors that influence sexual maturity timing has important practical implications for breeding program management. Breeding facilities should implement standardized protocols for nutrition, housing, and environmental conditions to ensure consistent reproductive development among animals (von Engelhardt *et al*., 2015).

Key management strategies include providing optimal nutrition with adequate protein (20-25%) and vitamin C supplementation (≥900 mg/kg feed), maintaining consistent environmental conditions with appropriate photoperiod (16L:8D) and temperature (20-25°C), minimizing stress through proper housing design and handling procedures, monitoring growth rates and body condition throughout the juvenile period, and implementing health monitoring and disease prevention protocols (Castro-Bedriñana & Chirinos-Peinado, 2021).

Recent research on time mating protocols has shown that systematic monitoring of reproductive development can improve breeding efficiency. Techniques such as vaginal membrane monitoring and ultrasound confirmation can help predict optimal mating times and improve reproductive success rates (Wilson *et al*., 2021).

Early Detection of Delayed Maturity

Early identification of animals with delayed sexual maturity is important for breeding program management and animal welfare. Regular monitoring of body weight, growth rate, and behavioral indicators can help identify individuals requiring intervention or removal from breeding programs (Genzer *et al*., 2023). Animals showing signs of delayed maturity, such as failure to achieve expected weight milestones or absence of typical reproductive behaviors by 8-10 weeks of age, should undergo thorough evaluation for underlying causes including assessment of nutritional status, health screening, and review of environmental conditions (Shomer *et al*., 2015). Standard weaning protocols typically involve separation at 21 days of age and weighing at >180g, but recent evidence suggests that some females may reach sexual maturity as early as 16-17 days of age, necessitating earlier separation in breeding colonies. This finding has led to recommendations for separating female offspring from breeding males at 16 days of age to prevent unwanted pregnancies (Miegoue *et al*., 2018).

Therapeutic Interventions

In cases where delayed sexual maturity is identified, several therapeutic interventions may be considered including nutritional supplementation to address deficiencies, environmental modifications to reduce stress and optimize conditions, treatment of underlying health conditions, and in severe cases, hormonal evaluation and potential endocrine intervention. However, research has shown that attempts to induce precocious sexual behavior through testosterone propionate injections are not effective in guinea pigs, unlike in rats (Smołucha *et al*., 2024). This suggests that guinea pigs have different sensitivity to hormonal manipulation during postnatal development compared to other rodent species. Prevention through optimal management practices is generally more effective than therapeutic intervention after delays have occurred. This emphasizes the importance of providing appropriate husbandry from birth through sexual maturation (Hirst *et al*., 2018).

Future Research Directions

Epigenetic Programming and Long-term Effects

Recent research has begun to explore the role of epigenetic mechanisms in programming reproductive development. Studies suggest that environmental conditions during critical developmental windows may cause epigenetic modifications that affect long-term reproductive function. Future research should investigate how early life experiences influence DNA methylation patterns and gene expression related to reproductive development (Coker *et al*., 2022).

Studies on maternal vitamin C status have shown that deficiency during pregnancy can affect offspring characteristics and potentially program long-term reproductive outcomes. Understanding these transgenerational effects could lead to improved nutritional recommendations for breeding animals (Coker *et al*., 2024).

Nutritional Genomics and Personalized Feeding

The interaction between specific nutrients and gene expression in reproductive development represents an emerging area of research. Understanding how nutritional status influences the expression of genes involved in sexual development could lead to more targeted nutritional interventions (Morrison *et al*., 2018). Research on amino acid requirements, particularly lysine, has shown significant effects on reproductive performance. Future studies should investigate optimal amino acid profiles for different developmental stages and genetic backgrounds (Vargas-Jauja *et al*., 2025).

Environmental Enrichment and Welfare Optimization

Studies on housing and environmental enrichment effects on reproductive development could lead to improved welfare standards and breeding outcomes. Research should investigate optimal social grouping strategies, environmental complexity, and handling protocols to minimize stress during critical developmental periods (Godyń *et al*., 2019).The development of non-invasive monitoring techniques, such as saliva cortisol measurement and behavioral assessment tools, could improve our ability to detect stress and optimize environmental conditions for reproductive development (Kaszycka *et al*., 2025).

Precision Breeding Technologies

Development of genomic selection tools and reproductive technologies could improve breeding efficiency and reduce the impact of delaying factors. Research into artificial insemination, embryo transfer, and genetic markers for reproductive traits could revolutionize guinea pig breeding programs (Menchaca, 2023). Investigation of metabolomic biomarkers for predicting sexual maturity timing could enable early intervention and optimization of management practices. Such biomarkers could also facilitate research into the mechanisms underlying developmental delays (Schyman *et al*., 2021).

Conclusion

Sexual maturity in male guinea pigs is a complex developmental process that typically occurs between 45-55 days of age under optimal conditions. However, numerous factors can significantly delay this milestone, with nutritional status representing the most significant modifiable influence. Severe under nutrition, protein deficiency, and vitamin C deficiency can all cause substantial delays in sexual development through various mechanisms involving hormonal disruption and resource limitation. Environmental factors, including photoperiod, temperature, and social stress levels, also play important roles in determining maturity timing, with males appearing more sensitive to these influences than females. Physical factors such as birth weight and genetic background contribute additional variation in developmental timing, while health conditions and infectious diseases can further complicate normal development. Evidence clearly demonstrates that optimal management of nutrition, environment, and health during the critical juvenile period is essential for ensuring normal sexual development. This understanding has important practical implications for breeding programs, research protocols, and animal welfare considerations in both laboratory and domestic settings. Future research should focus on developing a deeper understanding of the molecular mechanisms underlying these developmental processes, with particular attention to epigenetic programming, nutritional genomics, and precision breeding technologies. Such research could lead to more sophisticated approaches to optimizing reproductive development and improving breeding outcomes in guinea pig populations. The comprehensive nature of factors influencing sexual maturity in male guinea pigs underscores the importance of holistic management approaches that consider the complex interactions between nutrition, environment, genetics, and health status. Only through such integrated approaches can we ensure optimal reproductive development and welfare outcomes for these important animals in research, agriculture, and companion animal settings.

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REFERENCES

Alberts, A., Moldoveanu, E.-T., Niculescu, A.-G., & Grumezescu, A. M. (2025). Vitamin C: A Comprehensive Review of Its Role in Health, Disease Prevention, and Therapeutic Potential. *Molecules*, *30*(3), 748. https://doi.org/10.3390/molecules30030748

Arnold, A. M., Peralta, J. M., & Thonney, M. L. (1996). Ontogeny of growth hormone, insulin-like growth factor-I, estradiol and cortisol in the growing lamb: effect of testosterone. *Journal of Endocrinology*, *150*(3), 391-399. Retrieved Sep 17, 2025, from https://doi.org/10.1677/joe.0.1500391

Ayala Guanga, L., Astiz, S., Nieto Escandon, P., Dutan Saramago, J., Rodas Carpio, R., Pesantez-Pacheco, J. L., & Rosales Jaramillo, C. (2020). Relationship between testosterone and penile spicules in Guinea pigs (Cavia porcellus). *Theriogenology*, *158*, 368–374. https://doi.org/10.1016/j.theriogenology.2020.09.034

Balzani, A., & Hanlon, A. (2020). Factors that Influence Farmers' Views on Farm Animal Welfare: A Semi-Systematic Review and Thematic Analysis. *Animals: an open access journal from MDPI*, *10*(9), 1524. https://doi.org/10.3390/ani10091524

Bauer, B., Dittami, J., & Huber, S. (2009). Effects of nutritional quality during early development on body weight and reproductive maturation of guinea pigs (Cavia aperea f. porcellus). *General and comparative endocrinology*, *161*(3), 384–389. https://doi.org/10.1016/j.ygcen.2009.02.003

Bauer, B., Womastek, I., Dittami, J., & Huber, S. (2008). The effects of early environmental conditions on the reproductive and somatic development of juvenile guinea pigs (Cavia aperea f. porcellus). *General and comparative endocrinology*, *155*(3), 680–685. https://doi.org/10.1016/j.ygcen.2007.09.015

Benavides, F., Sutovsky, P., López, V., Kennedy, C., & Echevarría, L. (2020). Semen Parameters of Fertile Guinea Pigs *(Cavia porcellus)* Collected by Transrectal Electroejaculation. *Animals: an open access journal from MDPI*, *10*(5), 767. https://doi.org/10.3390/ani10050767

Bork, K., Chevrier, C., Paquignon, M., Jouannet, P., Dacheux, J.L., 1988. Flagellar motility and movement of boar spermatozoa during epididymal transit. Reprod. Nutr. Dev. 28, 1307–1315. https://doi.org/10.1051/rnd:19880811.

Brown-Grant, K., & Sherwood, M. R. (1971). The 'early androgen syndrome' in the guinea-pig. *Journal of Endocrinology*, *49*(2), 277-291. https://doi.org/10.1677/joe.0.0490277

Castro-Bedriñana, J., & Chirinos-Peinado, D. (2021). Nutritional value of some raw materials for guinea pigs (*Cavia porcellus*) feeding. *Translational animal science*, *5*(2), txab019. https://doi.org/10.1093/tas/txab019

Chambial, S., Dwivedi, S., Shukla, K. K., John, P. J., & Sharma, P. (2013). Vitamin C in disease prevention and cure: an overview. *Indian journal of clinical biochemistry: IJCB*, *28*(4), 314–328. https://doi.org/10.1007/s12291-013-0375-3.

Ciuria, S., Brouwer, M. S. M., de Gier, M. M., van Zeeland, Y., Bossers, A., Prähauser, B., Schädler, J., Hatt, J. M., Heijne, M., & Borel, N. (2021). *Chlamydia caviae* in Swiss and Dutch Guinea Pigs-Occurrence and Genetic Diversity. *Pathogens (Basel, Switzerland)*, *10*(10), 1230. https://doi.org/10.3390/pathogens10101230

Coker, S. J., Berry, M. J., Vissers, M. C. M., & Dyson, R. M. (2024). Maternal Vitamin C Intake during Pregnancy Influences Long-Term Offspring Growth with Timing- and Sex-Specific Effects in Guinea Pigs. *Nutrients*, *16*(3), 369. https://doi.org/10.3390/nu16030369

Coker, S. J., Dyson, R. M., Smith-Díaz, C. C., Vissers, M. C. M., & Berry, M. J. (2023). Effects of Low Vitamin C Intake on Fertility Parameters and Pregnancy Outcomes in Guinea Pigs. *Nutrients*, *15*(19), 4107. https://doi.org/10.3390/nu15194107

Coker, S. J., Smith-Díaz, C. C., Dyson, R. M., Vissers, M. C. M., & Berry, M. J. (2022). The Epigenetic Role of Vitamin C in Neurodevelopment. *International Journal of Molecular Sciences*, *23*(3), 1208. https://doi.org/10.3390/ijms23031208

de Figueiredo, L. B. F., Rodrigues, R. T. S., Leite, M. F. S., Gois, G. C., Araújo, D. H. D. S., de Alencar, M. G., Oliveira, T. P. R., Figueirêdo Neto, A., Silva Junior, R. G. C., & Queiroz, M. A. Á. (2020). Effect of sex on carcass yield and meat quality of guinea pig. *Journal of food science and technology*, *57*(8), 3024–3030. https://doi.org/10.1007/s13197-020-04335-3

de Matos, A. S., Kugelmeier, T., Guimarães, D. A. A., & da Silva, K. S. M. (2022). Early puberty in short-haired Guinea pigs kept in laboratory animal facilities. *Animal reproduction*, *19*(1), e20210068. https://doi.org/10.1590/1984-3143-AR2021-0068

Elsbacher, T., Sommese, A., Waiblinger, S., Künzel, F., Arhant, C., & Windschnurer, I. (2025). Guinea Pig (*Cavia porcellus*) Welfare: Associations Between Husbandry Practices, Human-Animal Interactions, and Animal Behaviour. *Animals : an open access journal from MDPI*, *15*(8), 1157. https://doi.org/10.3390/ani15081157

Emokpae, M. A., & Brown, S. I. (2021). Effects of lifestyle factors on fertility: practical recommendations for modification. *Reproduction & fertility*, *2*(1), R13–R26. https://doi.org/10.1530/RAF-20-0046

Ewing, L. L., Zirkin, B. R., Cochran, R. C., Kromann, N., Peters, C., & Ruiz-Bravo, N. (1979). Testosterone secretion by rat, rabbit, guinea pig, dog, and hamster testes perfused in vitro: correlation with Leydig cell mass. *Endocrinology*, *105*(5), 1135–1142. https://doi.org/10.1210/endo-105-5-1135

Fernandes, G. S., Fernandez, C. D., Campos, K. E., Damasceno, D. C., Anselmo-Franci, J. A., & Kempinas, W. D. (2011). Vitamin C partially attenuates male reproductive deficits in hyperglycemic rats. *Reproductive biology and endocrinology: RB&E*, *9*, 100.

https://doi.org/10.1186/1477-7827-9-100.

Fitria, L., Wijayanti, N., Arisuryanti, T., & Salasia, S. I. O. (2022). Health comparison between guinea pigs raised in uncontrolled and controlled environments. *Veterinary world*, *15*(6), 1575–1582. https://doi.org/10.14202/vetworld.2022.1575-1582

Genovese, P., Núñez, M. E., Pombo, C., & Bielli, A. (2010). Undernutrition during foetal and post-natal life affects testicular structure and reduces the number of Sertoli cells in the adult rat. *Reproduction in domestic animals = Zuchthygiene*, *45*(2), 233–236. https://doi.org/10.1111/j.1439-0531.2008.01244.x

Genzer, S. C., Flietstra, T., Coleman-McCray, J. D., Tansey, C., Welch, S. R., & Spengler, J. R. (2023). Effect of Parental Age, Parity, and Pairing Approach on Reproduction in Strain 13/N Guinea Pigs (*Cavia porcellus*). *Animals*, *13*(5), 895. https://doi.org/10.3390/ani13050895

Glass, A., Herbert, D. & Anderson, J. (1986).Fertility Onset, Spermatogenesis, and Pubertal Development in Male Rats: Effect of Graded Underfeeding. *Pediatr Res* **20**, 1161–1167. https://doi.org/10.1203/00006450-198611000-00024

Godyń, D., Nowicki, J., & Herbut, P. (2019). Effects of Environmental Enrichment on Pig Welfare-A Review. *Animals : an open access journal from MDPI*, *9*(6), 383. https://doi.org/10.3390/ani9060383

Han, F., Yin, L., Jiang, X., Zhang, X., Zhang, N., Yang, J. T., Ouyang, W. M., Hao, X. L., Liu, W. B., Huang, Y. S., Chen, H. Q., Gao, F., Li, Z. T., Guo, Q. N., Cao, J., & Liu, J. Y. (2021). Identification of SRY-box 30 as an age-related essential gatekeeper for male germ-cell meiosis and differentiation. *Aging cell*, *20*(5), e13343. https://doi.org/10.1111/acel.13343

Hennessy, M. B., Hornschuh, G., Kaiser, S., & Sachser, N. (2006). Cortisol responses and social buffering: a study throughout the life span. *Hormones and behavior*, *49*(3), 383–390. https://doi.org/10.1016/j.yhbeh.2005.08.006

Hennessy, M. B., Zate, R., & Maken, D. S. (2008). Social buffering of the cortisol response of adult female guinea pigs. *Physiology & behavior*, *93*(4-5), 883–888. https://doi.org/10.1016/j.physbeh.2007.12.005

Hirst, J. J., Palliser, H. K., Shaw, J. C., Crombie, G., Walker, D. W., & Zakar, T. (2018). Birth and Neonatal Transition in the Guinea Pig: Experimental Approaches to Prevent Preterm Birth and Protect the Premature Fetus. *Frontiers in physiology*, *9*, 1802. https://doi.org/10.3389/fphys.2018.01802

Holstein, A. F., Schulze, W., & Davidoff, M. (2003). Understanding spermatogenesis is a prerequisite for treatment. *Reproductive biology and endocrinology: RB&E*, *1*, 107. https://doi.org/10.1186/1477-7827-1-107

Jang, Y. D., Jang, S. K., Kim, D. H., Oh, H. K., & Kim, Y. Y. (2014). Effects of dietary protein levels for gestating gilts on reproductive performance, blood metabolites and milk composition. *Asian-Australasian journal of animal sciences*, *27*(1), 83–92. https://doi.org/10.5713/ajas.2013.13369

Kaiser, S., Harderthauer, S., Sachser, N., & Hennessy, M. B. (2007). Social housing conditions around puberty determine later changes in plasma cortisol levels and behavior. *Physiology & behavior*, *90*(2-3), 405–411. https://doi.org/10.1016/j.physbeh.2006.10.002

Kaiser, S., Korte, A., Wistuba, J., Baldy, M., Wissmann, A., Dubičanac, M., Richter, S. H., & Sachser, N. (2023). Effects of castration and sterilization on baseline and response levels of cortisol-A case study in male guinea pigs. *Frontiers in veterinary science*, *9*, 1093157. https://doi.org/10.3389/fvets.2022.1093157

Kapoor, A., & Matthews, S. G. (2011). Testosterone is involved in mediating the effects of prenatal stress in male guinea pig offspring. *The Journal of physiology*, *589*(Pt 3), 755–766. https://doi.org/10.1113/jphysiol.2010.200543

Kaszycka, K., Goleman, M., & Krupa, W. (2025). Testing the Level of Cortisol in Dogs. *Animals*, *15*(9), 1197. https://doi.org/10.3390/ani15091197

Kraus, S., Trillmich, F. & Guenther, A. Long-term effects of litter characteristics on reproduction in female cavies (*Cavia aperea*). *Behav Ecol Sociobiol* **78**, 91 (2024). https://doi.org/10.1007/s00265-024-03508-w

Le HH, Hagen MW, Louey S, Tavori H, Thornburg KL, Giraud GD, Hinds MT, Barnes AP. Development of a novel Guinea Pig model producing transgenerational endothelial transcriptional changes driven by maternal food restriction and a second metabolic insult of high fat diet. Front Physiol. 2023 Oct 24; 14:1266444. doi: 10.3389/fphys.2023.1266444. PMID: 37942229; PMCID: PMC10628814.

Mazza, E., Troiano, E., Ferro, Y., Lisso, F., Tosi, M., Turco, E., Pujia, R., & Montalcini, T. (2024). Obesity, Dietary Patterns, and Hormonal Balance Modulation: Gender-Specific Impacts. *Nutrients*, *16*(11), 1629. https://doi.org/10.3390/nu16111629.

Menchaca A. (2023). Assisted Reproductive Technologies (ART) and genome editing to support a sustainable livestock. *Animal reproduction*, *20*(2), e20230074. https://doi.org/10.1590/1984-3143-AR2023-0074

Mendis-Handagama, S. M., Zirkin, B. R., & Ewing, L. L. (1988). Comparison of components of the testis interstitium with testosterone secretion in hamster, rat, and guinea pig testes perfused in vitro. *The American journal of anatomy*, *181*(1), 12–22. https://doi.org/10.1002/aja.1001810103

Miegoue E, Tendonkeng F, Ngouopo NM, Ntsafack P, Mouchili M, Nkana JGK, Pamo TE. Reproductive and Pre-Weaning Growth Performance of Guinea Pigs (Cavia Porellus L.) Fed on Panicum Maximum or Pennisetum Purpureum. Int J Anim Sci. 2018; 2(6): 1037.

Mikami, H., Nishibata, R., Kawamoto, Y., & Ino, T. (1991). Selective breeding of two lines of guinea pigs differing in bronchial sensitivity to acetylcholine and histamine exposure. *Jikken dobutsu. Experimental animals*, *40*(2), 195–202. https://doi.org/10.1538/expanim1978.40.2_195

Morrison, J. L., Botting, K. J., Darby, J. R. T., David, A. L., Dyson, R. M., Gatford, K. L., Gray, C., Herrera, E. A., Hirst, J. J., Kim, B., Kind, K. L., Krause, B. J., Matthews, S. G., Palliser, H. K., Regnault, T. R. H., Richardson, B. S., Sasaki, A., Thompson, L. P., & Berry, M. J. (2018). Guinea pig models for translation of the developmental origins of health and disease hypothesis into the clinic. *The Journal of physiology*, *596*(23), 5535–5569. https://doi.org/10.1113/JP274948

Nemeth, M., Fritscher, S., Füreder, K., Wallner, B., & Millesi, E. (2024). Metabolic rate and saliva cortisol concentrations in socially housed adolescent guinea pigs. *Journal of comparative physiology. B, Biochemical, systemic, and environmental physiology*, *194*(6), 925–933. https://doi.org/10.1007/s00360-024-01576-y

Nemeth, M., Herrmann, S. M., Wallner, B., & Millesi, E. (2025). Effects of the estrous cycle and sex on stress responses in guinea pigs. *Scientific reports*, *15*(1), 25253. https://doi.org/10.1038/s41598-025-11101-y

Nemeth, M., Millesi, E., Puehringer-Sturmayr, V., Kaplan, A., Wagner, K. H., Quint, R., & Wallner, B. (2016). Sex-specific effects of dietary fatty acids on saliva cortisol and social behavior in guinea pigs under different social environmental conditions. *Biology of sex differences*, *7*, 51. https://doi.org/10.1186/s13293-016-0107-5

Ntsafack P, Miegoue E*, Noumbissi MNB, Nguedia G, Mouchili M, MBA TAL, Kwayep NC, Fossi J and Tendonkeng F (2021) Reproduction and pre weaning Growth Performances of Guinea Pigs (Cavia porcellus) Fed on the diets containing Ipomea batatas Leaves and/or Stylosanthes guianensis Meal. J Vet Sci Ani Husb 9(1): 101.

Pedersen, K., Poojari, A., Colberg, S. F., Mechernsee, S. M., Iversen, J. F., Barrès, R., Lykkesfeldt, J., & Tveden-Nyborg, P. (2025). A Guinea Pig Model of Pediatric Metabolic Dysfunction-Associated Steatohepatitis: Poor Vitamin C Status May Advance Disease. *Nutrients*, *17*(2), 291. https://doi.org/10.3390/nu17020291

Pinheiro, A. R., Salvucci, I. D., Aguila, M. B., & Mandarim-de-Lacerda, C. A. (2008). Protein restriction during gestation and/or lactation causes adverse transgenerational effects on biometry and glucose metabolism in F1 and F2 progenies of rats. *Clinical science (London, England: 1979)*, *114*(5), 381–392. https://doi.org/10.1042/CS20070302

Quispe-Ccasa, H. A., Briceño-Mendoza, Y. M., & Cayo-Colca, I. S. (2023). Guinea Pig Sperm Morphology and Fertility under Different Photoperiod. *Animals : an open access journal from MDPI*, *13*(14), 2249. https://doi.org/10.3390/ani13142249

Rosero J, Rosero-Alpala MG, Rosero D, Rosero A, and Tapie WA (2024). Phenotypic Variability of Native Guinea Pig (Cavia porcellus) Lines Associated with Productive and Reproductive Variables in the Traditional Production Systems of the Pastos Indigenous Reserve.

World Vet. J., 14(4): 559-571. DOI: https://dx.doi.org/10.54203/scil.2024.wvj64

Roy M. M. (1992). Effects of prenatal testosterone and ATD on reproductive behavior in guinea pigs. *Physiology & behavior*, *51*(1), 105–109. https://doi.org/10.1016/0031-9384(92)90210-s

Rubim Sacramento, R. C., Neuenschwander Maciel, L. P., Paiva Coimbra, J. L., Corcini, C. D., Junior, A. S. V., Komninou, E. R., Hogg, C. O., Ashworth, C. J., de Albuquerque Lagares, M., Chiarini-Garcia, H., & Almeida, F. R. C. L. (2022). Birthweight leads to seminal and testicular morphofunctional commitment in sexually mature boars. *Theriogenology*, *189*, 237–245. https://doi.org/10.1016/j.theriogenology.2022.06.024

Santos, A. M., Ferraz, M. R., Teixeira, C. V., Sampaio, F. J., & da Fonte Ramos, C. (2004). Effects of undernutrition on serum and testicular testosterone levels and sexual function in adult rats. *Hormone and metabolic research = Hormon- und Stoffwechselforschung = Hormones et metabolisme*, *36*(1), 27–33. https://doi.org/10.1055/s-2004-814198

Sarr, O., Thompson, J. A., Zhao, L., Lee, T. Y., & Regnault, T. R. (2014). Low birth weight male guinea pig offspring display increased visceral adiposity in early adulthood. *PloS one*, *9*(6), e98433. https://doi.org/10.1371/journal.pone.0098433

Schyman, P., Printz, R. L., Pannala, V. R., AbdulHameed, M. D. M., Estes, S. K., Shiota, C., Boyd, K. L., Shiota, M., & Wallqvist, A. (2021). Genomics and metabolomics of early-stage thioacetamide-induced liver injury: An interspecies study between guinea pig and rat. *Toxicology and applied pharmacology*, *430*, 115713. https://doi.org/10.1016/j.taap.2021.115713

Shomer, N. H., Holcombe, H., & Harkness, J. E. (2015). Biology and Diseases of Guinea Pigs. *Laboratory Animal Medicine*, 247–283. https://doi.org/10.1016/B978-0-12-409527-4.00006-7

Shukla S, & Shrivastava D (2024) Nutritional Deficiencies and Subfertility: A Comprehensive Review of Current Evidence. Cureus 16(8): e66477. doi:10.7759/cureus.66477

Simões, Luciana S. Rici, Rose E.G. Favaron, Phelipe O. Sasahara, Taís Harumi de Castro Barreto, Rodrigo S.N. Borghesi, Jessica Miglino, Maria A. (2016). *Pesquisa Veterinária Brasileira , Volume 36 Suppl. 1 Pages 89–94.* https://doi.org/10.1590/S0100-736X2016001300013

Slob, A. K., Vreeburg, J. T., & Van der Werff ten Bosch, J. J. (1979). Body growth, puberty and undernutrition in the male guinea-pig. *The British journal of nutrition*, *41*(2), 231–237. https://doi.org/10.1079/bjn19790032

Smołucha, G., Steg, A., & Oczkowicz, M. (2024). The Role of Vitamins in Mitigating the Effects of Various Stress Factors in Pigs Breeding. *Animals*, *14*(8), 1218. https://doi.org/10.3390/ani14081218

Trillmich, F., Guenther, A., Jäckel, M., & Czirják, G. Á. (2020). Reproduction affects immune defenses in the guinea pig even under ad libitum food. *PloS one*, *15*(3), e0230081. https://doi.org/10.1371/journal.pone.0230081

Typpo, J. T., Anderson, H. L., Krause, G. F., & Yu, D. T. (1985). The lysine requirement of young growing male guinea pigs. *The Journal of nutrition*, *115*(5), 579–587. https://doi.org/10.1093/jn/115.5.579

Vargas-Jauja, Y. C., Casilla-Huallpa, K. M., Chino-Velasquez, L. B., Díaz-Céspedes, M. A., Gómez-Quispe, O. E., Camero-DeLaCuba, J., Estrada-Zúñiga, A. C., Tupayachi-Solorzano, G. & Moscoso-Muñoz, J. E. (2025). Production and Reproduction of Primiparous Guinea Pigs Concerning Lysine Levels. *American Journal of Animal and Veterinary Sciences*, *20*(2), 103-111. https://doi.org/10.3844/ajavsp.2025.103.111

Vargas-Jauja, Yasmeen Camila, Karin Marleny Casilla-Huallpa, Liz Beatriz Chino-Velasquez, Medardo Antonio Díaz-Céspedes, Oscar Elisban Gómez-Quispe, Jesús Camero-DeLaCuba, Andrés Corsino Estrada-Zúñiga, Gardenia Tupayachi-Solorzano and Juan Elmer Moscoso-Muñoz. (2025). Production and Reproduction of Primiparous Guinea Pigs Concerning Lysine Levels. American Journal of Animal and Veterinary Sciences. Volume 20 No. 2, 2025, 103-111.DOI: https://doi.org/10.3844/ajavsp.2025.103.111

Ventura, W.P., FREUND, M., & Knapp, F. (1968). Motility of the vagina and uterine body and horns in the guinea pig. Effects of semen and male accessory gland secretions. *Fertility and sterility*, *19*(3), 42–74.

von Engelhardt, N., Kowalski, G.J. & Guenther, A. (2015). The maternal social environment shapes offspring growth, physiology, and behavioural phenotype in guinea pigs. *Front Zool* **12** (Suppl 1), S13 (2015). https://doi.org/10.1186/1742-9994-12-S1-S13

Wang, J., Li, J., Ge, Q., Chen, Z., & Li, J. (2020). Effects of Inbreeding on Genetic Characteristic, Growth, Survival Rates, and Immune Responses of a New Inbred Line of *Exopalaemon carinicauda*. *International journal of genomics*, *2020*, 5735968. https://doi.org/10.1155/2020/5735968

Wilson, R. L., Lampe, K., Matushewski, B. J., Regnault, T. R. H., & Jones, H. N. (2021). Time Mating Guinea Pigs by Monitoring Changes to the Vaginal Membrane throughout the Estrus Cycle and with Ultrasound Confirmation. *Methods and protocols*, *4*(3), 58. https://doi.org/10.3390/mps4030058

Young, W. C., & Grunt, J. A. (1951). The pattern and measurement of sexual behavior in the male guinea pig. *Journal of Comparative and Physiological Psychology,* *44*(5), 492–500. https://doi.org/10.1037/h0055063

Zheng, L., Su, J., Fang, R., Jin, M., Lei, Z., Hou, Y., Ma, Z., & Guo, T. (2015). Developmental changes in the role of gonadotropin-inhibitory hormone (GnIH) and its receptors in the reproductive axis of male Xiaomeishan pigs. *Animal reproduction science*, *154*, 113–120. https://doi.org/10.1016/j.anireprosci.2015.01.004

Zheng, Y., Gao, Q., Li, T., Liu, R., Cheng, Z., Guo, M., Xiao, J., Wu, D., & Zeng, W. (2022). Sertoli cell and spermatogonial development in pigs. *Journal of animal science and biotechnology*, *13*(1), 45. https://doi.org/10.1186/s40104-022-00687-2

Zirkin, B. R., Ewing, L. L., Kromann, N., & Cochran, R. C. (1980). Testosterone secretion by rat, rabbit, guinea pig, dog, and hamster testes perfused in vitro: correlation with Leydig cell ultrastructure. *Endocrinology*, *107*(6), 1867–1874. https://doi.org/10.1210/endo-107-6-1867.