Research Article

Effects of *Panax ginseng* Dry Extract Supplementation on Semen Quality and Reproductive Physiological Parameters in Indigenous Vietnamese Mong Cai Boars

Phan Nhan*, Nguyen Thi Chuc

Faculty of Applied Biology, Tay Do University, 68 Tran Chien Street, Cai Rang Ward, Can Tho 900000, Vietnam.

Abstract | Reproductive efficiency in indigenous pig breeds like Mong Cai is often under-researched, despite their genetic and economic value. Natural phytogenic additives such as *Panax ginseng* offer potential for enhancing fertility without synthetic interventions. This study aimed to evaluate the effects of *Panax ginseng* dry extract supplementation on sexual behavior, semen quality, and testosterone levels in Mong Cai boars. Methods: Nine healthy Mong Cai boars (7–8 months old) were randomly assigned to three groups (n = 3): a control group, a low-dose group (5 g ginseng/day), and a high-dose group (10 g ginseng/day) for six weeks. Sexual behavior was assessed weekly; semen quality and testosterone levels were measured using standard laboratory techniques. Ginseng supplementation significantly improved sexual performance, reducing reaction time from 45.31 ± 2.11 s to 25.82 ± 1.18 s, increasing mounting frequency (2.32 ± 0.35 to 4.71 ± 0.15), and enhancing libido scores. Semen volume (110.12 ± 5.16 to 128.32 ± 6.01 mL), sperm concentration (1.25 ± 0.21 to 1.81 ± 0.02 billion/mL), motility parameters, and testosterone levels (1.85 ± 0.11 to 2.67 ± 0.16 ng/mL) were significantly improved in the high-dose group. *Panax ginseng* dry extract, particularly at 10 g/day, enhances reproductive traits in Mong Cai boars. This study is the first to demonstrate the efficacy of ginseng in native Vietnamese pigs, supporting its role as a natural reproductive enhancer in swine production.

Keywords | Mong Cai boars, *Panax ginseng*, Herbal medicine, Semen quality, Reproduction, Antioxidants, Swine production

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***Correspondence** | Phan Nhan, Faculty of Applied Biology, Tay Do University, 68 Tran Chien Street, Cai Rang Ward, Can Tho 900000, Vietnam; **Email:** pnhan@tdu.edu.vn
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INTRODUCTION

In both developed and developing countries, artificial insemination (AI) has become the predominant method for pig reproduction. However, its success depends not only on appropriate catheter use and skilled personnel but also on optimal semen preservation conditions to maintain fertility outcomes (Yeste, 2018). Reproductive efficiency in boars plays a pivotal role in swine production, particularly in breeding programs aimed at improving genetic potential and conserving indigenous breeds. The reproductive technology described is recognized for enhancing livestock breeds (Ministry of Agriculture, 2019). Mong Cai pig is one of the most widespread indigenous pig breeds in Vietnam, having been established and developed over centuries in the climatic and soil conditions of the Northeastern region, particularly Quang Ninh province. This breed is known for its adaptability to various farming systems, resilience to diseases, and strong reproductive performance. Notably, Mong Cai is the only native pig breed widely used as the maternal line in crossbreeding programs with exotic breeds to produce piglets and fatteners for both domestic markets

and export (Van *et al*., 2024).

Numerous studies have been conducted to evaluate the effects of various factors on the quality of frozen-thawed boar semen, including comparisons between different breeds or among individuals within the same breed (Techakumphu *et al*., 2013). External factors such as the composition of extenders, types and concentrations of cryoprotectants, dilution ratios, cooling rates, equilibration times, and freezing-thawing protocols have also been explored (Johnson *et al*., 2000). In addition, the roles of cryopreservatives, antioxidants, animal serum, antifreeze proteins, and fatty acids in cryopreservation media have been investigated (Hezavehei *et al*., 2018). However, to date, no study has been reported on the use of herbal supplementation, particularly *Panax ginseng*, as a strategy to enhance sperm quality in boars. Recent trends in animal reproduction research have focused on natural bioactive compounds, including medicinal herbs, to improve reproductive function without adverse side effects. Among these, Panax ginseng, commonly known as Asian or Korean ginseng, has attracted considerable attention due to its rich content of ginsenosides, which are known to modulate endocrine function, exert antioxidant activity, and improve sperm quality in various animal models. The pharmacological properties of Panax ginseng are primarily attributed to ginsenosides, a class of triterpene saponins that have been the focus of most scientific investigations into its medicinal potential (World Health Organization, 1999). Several studies have demonstrated the potential of *Panax ginseng* extract in enhancing reproductive parameters in poultry, rodents, and livestock. Similar to the study by Hwang *et al*. (2004) found that *Panax ginseng* supplementation enhanced sperm motility and reduced oxidative stress, supporting the hypothesis that ginseng can promote male reproductive health and improve sperm quality under stressful conditions. Ginsenosides, the principal active components in ginseng, have been shown to stimulate testosterone production, improve spermatogenesis, and enhance sperm motility and viability. Despite these promising results, little is known about the effects of ginseng supplementation on the reproductive performance of boars, especially in local breeds like Mong Cai.

This study aimed to investigate the effects of dietary supplementation with dry extract of *Panax ginseng* on semen quality and selected reproductive physiological parameters in Mong Cai boars. The findings are expected to provide a scientific basis for using herbal supplementation to improve reproductive traits in indigenous pig breeds, contributing to their sustainable use and genetic conservation.

MATERIALS AND METHODS

Location and time

The experiment was conducted at Hong Lac farm in Dai Thanh commune, Nga Bay city, Hau Giang Province Vietnam from September 2023 to January 2024. The experimental analysis was conducted at the veterinary practice laboratory, Tay Do University.

Animals and experimental design

This study was conducted using nine healthy Mong Cai boars, aged approximately 7–8 months, with characteristics of purebred origin. The animals were individually housed in pens under uniform management and environmental conditions at a pig breeding farm in Hau Giang Province, Vietnam.

Prior to the experiment, all boars underwent a 4-week habituation period during which they were trained for semen collection using the gloved-hand technique. This phase ensured familiarity with handling procedures and reduced stress responses during the collection phase.

All animals remained clinically healthy throughout the study period. No abnormal behaviors such as lethargy, aggression, or inappetence were observed. There were no cases of mortality, and no animals were excluded from the trial due to illness or injury. Therefore, post-mortem evaluation was not necessary.

The experimental grouping and supplementation protocol (n = 3 per group for a duration of six weeks) are illustrated in Figure 1.

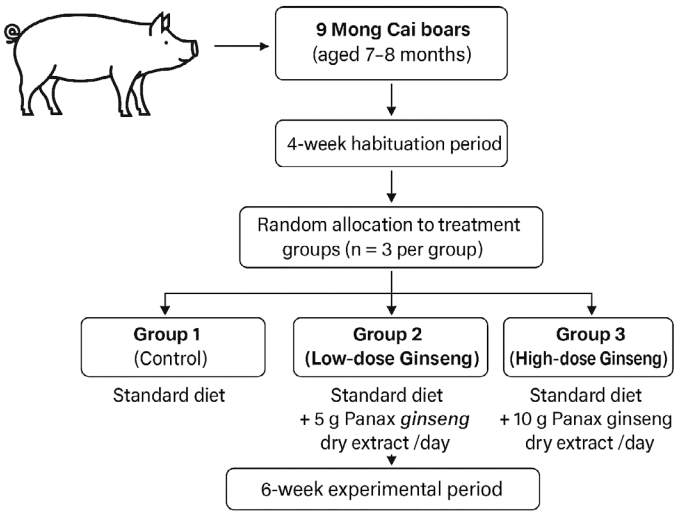

Figure 1: Experimental design for the dietary supplementation of Mong Cai boars with Panax ginseng dry extract.

Group 1 (Control): Fed a standard commercial pelleted diet without supplementation.
Group 2 (Low-dose Ginseng): Fed the standard diet supplemented with 5 g of *Panax ginseng* dry extract per head per day.
Group 3 (High-dose Ginseng): Fed the standard diet

supplemented with 10 g of *Panax ginseng* dry extract per head per day.

The experimental design followed a completely randomized layout. Each animal was housed individually in a separate pen under identical environmental conditions to ensure consistency across treatments. The pens were arranged in parallel rows within a ventilated housing facility with ambient temperatures ranging from 26 to 32°C and natural light cycles. Standardized feeding, cleaning, and health monitoring protocols were applied uniformly. This layout minimized external variability and ensured that observed differences were attributable to the dietary treatments.

Feeds and feeding

All animals were fed a commercially pelleted diet formulated for boars. The feed was composed of rice bran, wheat bran, corn, soybean oil, and fish meal, and was formulated to contain 13% crude protein and 2900 kcal/kg metabolizable energy. Calcium and phosphorus contents ranged from 0.6%–1.8% and 0.5%–1.5%, respectively.

Feed was offered twice daily (morning and afternoon), and clean drinking water was provided ad libitum. For the experimental groups, *Panax ginseng* dry extract was mixed daily into the feed at doses of 5 g/head/day (Group 2) and 10 g/head/day (Group 3). All feed was consumed fully, and no signs of feed refusal or digestive disturbance were observed throughout the experiment.

Panax ginseng roots used in this study were obtained from a certified herbal supplier in Vietnam. To produce a powdered dry extract suitable for oral supplementation via feed, the roots were first thoroughly washed to remove soil and impurities, then sliced into uniform pieces (approximately 3–5 mm thick) to facilitate drying. The sliced roots underwent aqueous extraction by boiling in distilled water at 95–100°C for 3 hours, using a root-to-water ratio of 1:10 (w/v), and the extraction process was repeated twice to maximize the yield of active compounds. The resulting combined extract was filtered sequentially through muslin cloth and Whatman filter paper to eliminate insoluble materials. The clear filtrate was then concentrated under reduced pressure using a rotary evaporator at 50–55°C until it reached approximately one-fourth of its original volume, forming a semi-solid concentrate. This concentrate was subsequently dried via freeze-drying (lyophilization) to preserve ginsenosides. In field settings where lyophilization was not feasible, oven-drying at 50–60°C for 48–72 hours under low humidity was used as an alternative. The dried extract was ground into a fine brownish powder using a laboratory grinder and sieved through a 0.5 mm mesh. The final product was stored in airtight, opaque containers at 4°C, protected from light and moisture, and mixed freshly into the feed each day to maintain stability and bioactivity.

Measurements

Sexual behavior was evaluated once weekly during weeks 4 to 6 of the experiment. Observations were conducted in the early morning when libido is typically highest. Each boar was exposed individually to a teaser sow in estrus in a designated mating pen. The following parameters were recorded:

- Reaction time (sec): Time from exposure to the sow until first mounting attempt.
- Mounting frequency: Number of mounts within a 10-minute observation period.
- Ejaculation latency (sec): Time from first mount to ejaculation (if achieved).
- Libido score: A subjective scale ranging from 0 (no sexual interest) to 4 (very active sexual behavior), based on the standardized criteria proposed by Chenoweth (1981). Libido was assessed by two trained observers who were blinded to the treatment groups. Observers were pre-calibrated using training sessions with video recordings to ensure consistency. Any discrepancies in scoring were resolved through discussion and consensus.

Semen samples were collected twice per week from each boar during weeks 4 to 6 of the experiment using the gloved-hand technique, a standard method for boar semen collection. Immediately after collection, each ejaculate was stored at 4°C in sterile 15 mL Falcon tubes and transported to the veterinary practice laboratory, Tay Do University, Can Tho City, Vietnam, for evaluation within 2 hours.

The following parameters were measured to assess semen quality and reproductive physiological characteristics:

- Semen volume (V, mL): was measured directly using a graduated collection tube. Each ejaculate was visually inspected, and only complete, uncontaminated samples were included for analysis. The volume was recorded to the nearest 0.1 mL.
- Sperm concentration (C, billion/mL): was measured using a sperm densimeter (SDM1, Minitube, Germany), a portable photometric device specifically designed to estimate sperm density in boar semen. After thorough homogenization, a small aliquot (approximately 1 mL) of fresh semen was gently aspirated and introduced into the pre-calibrated measuring chamber of the densimeter.
- Sperm motility (CASA analysis): was assessed using a Computer-Assisted Sperm Analysis (CASA) system (Hamilton Thorne). After gentle mixing, a 10 µL semen aliquot was placed on a pre-warmed Makler counting chamber and analyzed at 37°C.
- Straight line velocity (VSL, µm/s): Linear velocity from origin to endpoint.
- Curvilinear velocity (VCL, µm/s): Total velocity along the sperm trajectory.

- Straightness (STR, %): Ratio of VSL to VAP (Average Path Velocity), indicating directional movement.
- Amplitude of lateral head displacement (ALH, μm): The side-to-side motion of the sperm head.
- Beat Cross Frequency (BCF, Hz): Frequency at which the sperm head crosses its average trajectory path.
- Abnormal sperm morphology (K, %): was mixed with 0.85% NaCl on a clean slide and stained with methylene blue. After air-drying and fixing via heat, 300–500 spermatozoa per slide were examined under a 400× magnification microscope (Olympus). The proportion of morphologically abnormal sperm was calculated as:

$$K(\%) = (n/N) \times 100$$

Notes: n= number of abnormal sperm, N = total sperm counted.

Semen pH was measured using a digital pH meter (WINLAB, Japan). Each measurement was conducted in triplicate, and the average value was reported.

- Mass activity (%): was objectively assessed using a computer-assisted sperm analysis (CASA) system, which quantifies the intensity of swirling and collective wave motion in undiluted semen samples. The CASA software analyzes pixel displacement patterns under phase-contrast microscopy to produce a numerical score representing overall sperm motility vigor, expressed as a percentage. This method provides a standardized and reproducible evaluation of mass motility across treatment groups.
- Osmotic pressure (mOsm/kg): was measured using an osmometer (BKD-30SMC, BIOBASE). The sample was equilibrated at room temperature before measurement to ensure consistency.
- Viscosity (η): Determined using a micropipette. The viscosity is measured at 20°C.

$$\eta = (d.t)/(d_o.t_o)$$

Notes: η: Relative viscosity compared to double-distilled water. d: Density of the liquid to be measured. t: Flow time of the liquid through a bulb or capillary. d_o: Density of double-distilled water. t_o: Flow time of water through a bulb or capillary.

Buffering capacity (β): According to the Salisbury method (1978) for 0.1N HCl. Use a clean, dry, neutral bottle with a capacity of 5–10 mL. Add 0,5 mL of the liquid to be tested and measure its pH. Using a micropipette, gradually add 0.1N HCl solution (n=3,6) into the bottle until the pH reaches 4.0. Record the pH deviation (dpH).

$$\beta = (a.n.1000)/(dpH.v) \times 100$$

Notes: β: Buffering capacity calculated per 1000 mL of liquid. a: Volume of acid used (amount of 0.1 N HCl). n: Equivalent weight of the acid. dpH: pH deviation before and after treatment. v: Volume of liquid used.

Testosterone assay: Blood samples were collected from the auricular vein of each boar at three time points: day 0 (before supplementation), day 28, and day 42 (end of experiment). Approximately 5 mL of blood was collected into serum separator tubes and centrifuged at 3,000 rpm for 10 minutes to obtain serum. The serum samples were stored at -20°C until analysis.

Serum testosterone concentrations were determined using a commercially available ELISA kit (Monobind, USA) according to the manufacturer's instructions. All samples were analyzed in duplicate, and absorbance was read using a microplate reader at 450 nm. The intra- and inter-assay coefficients of variation were maintained below 10%.

Ethical approval

This study did not require formal ethical approval, as no invasive procedures were performed. All animal care, handling, and sample collection were conducted in compliance with the Law on Animal Husbandry (No. 32/2018/QH14) issued by the National Assembly of the Socialist Republic of Vietnam. Animal welfare was monitored and ensured throughout the entire experimental period.

Statistical analysis

Statistical analyses were performed using Minitab 16.0 software. Data were tested for normality and homogeneity of variance prior to analysis. Differences among treatment groups were assessed using one-way analysis of variance (ANOVA). Tukey's Honest Significant Difference (HSD) test was applied for post hoc comparisons. All data are presented as means ± standard deviations (SD), and statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Sexual behavior parameters of Mong Cai boars fed with different levels of *Panax ginseng* dry extract

To begin with, the effects of Panax ginseng supplementation on sexual behavior parameters are presented in Table 1. The results demonstrate a clear, dose-dependent improvement in reproductive activity among Mong Cai boars receiving ginseng, indicating enhanced libido and mating efficiency compared to the control group.

As shown in Table 1, one of the most notable changes in sexual behavior was observed in the reaction time, reflecting

Table 1: Sexual behavior parameters of Mong Cai boars fed with different levels of *Panax ginseng* dry extract (Mean±SD).

Item	Group 1	Group 2	Group 3
Reaction time (s)	45.31±2.11[a]	32.62±1.75[b]	25.82±1.18[c]
Mounting frequency (times/10 min)	2.32±0.35[c]	3.84±0.14[b]	4.71±0.15[a]
Ejaculation latency (s)	124.41±10.21[a]	98.67±8.74[b]	86.54±7.6[c]
Libido score (0–4)	2.06±0.22[c]	2.81±0.23[b]	3.82±0.03[a]

[abc] Mean values within rows with different superscripts are different at $p<0.05$

Table 2: Semen quality and physical and chemical characteristics of semen in Mong Cai boars (Mean±SD).

Item	Group 1	Group 2	Group 3
Semen volume (mL)	110.12±5.16[c]	121.16±4.28[b]	128.32±6.01[a]
Sperm concentration (billion/mL)	1.25±0.21[c]	1.57±0.32[b]	1.81±0.02[a]
VSL (μm/s)	15.53±4.23[c]	18.53±4.11[b]	22.78±5.12[a]
VCL (μm/s)	48.19±5.13[c]	53.46±4.77[b]	58.25±5.52[a]
STR (%)	52.34±6.41[c]	56.89±4.65[b]	61.23±5.34[a]
ALH (μm)	2.14±0.03[c]	2.56±0.14[b]	2.92±0.14[a]
BCF (Hz)	9.21±2.05[c]	9.32±2.07[b]	9.41±3.25[a]
Abnormal sperm (%)	15.76±3.12[a]	9.89±1.08[b]	6.31±1.51[c]
Mass activity (%)	64.54±5.32[c]	70.14±4.07[b]	75.29±4.09[a]
Semen pH	7.22±0.12	7.22±0.14	7.23±0.12
Osmotic pressure (mOsm/kg)	300.83±14.66[c]	310.24±18.57[b]	318.95±20.31[a]
Viscosity (η)	1.23±0.11	1.24±0.12	1.24±0.14
Buffering capacity (β)	35.21±2.15[c]	38.97±3.12[b]	41.68±3.24[a]

[abc] Mean values within rows with different superscripts are different at $p<0.05$. VCL: curvilinear velocity (μm/sec); VSL: straight line velocity (μm/sec); STR: straightness (%); ALH: amplitude of lateral head displacement (μm); BCF: beat cross frequency (Hz).

the boars readiness to initiate mating activity following ginseng supplementation. Reaction time decreased from 45.31 ± 2.11 seconds in the control group to 25.82 ± 1.18 seconds in the high-dose group, suggesting that ginseng enhances sexual responsiveness. This effect may be attributed to ginseng's known ability to stimulate the central nervous system and improve circulation, both of which are critical for reproductive activation (Hemsworth and Tilbrook, 2007). An increase in mounting frequency (from 2.32 ± 0.35 to 4.71 ± 0.15) and libido score (from 2.06 ± 0.22 to 3.82 ± 0.03) further confirms that ginseng positively influences sexual motivation. These behavioral improvements align with previous studies in other pig breeds, such as the work by Pinho *et al.* (2013) on Piau boars, which documented increased courtship behaviors and semen collection efficiency. The underlying hormonal and neurodevelopmental processes shaping male sexual behavior, particularly the organizational effects of androgens and estrogens in the brain (Gorski, 1985), are likely modulated by ginseng's bioactive compounds, including ginsenosides. Moreover, sexual behavior in pigs is well recognized as being influenced by social context and environment. Ford (1990) and McGlone *et al.* (2020) highlighted that boars readily exhibit indiscriminate mounting, including attempts with inanimate objects, reflecting a biologically driven mating behavior. Hemsworth *et al.* (1977) demonstrated that the rearing environment plays a decisive role in shaping sexual behavior, with socially restricted males exhibiting reduced libido. The consistent improvements observed in the current study indicate that ginseng may counteract some of these environmental limitations, potentially through hormonal regulation. This view is further supported by Kowalewski *et al.* (2016), who emphasized the interaction between environment and male reproductive drive. Ejaculation latency also decreased significantly, from 124.41 ± 10.21 seconds in the control group to 86.54 ± 7.6 seconds in the high-dose group. Shorter ejaculation time is not only associated with improved sexual efficiency but is also often linked to enhanced sperm output. Kondracki *et al.* (2021) demonstrated that boars with faster ejaculation times produced ejaculates with up to 22 × 10^9/mL more sperm over time. These findings support the present study's data and reinforce the functional relevance of behavioral improvements.

Semen quality and physical and chemical characteristics of semen in Mong Cai boars

Table 2 highlights improvements in seminal characteristics, most notably semen volume, sperm concentration, and sperm motility. Volume increased from 110.12 ± 5.16 to 128.32 ± 6.01 mL, while sperm concentration rose from 1.25 ± 0.21 to 1.81 ± 0.02 billion/mL. These parameters are critical indicators of spermatogenic efficiency and

accessory gland function. Increased sperm motility, with straight line velocity (VSL) and curvilinear velocity (VCL) values improving from 15.53 ± 4.23 to 22.78 ± 5.12 µm/s and 48.19 ± 5.13 to 58.25 ± 5.52 µm/s respectively, suggests enhanced mitochondrial activity and progressive movement. This is consistent with findings by Lee *et al.* (2014) and Michos *et al.* (2020), who underscored the relevance of VSL in relation to seasonal fertility and litter size. Other motility-related traits such as straightness (STR), amplitude of lateral head displacement (ALH), and beat cross frequency (BCF) also improved with increasing ginseng dosage. Notably, STR reached 61.23 ± 5.34% and ALH reached 2.92 ± 0.14 µm in the high-dose group, indicating better directional movement. These are key factors for cryopreservation success, as highlighted by Casas *et al.* (2009), where STR and LIN are predictive of post-thaw sperm function. The evaluation of boar semen quality involves multiple parameters, among which sperm morphology is a key indicator of sperm viability and fertility. This characteristic can be assessed through routine microscopic examination and is widely recognized for its relevance to male reproductive potential (Britt *et al.*, 1999). Additionally, the abnormal sperm rate decreased significantly from 15.76 ± 3.12% to 6.31 ± 1.51%, suggesting enhanced spermatogenic integrity and reduced oxidative stress. Ginseng's antioxidant properties, likely mediated via ginsenosides, contribute to this protective effect. In a study on Duroc boars in China using the Computer-Assisted Sperm Analysis (CASA) system, Zhao *et al.* (2019) identified five major types of sperm abnormalities: Double-coiled tails, tail bending, proximal cytoplasmic droplets, distal cytoplasmic droplets, and tails wrapped around droplets. Among these, distal cytoplasmic droplets were the most prevalent abnormality (7.25%), while double-coiled tails were the least frequent (0.15%). According to Weitze (2011), total abnormal spermatozoa should remain below 25%, with head and acrosome defects limited to approximately 5% and 10%, respectively. Additionally, the incidence of cytoplasmic droplets and coiled tails should not exceed 15%. When compared with these criteria, the semen samples of Mong Cai boars in the present study met the acceptable standards for artificial insemination. The findings also support a correlation between altered sperm morphology and reduced fertilization capacity. Additionally, according to Johnson *et al.* (2000), there is an inverse relationship between the location of cytoplasmic droplets on spermatozoa and fertilization rate, with distal droplets being less harmful to fertility than proximal ones. During semen preservation, the presence of bacterial contaminants has been associated with reduced sperm motility and increased morphological abnormalities (Auroux *et al.*, 1991; Ubeda *et al.*, 2013). These microbial influences can also lead to semen coagulation (Wolff *et al.*, 1993), decreased sperm viability, and compromised acrosomal membrane integrity (El-Mulla *et al.*, 1996; Sepúlveda *et al.*, 2014).

Enhanced osmotic pressure and buffering capacity (318.95 ± 20.31 mOsm/kg and 41.68 ± 3.24, respectively) further support the sperm's resilience under environmental challenges. In contrast, baseline traits such as semen pH (7.22) and viscosity (1.24) remained unchanged, indicating that Panax ginseng selectively enhances functional rather than physicochemical attributes. Overall, these results highlight the potential of Panax ginseng as a natural feed additive for boosting reproductive performance in native boar breeds under tropical conditions. These results agree with Banaszewska and Kondracki (2012), who observed progressive improvements in ejaculate traits in young boars over time, and with Clark *et al.* (2003), who linked increased semen output to glandular maturation.

Serum testosterone levels at different time points

The hormone profile in Table 3 confirms the physiological basis for the behavioral and semen improvements observed. Testosterone levels increased significantly in both treatment groups over time. By day 42, the high-dose group reached 2.67 ± 0.16 ng/mL compared to 1.88 ± 0.09 ng/mL in the control group. This rising trend mirrors improvements in libido and semen output and is consistent with the hormone's known role in regulating reproductive function. Prior studies such as Yun *et al.* (2016) demonstrated similar hormonal and spermatogenic enhancements following ginseng treatment, reinforcing the concept that Panax ginseng acts as a natural stimulator of the male reproductive axis.

Table 3: Serum testosterone levels (ng/mL) at different time points (Mean±SD).

Item	Group 1	Group 2	Group 3
Day 0	1.85±0.11^{c}	1.87±0.05^{b}	1.92±0.05^{a}
Day 28	1.92±0.08^{c}	2.15±0.11^{b}	2.42±0.18^{a}
Day 42	1.88±0.09^{c}	2.25±0.11^{b}	2.67±0.16^{a}

^{abc} Mean values within rows with different superscripts are different at $p<0.05$

Collectively, these findings underscore the potential of *Panax ginseng* as an effective phytogenic additive for enhancing male fertility traits in indigenous pig breeds. The consistent dose-response effect, coupled with improved behavioral, physiological, and biochemical parameters, supports its application in swine breeding programs particularly under tropical conditions where native genetic resources like Mong Cai boars play a vital role in sustainable livestock development.

CONCLUSION

Panax ginseng supplementation, particularly at 10 g/day, significantly improved reproductive performance in Mong Cai boars. Notable enhancements included shorter reaction time (25.82 s), higher sperm concentration (1.81 billion/mL), reduced abnormal sperm rate (6.31%), and increased testosterone levels (2.67 ng/mL). These findings support its potential as a natural feed additive to enhance boar fertility in breeding programs.

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NOVELTY STATEMENT

This is the first study to assess the effects of Panax ginseng dry extract on semen quality and reproductive hormones in indigenous Vietnamese Mong Cai boars. While previous research has focused primarily on ginseng supplementation in poultry and rodents, this study uniquely evaluates its reproductive benefits in a native pig breed adapted to tropical conditions. The findings introduce a natural herbal strategy to enhance fertility in under-studied local pigs and support ginseng's potential use in sustainable swine reproduction programs.

AUTHOR'S CONTRIBUTION

Phan Nhan: Conceived, designed, and analyzed the data. Nguyen Thi Chuc: Wrote the draft, and performed the experiments. All authors reviewed and approved the final manuscript.

Abbreviation

AI, Artificial insemination; CASA, Computer-assisted sperm analysis; VSL, Straight-line velocity; VCL, Curvilinear velocity; STR, Straightness; ALH, Amplitude of lateral head displacement; BCF, Beat cross frequency

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None.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Auroux MR, Jacques L, Mathieu D, Auer J (1991). Is the sperm bacterial ratio a determining factor in impairment of sperm motility: An *in vitro* study in man with *Escherichia coli*. Int. J. Androl., 14(4): 264–270. https://doi.org/10.1111/j.1365-2605.1991.tb01091.x

Banaszewska D, Kondracki S (2012). An assessment of the breeding maturity of insemination boars based on ejaculate quality changes. Folia Biol., 60(3): 151–162. https://doi.org/10.3409/fb60_34.151162

Brockhuijse ML, Sostarié E, Feitsma H, Gadella BM (2012). Application of computer-assisted semen analysis to explain variations in pig fertility. J. Anim. Sci., 90(3): 779–789. https://doi.org/10.2527/jas.2011-4311

Britt JH, Almond GW, Flowers WL (1999). Diseases of the reproductive system. In: (eds. Straw B, D'Allaire S, Mengeling W, Taylor DJ (eds), Diseases of Swine, 8th edn. Blackwell Science Ltd, Ames, IA, pp. 905.

Casas I, Sancho S, Briz M, Pinart E, Bussalleu E, Yeste M, Bonet S (2009). Freezability prediction of boar ejaculates assessed by functional sperm parameters and sperm proteins. Theriogenology, 86(6): 1460–1466. https://doi.org/10.1016/j.theriogenology.2009.07.001

Clark SG, Schaeffer DJ, Althouse GC (2003). B-mode ultrasonographic evaluation of paired testicular diameter of mature boars in relation to average total sperm numbers. Theriogenology, 60(6): 1011–1023. https://doi.org/10.1016/S0093-691X(03)00127-4

Chenoweth PJ (1981). Libido and mating behavior in bulls, boars and rams. A review. Theriogenology, 16: 155–177. https://doi.org/10.1016/0093-691X(81)90098-4

El-Mulla KF, Köhn FM, Dandal M, El-Beheiry AH, Schiefer HG, Weidner W, Schill WB (1996). *In vitro* effect of *Escherichia coli* on human sperm acrosome reaction. Arch. Androl., 37(2): 73–78. https://doi.org/10.3109/01485019608988505

Ford JJ (1990). Differentiation of sexual behaviour in pigs. J. Reprod. Fertil. Suppl., 40: 311–321.

Gorski RA (1985). Sexual dimorphisms of the brain. J. Anim. Sci., 61(3): 38–61. https://doi.org/10.1093/ansci/61.Supplement_3.38

Hezavehei M, Sharafi M, Kouchesfahani HM, Henkel R, Agarwal A, Esmaeili V, Shahverdi A (2018). Sperm cryopreservation: A review on current molecular cryobiology and advanced approaches. Reprod. BioMed. Online, 37(3): 327–339. https://doi.org/10.1016/j.rbmo.2018.05.012

Hemsworth PH, Beilharz RG, Galloway DB (1977). Influence of social conditions during rearing on the sexual behaviour of the domestic boar. Anim. Sci., 24(2): 245–251. https://doi.org/10.1017/S0003356100011727

Hemsworth PH, Tilbrook AJ (2007). Sexual behavior of male pigs. Horm. Behav., 52(1): 39–44. https://doi.org/10.1016/j.yhbeh.2007.03.013

Hwang SY, Kim WJ, Wee JJ, Choi JS, Kim SK (2004). *Panax ginseng* improves survival and sperm quality in guinea pigs exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin. BJU Int., 94(4): 663–668. https://doi.org/10.1111/j.1464-410X.2004.05019.x

Johnson LA, Weitze KF, Fiser P, Maxwell WM (2000). Storage of boar semen. Anim. Reprod. Sci., 62(1–3): 143–172. https://doi.org/10.1016/S0378-4320(00)00157-3

Kondracki S, Iwanina M, Wysokińska A, Banaszewska D, Kordan W, Fraser L, Rymuza K, Górskin K (2021). The usefulness of sexual behaviour assessment at the beginning of service to predict the suitability of boars for artificial insemination. Animals, 11(12): 3341. https://doi.org/10.3390/ani11123341

Kowalewski D, Kondracki S, Gorski K, Bajena M, Wysokińska A (2016). Effect of piggery microclimate on ejaculate

performance of artificial insemination boars. Kafkas Univ. Vet. Fakult. Dergisi, 22(2): 199–204.

Lee WY, Lee R, Kim HC, Lee KH, Cui XS, Kim NH, Kim SH, Lee JI, Uhm SJ, Yoon MJ, Song H (2014). Pig spermatozoa defect in acrosome formation caused poor motion parameters and fertilization failure through artificial insemination and in vitro fertilization. Asian Austral. J. Anim. Sci., 27(10): 1417–1425. https://doi.org/10.5713/ajas.2014.14206

McGlone JJ, Aviles-Rosa EO, Archer C, Wilson MM, Jones KD, Matthews EM, Gonzalez AA, Reyes E (2020). Understanding sow sexual behavior and the application of the boar pheromone to stimulate sow reproduction. In: Reproductive Management, IntechOpen.

Michos I, Tsakmakidis I, Tsantarliotou M, Tsousis G, Hadweh P, Boscos C (2020). Effect of seasonal infertility period on boar sperm proteins and quality characteristics. J. Hellenic Vet. Med. Soc., 70(4): 1875–1882. https://doi.org/10.12681/jhvms.22238

Ministry of Agriculture (2019). Program Upsus Siwab Kementan dorong peningkatan populasi sapi/kerbau secara signifikan. Directorate General of Livestock and Animal Health Services. [Online] Available at: https://ditjenpkh.pertanian.go.id/berita/896-program-upsus-siwab-kementan-dorong-peningkatanpopulasi-sapi-kerbau-secara-signifikan [Accessed 5 May 2024].

Pinho RO, Shiomi HH, Lima DMA, Costa EV, Chaya AY, Lopes PS, Guimarães SEF, Guimaraes JD (2013). Sexual behavior and seminal quality of Piau boars. J. Vet. Behav. Clin. Appl. Res., 8(5): 357–361. https://doi.org/10.1016/j.jveb.2013.05.002

Sepúlveda L, Bussalleu E, Yeste M, Bonet S (2014). Effects of different concentrations of *Pseudomonas aeruginosa* on boar sperm quality. Anim. Reprod. Sci., 150(3–4): 96–106. https://doi.org/10.1016/j.anireprosci.2014.09.001

Soriano-Úbeda C, Romero-Aguirregomezcorta J, Matás C, Visconti PE, García-Vázquez FA (2019). Manipulation of bicarbonate concentration in sperm capacitation media improves in vitro fertilisation output in porcine species. J. Anim. Sci. Biotechnol., 10(1): 19. https://doi.org/10.1186/s40104-019-0324-y

Techakumphu M, Buranaamnuay K, Tantasuparuk W, Amin N (2013). Improvement of semen quality by feed supplement and semen cryopreservation in swine. In: Lemma, A. (ed.), Success in artificial insemination – Quality of semen and diagnostics employed, pp. 17–37. https://doi.org/10.5772/51737

Ubeda JL, Ausejo R, Dahmani Y, Falceto MV, Usan A, Malo C, Perez-Martinez FC (2013). Adverse effects of members of the *Enterobacteriaceae* family on boar sperm quality. Theriogenology, 80(6): 565–570. https://doi.org/10.1016/j.theriogenology.2013.05.022

Van NTT, Huong NT, Tu BT, Huyen LV, Anh NT (2024). Semen quality of Mong Cai boars and some influencing factors. J. Anim. Sci. Technol., 146: 95–100.

Weitze KF (2011). The importance of boar sperm motility and morphology for fertility. Int. Pig Topics, 27(5): 13–15.

Wolff H, Panhans A, Stolz W, Meurer M (1993). Adherence of *Escherichia coli* to sperm: A mannose mediated phenomenon leading to agglutination of sperm and *E. coli*. Fertil. Steril., 60(1): 154–158. https://doi.org/10.1016/0014-5793(93)81757-Q

World Health Organization (1999). WHO monographs on selected medicinal plants. Geneva: World Health Organization.

Yeste M (2018). State of the art of boar sperm preservation in liquid and frozen state. Anim. Reprod., 14(1): 69–81. https://doi.org/10.21451/1984-3143-AR895

Yun SJ, Bae GS, Park JH, Song TH, Choi A, Ryu BY, Pang MG, Kim EJ, Yoon M, Chang MB (2016). Antioxidant effects of cultured wild ginseng root extracts on the male reproductive function of boars and guinea pigs. Anim. Reprod. Sci., 170: 51–60. https://doi.org/10.1016/j.anireprosci.2016.04.002

Zhao Y, Gao N, Cheng J, El-Ashram S, Zhu L, Zhang C, Li Z (2019). Genetic parameter estimation and genomic prediction of Duroc boars' sperm morphology abnormalities. Animals, 9(10): 710. https://doi.org/10.3390/ani9100710