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Rambutan Peel Extract (*Nephelium lappaceum* L.) Improves Sperm Morphology, Viability, Motility in High-Fat-Diet Obese Rats

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ABSTRACT

Obesity in men reduces sperm quality through hormonal imbalance and increased oxidative stress due to *Reactive Oxygen Species* (ROS). This study aimed to determine the effect of rambutan peel extract (*Nephelium lappaceum* L.) on sperm quality in terms of morphology, viability, and motility in obese male rats. This study used a quantitative experimental design with 25 male *Sprague-Dawley* rats wich were divided into five groups: normal (K−); obese (K+); obese with *ellagic acid* (T1); obese with RPE 15 mg/kg BW (T2); and obese with RPE 30 mg/kg BW (T3), and obesitywas induced by a high-fat diet using coconut oil and 15% sucrose for seven weeks, and sperm parameters analyzed under a light microscope. Obesity reduced sperm morphology, viability, and motility. Administration of *ellagic acid* (T1) moderately improved sperm quality but had limited effects on morphology and motility, RPE 15 mg/kg BW (T2) significant and optimal improvement in morphology (94.2 ± 2.28%) and motility (56.0 ± 4.00%), and viability also higher (82.2 ± 5.06%) compared to the obesity group ($p < 0.05$), and RPE 30 mg/kg BW (T3) showed a decrease in effect due to the hormesis. The results showed that RPE at a dose 15 mg/kg BW was the most effective in improving sperm quality in obese rats, suggesting its potential application for supporting male reproductive health under conditions of obesity.

Keywords:
Rambutan peel extract; *Ellagic acid*; Obesity; Sperm quality; Rat model; High-fat diet

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1. Introduction

According data from the *World Health Organisation* (WHO) in 2022, obesity affects approximately 2.5 billion adults worldwide and is increasingly recognized as a contributing factor to male infertility. Based on study, male factors contribute to around 20–30% of infertility cases, with around 50% of couples affected by male factors[1]. Obesity in men can cause secondary hypogonadism, decreasing testosterone and SHBG and increasing oestrogen, thereby disrupting spermatogenesis [2].

Obesity has a negative impact on the male reproductive system and is one of the main causes of infertility, including decreased sperm motility, viability, and morphology due to increased oxidative stress from *Reactive Oxygen Species* (ROS) and hormonal

imbalances [3],[4]. Excessive oxidative stress due to increased *Reactive Oxygen Species* (ROS) can disrupt the structure of membranes, DNA, and spermatozoa function, thereby reducing fertility [5]. In addition, obesity can cause hyperleptinaemia, chronic inflammation, insulin resistance, and increased scrotal temperature, which can interfere with spermatogenesis and testicular function.

The accumulation of adipose tissue in obesity increases the production of oestradiol and leptin and inhibits the secretion of *Luteinising Hormone* (LH) and *Follicle-Stimulating Hormone* (FSH), and testosterone through disruption of the pituitary-gonadal sensitivity to *Gonadotropin-Releasing Hormone* (GnRH). A decrease in LH reduces testosterone synthesis by Leydig cells, while a decrease in FSH reduces the stimulation of Sertoli cells for the production of Androgen Binding Protein (ABP), resulting in insufficient testosterone levels and disrupting spermatogenesis. This hormonal imbalance further triggers oxidative stress, apoptosis, and chronic inflammation in the testes, which reduces sperm quality [6],[7].

One natural ingredient with potential as an anti-obesity agent is rambutan peel (*Nephelium lappaceum* L.) [8]. Although often considered agricultural waste, rambutan peel has been found to contain antioxidant compounds such as steroids, terpenoids, tannins, saponins, phenolics, flavonoids, β-carotene, vitamin C, and alkaloids [9], [10]. Protocatechuic acid, a phenolic compound, has also been found in rambutan peel extract. The main phenolic polyphenol compounds in rambutan peel are *ellagic acid*, coralligin, and geraniin [11]. Ethanol extract of rambutan peel from the Sapindaceae family contains flavonoids and phenolic compounds with high antioxidant activity, with an IC50 value of 1.155 µg/mL [10]. This extract has been shown to suppress ROS and improve sperm quality in obese rats, although the specific role of *ellagic acid* as the main polyphenol component has not been extensively studied [12],[13]. The utilisation of rambutan peel also supports the concept of zero waste and the development of phytopharmaceuticals from agricultural waste [14].

This study aims to analyze the effects of commercial *ellagic acid* and rambutan peel extract at doses of 15 mg/kg BW and 30 mg/kg BW on the comparison of spermatozoa quality in obese rats. The research specifically focused on analyzing morphology, viability, and motility to determine whether this treatment could significantly increase sperm quality compared to obese control rats.

2. Methods

Study design

This study employed a quantitative approach with an experimental research design laboratory. The research was conducted at the Averroes Dental Research Laboratory, Faculty of Dentistry, UNISSULA Semarang, from May to August 2025.

Materials

The materials used were male *Sprague Dawley* white rats, rambutan peel as the extraction material, spermatozoa obtained from the reproductive organs of rats, standard feed, 15% sugar water, coconut oil, ethanol, distilled water, commercial *ellagic acid* (Biotech Nutritions), chloroform, physiological NaCl, and eosin dye.

The research equipment used included rat cages, drinking bottles, stomach probes, gloves, OHAUS balances, analytical balance, oven, blender, separating funnel, measuring cup, beaker, evaporator, dissecting board, surgical set, tweezers, petri dish, cover glass, staining jar, pipette, microscope, and computer equipped with Optilab software.

Preparation of Rambutan Peel Extract

Rambutan peel extraction was carried out using the maceration method. Dried rambutan peel was ground using a blender until it became a dry powder (simplicia). In this research used 2 kg of dried rambutan peel were ground to produce 1.2 kg of rambutan peel simplicia. A total of 1,2 kg of powder was prepared and soaked in 70% ethanol at a ratio of 1:6 (1 kg of simplicia: 6 L of ethanol), stirred for 3 hours and left to stand for 3x24 hours. After that, the filtrate was separated using filter paper. The alcohol in the filtrate is then evaporated using a rotary evaporator at 40°C for 1-2 weeks until a thick extract is obtained [15]. The extraction process yielded 16.9%. The concentrated extract should be stored in a tightly sealed container at 2-4°C until further use to prevent oxidation or microbial contamination.

Preparation of Test Animals

The test animals in this study were male white rats (*Sprague-Dawley*) aged 6-8 weeks with a weight range of 160-200 g. Weight was measured weekly. Rats were categorised as obese if the Lee Index reached ≥ 0.30.

$$\text{Formula Lee Index} = \frac{\sqrt[3]{Body\ weight\ (g)}}{\text{Naso}-\text{anal length (cm)}}$$

Before treatment, all test animals underwent an acclimatisation process for 7 days. Five rats were kept per cage and fed a standard diet of 122 grams/day. Obesity was induced for seven weeks through a high-fat diet consisting of a combination of 3 mL of coconut oil/rat per day and 15% sucrose sugar water, 250 mL per cage per day in addition to the strandard diet. The composition of the standard diet included 19–20% crude protein, 8% crude fat, ≤5% crude fiber, ≤6% ash, 0.9% calcium, ≥0.5% phosphorus, ≥1% lysine, ≥0.4% methionine, ≥0.8% methionine + cysteine, and 0.7% threonine. Obesity induction was confirmed by measuring body weight weekly and calculating the Lee index using the formula above.

The test animals were grouped into 5 categories (n = 5 rats per group) with the following group divisions: normal (K-), obese (K+), obese + *Ellagic acid* administration (T1), obese + rambutan peel extract administration 15 mg/kg BW (T2), and obese + rambutan peel extract administration 30 mg/kg BW (T3).

Testing on Test Animals

Treatments were initiated 7 days after the last day of high-fat diet induction (July 11, 2025). The treatment included the administration of *ellagic acid* at a dose of 1.2 mL/rat and rambutan peel extract at doses of 15 mg/kg BW and 30 mg/kg BW, which were administered oral gavage using a gastric tube. The rambutan peel extract was administered once a day at 09.00 WIB for a period of 30 days (July 19 to August 17, 2025), and termination was carried out on the 31st day wich was the day after the last treatment.

Observation of Research Variables

Sperm samples were obtained through the termination of test animals via anaesthesia with chloroform followed by cervical dislocation. Abdominal dissection was then performed to retrieve the vas deferens, thereby obtaining sperm samples. Sperm were suspended in 1 mL of 0.9% physiological NaCl solution [16].

Spermatozoa Morphology

Sperm morphology was observed using eosin-stained smear preparations and examined under an Olympus CX-21 light microscope at 100x magnification. A total of 100 spermatozoa were observed and classified as normal or abnormal based on the

condition of the head, midpiece, and tail [17]. The percentage of spermatozoa can be calculated using the formula:

$$\text{Spermatozoa Morphology} = \frac{Number\ of\ Spermatozoa\ Normal}{Total\ Spermatozoa\ Count} \times 100\%$$

Spermatozoa Viability

Spermatozoa viability was observed on smear preparations stained with eosin dye and then observed using an Olympus CX-21 light microscope at 100x magnification. A total of 100 spermatozoa were observed [18]. Live spermatozoa were characterised by an unstained head, while dead spermatozoa were stained red. The percentage of spermatozoa viability was determined using the formula:

$$\text{Spermatozoa Viability} = \frac{Number\ of\ Viable\ Spermatozoa}{Total\ Spermatozoa\ Count} \times 100\%$$

Sperm Motility

Sperm motility analysis was performed by placing a sperm suspension on an object glass, then analysing it using an Olympus CX-21 light microscope with 100x magnification. Observations were made in five fields of view, each containing 100 spermatozoa, and categorised as progressive (moving), non-progressive (moving in place), or immotile (not moving). To determine the percentage of sperm motility, the following formula can be used:

$$\text{Spermztozoa Motility} = \frac{Number\ of\ Motile\ Spermatozoa}{Total\ Spermatozoa\ Count} \times 100\%$$

Data analysis

Data analysis was performed statistically using SPSS software. Data normality was determined using the Shapiro–Wilk test because the sample size was less than 50, followed by a homogeneity of variance test. For normally distributed and homogeneous data, differences between groups were tested using One-Way ANOVA, followed by the Tukey HSD test if the results showed significance ($p < 0.05$). If the parametric assumption was not met, the analysis was shifted to the non-parametric Kruskal–Wallis test.

Ethical Approval

This study has been approved by the Health Research Ethics Committee (KEPK), Faculty of Medicine, University of Negeri Semarang, with No. 1011/KEPK/FK/KLE/2025.

3. Results and Discussion

High-Fat Diet-Induced Obesity

Obesity is a multifactorial condition influenced by genetic factors and lifestyle. In this study, obesity was caused by lifestyle factors through the administration of a high-fat and sucrose diet, which triggered an energy imbalance between intake and expenditure, leading to the accumulation of adipose tissue and metabolic disorders. The administration of coconut oil and sucrose water for seven weeks increased the body weight of rats and caused obesity based on a Lee Index value of ≥ 0.30. Coconut oil is rich in saturated fatty acids, which play a role in increasing visceral fat accumulation and adipocyte hypertrophy and trigger oxidative stress due to increased production of *Reactive Oxygen Species* (ROS) [19]. Meanwhile, sucrose can increase insulin levels and *de novo lipogenesis*, which contribute to fat accumulation and weight gain [20]. Thus, the combination of coconut oil and sucrose is effective as a high-fat diet model because both play a role in increasing food intake, adipose tissue accumulation, and body weight in rats.

The Effect of Obesity Due to a High-Fat Diet on Spermatozoa Quality

Obesity is a condition of excessive fat accumulation in the body and affects the male reproductive system, one of which is spermatozoa quality through the mechanisms of hormonal imbalance and oxidative stress.

Table 1. Mean of Morphology, Viability, and Motility of Rat Spermatozoa After Treatment

Treatment Group	Mean (%) ± Standard Deviation (n=5)		
	Morphology	**Viability**	**Progressive Motility**
K- (Normal)	90.20 ± 1.64^{b}	79.80 ± 9.23^{a}	49.40 ± 5.81^{ab}
K+ (Obesity)	85.00 ± 1.87^{a}	66.40 ± 4.39^{a}	40.00 ± 11.37^{a}
T1 (Obesity + *Ellagic acid*)	88.20 ± 1.78^{ab}	73.20 ± 2.77^{a}	45.00 ± 6.44^{ab}
T2 (Obesity + RPE 15mg/kg BW)	94.20 ± 2.28^{c}	82.20 ± 5.06 ^{a}	56.00 ± 4.00^{b}
T3 (Obesity + RPE 30 mg/kg BW)	90.00 ± 1.87^{b}	80.60 ± 6.22^{a}	50.00 ± 8.38^{ab}

Note: Numbers followed by different superscript letters (a, b, c) within the same column indicate significant differences between treatment groups ($p < 0.05$)

The normality of the data was tested using the Shapiro–Wilk test. Morphology and progressive motility data were normally distributed ($p > 0.05$) and analyzed using one-way ANOVA. Morphology showed a significant difference ($p = 0.000$), and the progressive motility was also showed a significant difference ($p = 0.038$), followed by Tukey's post-hoc test. Viability data were not normally distributed ($p < 0.05$) and were analyzed using the Kruskal–Wallis test, which showed a significant difference ($p = 0.003$), followed by the Mann–Whitney post-hoc test.

Based on **Table 1**, the obesity group (K+) showed a significant decrease in sperm morphology (5.2%), viability (13.4%), and progressive motility (9.4%) compared to the normal group (K-). These results are consistent with previous reports stating that obesity due to a high-fat diet can interfere with spermatogenesis and reduce sperm quality through hormonal and oxidative stress mechanisms [21],[22].

Physiologically, obesity increases the accumulation of adipose tissue around the testes, thereby triggering oxidative stress and disrupting the hypothalamic-pituitary-testicular axis, characterised by a decrease *in Gonadotropin-Releasing Hormone* (GnRH), *Luteinising Hormone* (LH), and *Follicle-Stimulating Hormone* (FSH), thereby decreasing testosterone production [23]. Decreased testosterone levels are also associated with mitochondrial dysfunction, triggering a decrease in ATP levels and increasing the production of *Reactive Oxygen Species* (ROS) [24]. This triggers apoptosis, causing spermatogenesis disorders and abnormal spermatozoa morphology, as shown in **Figure 1**.

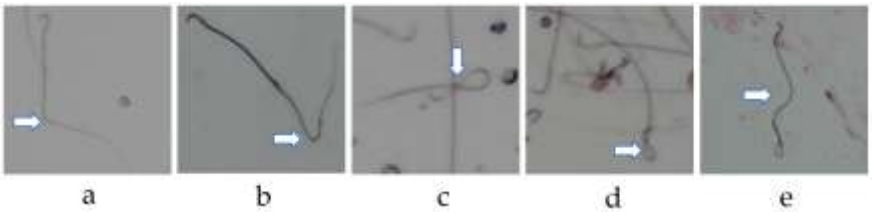

Figure 1. Morphology of Abnormal Spermatozoa in Obese Rats
(a) curved tail, (b) broken tail, (c) abnormal midpiece,

(d) abnormal head, (e) abnormal spermatozoa shape.

The plasma membrane of spermatozoa, which is rich in *polyunsaturated fatty acids* (PUFA), is susceptible to lipid peroxidation caused by ROS, thereby reducing membrane fluidity, damaging DNA, and disrupting the function of spermatozoa structural proteins [25]. Membrane damage increases permeability, allowing eosin dye to enter, so that non-viable spermatozoa are red, while viable spermatozoa remain unstained, as shown in **Figure 2.** Oxidative stress causes mitochondrial dysfunction and reduces the production of *adenosine triphosphate* (ATP) required for flagellum movement, thereby decreasing sperm motility and causing it to become non-progressive or immotile. Additionally, increased ROS disrupts Ca^{2+} ion homeostasis, which plays a crucial role in capacitation and spermatozoa movement, further worsening spermatozoa motility [26],[27].

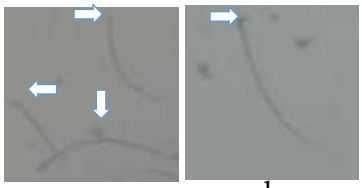

Figure 2. Viability of spermatozoa in obese rats (Eosin staining).
(a) Viable sperm (clear head); (b) Non-viable sperm (red head).

The decline in spermatozoa quality in obesity occurs in an interrelated manner between morphology, viability, and motility of spermatozoa. Morphological damage to the midpiece and tail of spermatozoa has a direct impact on decreased motility because the midpiece contains mitochondria that produce energy in the form of *adenosine triphosphate* (ATP) as a source of energy for flagellum movement, while damage to the tail causes uncoordinated flagellum movement. In addition, damage to the plasma membrane due to oxidative stress disrupts ion balance and intracellular metabolism, thereby reducing spermatozoa viability. Mitochondrial metabolic disorders also contribute to decreased spermatozoa motility [28]. These findings indicate that obesity triggers structural and functional disorders in spermatozoa, thereby reducing overall spermatozoa quality.

The Effect of *Ellagic Acid* on Sperm Quality

In this study, K− was the normal (non-obese) control group that was fed a standard diet and given drinking water, while K+ was the obese control group that was induced to consume a high-fat diet and did not receive any treatment. Group T1 was the treatment group given Ellagic acid, T2 was the treatment group given RPE at a dose of 15mg/BW, and lastly T3 was the group given RPE at a dose of 30mg/BW.

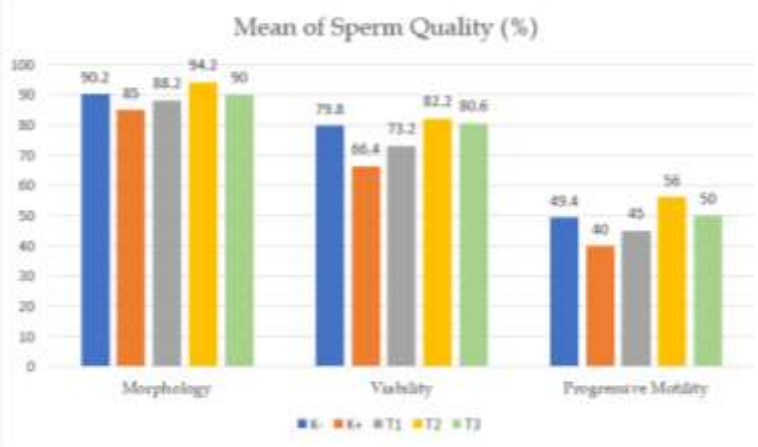

Figure 4. Average Sperm Quality Graph

Ellagic acid plays a role in improving spermatozoa quality in obese conditions. This can be seen in **Figure 4**, which shows that administering 1.2 mL/rat of *ellagic acid* to obese rats improved sperm morphology (3.2%), viability (6.8%), and progressive motility (5%), compared to the obese group without treatment. The significant increase in spermatozoa viability indicates the role *of ellagic acid* in maintaining membrane integrity through its antioxidant activity. However, improvements in sperm morphology and motility were not optimal because structural damage and mitochondrial dysfunction due to oxidative stress require more complex protective and repair mechanisms. This is in line with [29] which states that the antioxidant response is not always uniform across sperm parameters.

The Effect of Rambutan Peel Extract on Sperm Quality

Administration of rambutan peel extract at a dose of 15 mg/kg BW to the obese group had the most optimal effect on improving spermatozoa quality in terms of morphology, viability, and motility parameters. As shown in **Tabel 1**, that the RPE 15 mg/kg BW group had a significant difference from the obesity group (K+). RPE 15mg/kg BW can significantly increased sperm morphology (9.2%), viability (16.4%), and progressive motility (16%) compared to the obesity group (K+), as presented in **Figure 1**. This increase shows that RPE 15 mg/kg BW can improve sperm quality affected by obesity through a protective effect on sperm cell membrane integrity and support sperm physiological function. Overall, these data confirm this dose provides an optimal response to improving sperm quality in obese rats, both in terms of structure and function.

Based on the results presented in **Figure 1,** the obese group administered with rambutan peel extract at a dose of 30 mg/kg BW was able to significantly improve sperm morphology (5%), viability (14.2%), and progressive motility (10%) compared to the obese group (K+). However, the RPE 30 mg/kg BW group experienced a decrease in effect compared to the group administered 15 mg/kg BW of rambutan peel extract. This is due to the phenomenon of *dose-dependent biphasic* effect or hormesis. Hormesis is a condition where a low dose of a compound can have beneficial effects, while a higher dose has the opposite effect [30]. The decrease in effect at a dose of 30 mg/kg BW is likely due to the pro-oxidant activity at high doses increasing oxidative stress. This inhibits mitochondrial function and ATP production, thereby reducing the protective response to oxidative stress. Several studies have reported that flavonoid compounds such as quercetin exhibit protective properties at low doses, but high doses actually inhibit cell function and increase oxidative stress [31]. This explains why the effect of RPE 30 mg/kg BW is lower than that of RPE 15 mg/kg BW.

The improvement in sperm quality in the treatment group was related to the bioactive compounds in rambutan peel extract, such as *ellagic acid,* coraligin, graniin, quercetin, flavonoids, saponins, tannins, terpenoids, alkaloids, and vitamin C [10], [11]. Administration of rambutan peel extract to obese rats significantly improved sperm quality. This is due to bioactive compounds that function as antioxidants. These compounds protect sperm membranes and mitochondria from oxidative damage and support the spermatogenesis process, thereby improving sperm morphology, motility, and viability [32], [33], [34].

The data from this study show that *ellagic acid* and rambutan peel extract to obese rats showed varying effects on sperm quality. *Ellagic acid* had a modest effect on sperm morphology and motility, but significantly increased viability. RPE at a dose of 15

mg/kg BW is the most effective dose in improving the quality of damaged spermatozoa in obese conditions. This is shown by its ability to improve sperm morphology, viability, and motility in obese rats. Higher doses, RPE 30 mg/kg BW, also increased sperm quality, but the effect was reduced, showing a dose-dependent biphasic pattern. These results are in line with a previous study [15]which indicated that rambutan peel extract at a moderate dose can provide optimal effects in reducing spermatozoa abnormalities in obese rats.

This study has several limitations. This study used rambutan peel extract obtained from dried rambutan fruit peel extracted with 70% ethanol and administered to male *Sprague-Dawley* rats induced with a high-fat diet. Obesity in this model was experimentally induced, which may not fully represent obesity that occurs naturally or is caused by genetic factors. The sample size was limited, with five rats per group, which could potentially affect statistical power and generalizability. This study focused exclusively on sperm quality, including morphology, motility, and viability, without assessing other reproductive, hormonal, or biochemical parameters. Only three doses of the extract were tested, leaving the possibility that other optimal doses have not been explored.

4. Conclusion

Based on the results and discussion, the study concluded that a 15 mg/kg BW dose of rambutan peel extract is the optimal dose for improving sperm quality in obese conditions, as indicated by significant improvements in sperm morphology (9.2%), viability (16.4%), and progressive motility (16%) compared to the untreated obese group. Meanwhile, the 30 mg/kg dose showed a decrease in the improvement effect, which is thought to be due to the hormesis phenomenon. This study is still preclinical in nature conducted on laboratory animals, so its application in humans requires further study. Further research should use standardized extracts, larger sample sizes, and measurements of oxidative stress and reproductive hormone parameters to support its translational potential.

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Conflicts of Interest:

The authors declare no conflict of interest regarding the publication of this paper.

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