Honey Improves Sperm Parameters in High Cholesterol Diet-Fed Male Rabbits

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Overconsumption of a high-energy diet has a negative impact on sperm motility, morphology, vitality and concentration. Hence, this study aims to investigate the effects of honey on sperm parameters of high cholesterol diet-fed rabbits and compare its effects with atorvastatin. Forty-eight male New Zealand white rabbits were assigned into 6 groups: Control (C): commercial pellet; CH: commercial pellet and 600 mg/kg/day Trihoney; HCD: 1% cholesterol diet; DH1: 1% cholesterol diet and 300 mg/kg/day Trihoney; DH2: 1% cholesterol diet and 600 mg/kg/day Trihoney; DAt: 1% cholesterol diet and 2 mg/kg/day atorvastatin. After 12 weeks, each rabbit was anaesthetized. Sperm were obtained from the cauda of the epididymis. Percentages of progressive (PM) and total motility (TM) were assessed using light microscope. Vitality and morphology were assessed using Eosin-Nigrosin stain. Sperm concentration was calculated using haemocytometer. Administration of 1% cholesterol diet reduced the percentages of PM, TM and normal sperm. Treatment with atorvastatin reduced the percentages of PM, TM, live and normal sperm. A marked reduction in sperm concentration was detected in the HCD and DAt groups. Trihoney groups expressed significantly higher percentages of PM, TM, normal sperm, live sperm and sperm concentration than the HCD and DAt groups. These results indicate that Trihoney has the potential to minimize the negative impacts of a high cholesterol diet on sperm parameters.

Keywords: high cholesterol diet; sperm parameters; Trihoney; atorvastatin

I. INTRODUCTION

Spermatogenesis is a multistep process through which sperm are produced from male germ cells in the seminiferous tubules of the testes. It is a sensitive process requiring optimal conditions to occur perfectly as it is essential for male reproduction (Azenabor et al., 2015). Poor semen quality is a widespread problem and it is one of the causes of infertility in approximately half the number of couples seeking assistance in order to achieve parenthood (Jensen et al., 2013). Sperm count, motility and morphology are parameters used to estimate male fertility (Wong et al., 2000). They provide information about the functions of the seminiferous tubules, epididymis, and accessory sex glands. They also give an idea about the diagnosis and prognosis of infertility (Esteves, 2014). Abnormal sperm analysis includes oligozoospermia (sperm count less than 39×10^6/ejaculate or sperm concentration less than 15×10^6/mL), asthenozoospermia

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(progressive motility less than 32%) and teratozoospermia (normal morphology less than 4%) or a combination of any of these, in addition to several others (WHO, 2010). Overconsumption of a high energy diet has a negative impact on spermatogenesis at central and gonadal levels. It disrupts energy supply to male germ cells, induces sperm defects and spermatogenesis arrest (Rato et al., 2014). Hypercholesterolemia induced by a high cholesterol diet was found to reduce sperm functionality, count and motility coupled with an increase in sperm morphological abnormalities (Saez Lancellotti et al., 2010, 2013). Furthermore, it impairs spermatogenesis (Mohamed et al., 2020a) and markedly reduces epididymal mature sperm count (Mohamed et al., 2020b). Although extensive research has been conducted and abundant information are available about male infertility, the use of medical treatment is associated with various side effects (Dabaja & Schlegel, 2014) and assisted reproductive technology is expensive and not always available and successful (Mora-Esteves & Shin, 2013). The inclination of the general population nowadays is toward the use of herbal medicine (Zarei et al., 2014). Trihoney is a mixture of three types of honey namely Trigona, Mellifera and Tualang at a specific ratio. It is a product developed by the Department of Nutrition Sciences, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia. It was optimized using Response Surface Methodology (RSM) of Design Expert Version 6.0 software. It has a high total phenolic content. Hence, the objective of the current study is to investigate the protective effects of Trihoney on sperm parameters of high cholesterol diet-fed male rabbits and compare its effects with atorvastatin, which is the most commonly used among statins that are the first line lipid lowering agents.

II. MATERIALS AND METHOD

A. Ethics Statement

The details of the current animal experiment were reviewed and approved by the International Islamic University Malaysia Institutional Animal Care and Use Committee (IACUC-IIUM), IIUM, Kuantan campus.

| Group | Given name | Diet and Treatment |
|-------|------------|--------------------|
| I     | C          | Commercial rabbit pellet + No treatment |
| II    | CH         | Commercial pellet + 600 mg/kg/day of Trihoney |
| III   | HCD        | 1% cholesterol + No treatment |
| IV    | DA1        | 1% cholesterol +2 mg/kg/day atorvastatin |
| V     | DH1        | 1% cholesterol + 300 mg/kg/day of Trihoney |
| VI    | DH2        | 1% cholesterol + 600 mg/kg/day of Trihoney |

The high cholesterol diet was prepared according to Mohamed et al. (2020b). Trihoney doses were calculated according to Reagan-Shaw et al. (2007) by conversion of human equivalent dose, which is 0.1-0.2 g/Kg/day (Mohamed et al., 2011; Natural Medicines Comprehensive Database, 2016), to animal equivalent dose. The used dose of atorvastatin was 2 mg/kg/day (Du et al., 2013). Atorvastatin was reconstituted in 1 mL of distilled water before its oral administration (Song et al., 2014). The duration of
spermatogenesis in rabbits is between 7 to 8 weeks and the studies that aim to determine the effects of exogenous factors on spermatogenesis should be continued at least for 10 weeks (International Rabbit Reproduction Group, 2005), therefore this experiment was carried out for 12 weeks.

The purpose of having CH group was to evaluate the enhancing effect of Trihoney on sperm parameters of normocholesterolemic rabbits. It also investigates the safety of Trihoney to be consumed without negative impacts of Trihoney itself on the tested parameters.

D. Preparation of Caudal Epididymal Sperm Suspension

At the end of the 12 weeks, the rabbits fasted overnight and anaesthetized using intramuscular injection of ketamine/xylazine at a dose of 50/10 mg/kg body weight (Zhao et al., 2013). A longitudinal midline incision was made through the abdominal cavity and pelvis. The right testis and epididymis were immediately and carefully excised and separated from each other. The sperm were obtained from the cauda of the excised right epididymis (Chen et al., 2012; Yamamoto et al., 1999). The cauda was placed immediately into a sterile petri dish (Nalgene, Denmark) containing 4 mL of sperm washing media pre-warmed at 37°C (Yamamoto et al., 1999; Ilbey et al., 2009). The cauda was minced and incubated in the pre-warmed sperm washing media for 5 to 10 minutes to allow recovery and dispersion of sperm (Chen, Gong & Xu, 2012; Rato et al., 2013).

E. Analysis of Sperm Motility

Ten microliters of sperm suspension were placed on a pre-warmed slide (37°C) and covered with a pre-warmed cover slip (37°C) size 22 mm × 22 mm (MENZEL-GLASER®), to provide a chamber with 20 µm depth, and examined under ×400 magnification of the microscope (Leica, Germany) (WHO, 2010). Ten random fields were assessed and the average value was used as an indicator of motility (Rato et al., 2013). The percentages of progressive motility, total motility and immotile sperm were assessed for each rabbit (WHO, 2010).

F. Analysis of Sperm Vitality and Morphology

Sperm vitality was assessed by means of the dye exclusion method using Eosin-Nigrosin staining technique according to the protocol of VitalScreen kit (FertiPro, Belgium). A total of 200 sperm were assessed under ×400 and ×1000 magnifications to determine the percentages of live and dead sperm. Live sperm were identified by their white or light pink heads; whereas, dead sperm have dark pink or red coloured heads (WHO, 2010; Chen, Gong & Xu, 2012). Sperm morphology percentages were assessed from the same smears prepared for vitality analysis with assessment of 200 sperm under ×400 and ×1000 magnifications. The sperm were tested for head defects: large or small, tapered, pyriform, round, amorphous or double heads; neck and midpiece defects: asymmetrical insertion of the midpiece into the head, thick or irregular, bent or abnormally thin; tail defects: coiled, bent, short or double tails or any combination of these (Ping et al., 2014; WHO, 2010).

G. Analysis of Sperm Concentration

Sperm concentration was calculated using haemocytometer (Neubauer-improved, Hirschmann, European Union). An aliquot of 50 µL from the sperm suspension was diluted with distilled water in a sterile Eppendorf tube; two replicates were prepared. The dilution was performed based on the number of sperm which was seen in the preparation used for motility. If the sperm count per ×400 magnification was more than 101, a dilution of 1:20 (50 µL: 950 µL) was used; for sperm count between 16-100, the dilution was 1:5 (50 µL:200 µL); whereas, a dilution of 1:2 (50 µL:50 µL) was used if the sperm count was below 15 (WHO, 2010). After mixing the samples well, 10 µL from each replicate dilution was transferred into one of the two chambers of the haemocytometer which was kept horizontally in a humid chamber for 5 minutes to prevent drying. Two-hundred sperm were assessed in each replicate with assessment of the central grid (number 5) at first; if the count did not reach 200 sperm in the central grid, the counting was continued in the adjacent grids number 4 and number 6. For the samples of low concentrations, the counting was continued in the rest of the grids and involved all nine grids in some rabbits (WHO, 2010). The equation
used for calculation of the concentration is as follows (WHO, 2010):

\[ C = \frac{(N/n) \times (1/20) \times \text{dilution factor}}{10^6/\text{mL}} \]

where: \( C \) = Concentration, \( N \) = Total number of sperm in both chambers and \( n \) = number of rows or grids examined for the replicates.

**H. Statistical Analysis**

Data were processed using the Statistical Package for the Social Sciences Version 21 (SPSS Inc., Chicago, Illinois, USA). They were expressed as means and standard deviations. One-way analysis of variance test (ANOVA) was used for data analysis followed by a post hoc test to determine any significant differences between the means of the independent groups. Differences were considered to be statistically significant at p values less than 0.05.

**III. RESULT AND DISCUSSION**

The deleterious effects of a high cholesterol diet and hypercholesterolemia on sperm function and quality has been studied and reported both in animal and human studies. In human, hypercholesterolemia independent of obesity was found to be negatively associated with sperm morphology and vitality (Schisterman et al., 2014). In animals, hypercholesterolemia caused reduction in the sperm count, motility and vitality associated with an increase in the sperm morphological abnormalities (Saez Lancellotti et al., 2010, 2013; Ouvrier et al., 2011). However, for the first time, this study demonstrated that honey supplementation—using Trihoney—recovered almost all of the changes in sperm parameters induced by the high cholesterol diet.

The results of the effects of 1% cholesterol diet, Trihoney and atorvastatin on the different categories of sperm motility are summarized in Table 2.

**Table 2. Effects of 1% cholesterol diet, Trihoney and atorvastatin on percentages of sperm motility**

| Parameters | PM (%) | TM (%) | Immotile sperm (%) |
|------------|--------|--------|-------------------|
| C          | 85.38±7.96<sup>a</sup> | 96.40±1.16<sup>a</sup> | 3.60±1.16<sup>a</sup> |
| CH         | 82.72±15.49<sup>a</sup> | 95.73±4.95<sup>a</sup> | 4.27±4.05<sup>a</sup> |
| HCD        | 15.88±12.23<sup>b</sup> | 60.42±30.69<sup>b,c</sup> | 39.58±30.69<sup>b,c</sup> |
| DAT        | 42.36±40.47<sup>c</sup> | 79.43±27.34<sup>a,c</sup> | 20.56±27.34<sup>a,c</sup> |
| DH1        | 58.32±34.32<sup>a,c</sup> | 94.20±3.26<sup>a</sup> | 5.80±3.26<sup>a</sup> |
| DH2        | 75.20±20.44<sup>a</sup> | 94.20±3.26<sup>a</sup> | 5.80±3.26<sup>a</sup> |

Data were analysed using one-way analysis of variance. A Post Hoc test (LSD) was used to test the significant difference between the groups. Values are given as mean ± standard deviation. Values not sharing a common superscript letter within the same column differ significantly at p<0.05. PM: progressive motility; TM: total motility. C: commercial pellet; CH: commercial pellet plus 600 mg/kg/day Trihoney; HCD: 1% cholesterol diet; DH1: 1% cholesterol diet plus 300 mg/kg/day Trihoney; DH2: 1% cholesterol diet plus 600 mg/kg/day Trihoney; DAT: 1% cholesterol diet plus 2 mg/kg/day atorvastatin.

Motility is an important characteristic of fertile sperm. It is the most widely used indicator of sperm function as it reflects structural and functional competence of the sperm (Partyka et al., 2012). The extent of progressive motility is related to pregnancy rate (WHO, 2010). Only sperm moving in straight patterns succeed in the process of fertilization; whereas, those swim in tight circles are unable to pass through the utero-tubal junction (Amelar et al., 1980). In the present study, administration of a high cholesterol diet induced reduction in the percentages of progressive (p<0.05) and total motility (p<0.05) and increased the percentage of immotile sperm (p<0.05) compared to the control group. In agreement with this study, Saez Lancellotti et al. (2010, 2013) and Yamamoto et al. (1999) reported the same effects of a hypercholesterolemic diet on sperm motility in rabbits. The negative impact of a high cholesterol diet on sperm motility was also reported in transgenic mice (Ouvrier et al., 2011).

Normal morphology is another important attribute of sperm and its evaluation is essential in sperm analysis. It provides clinical information about the potential fertility of semen sample (Partyka et al., 2012). The alteration of normal sperm morphology could be a sign of subfertility (Saez Lancellotti et al., 2010). Cholesterol intake promotes several changes in sperm cells (Saez Lancellotti et al., 2013). In the
current study, a high cholesterol diet significantly decreased the percentage of sperm with normal morphology (p<0.05) and increased the percentage of sperm with abnormal morphology (p<0.05) as demonstrated in Table 3 and Figure 1. Similar results were reported by Saez Lancellotti et al. (2010, 2013). In those studies, the morphological abnormalities were in the form of folded head and presence of cytoplasmic droplets; however, the morphological alterations in the present study were mostly in the form of coiled or bent tail, bent neck and double tails. The morphological abnormalities which were reported in our study are in agreement in part with another study conducted by Shalaby (2004) to study the effect of α-tocopherol and simvastatin on infertility in hypercholesterolemic rats. Ouvrier et al. (2011) demonstrated an increase in the percentage of broken cells with high cholesterol diet. Table 3 also demonstrates the effects of 1% cholesterol diet on sperm concentration. Sperm concentration is used to measure the ability of the testes to produce an adequate number of sperm and the patency of the male reproductive tract. It is related to fertilization and pregnancy rate and is a predictor of pregnancy (WHO, 2010). In this study, administration of 1% cholesterol diet caused severe reductions in the sperm concentration (p<0.05). This result is in line with the results reported by Saez Lancellotti et al. (2013) and Shalaby (2004). However, Ouvrier et al. (2011) reported that there is no difference in epididymal sperm count after a high cholesterol diet administration, which was attributed to the normal testicular structure and function in that study.

Another essential parameter of potentially fertile semen sample is the viable sperm (Martınez, 2004). The effects of 1% cholesterol diet on sperm vitality are given in Table 3 and Figure 1. Even though there was a reduction in the percentage of live sperm after a high cholesterol diet administration in the present study, it lacks the significant difference from the control. Similar results were obtained by Saez Lancellotti et al. (2013) upon administration of a high cholesterol diet to male rabbits. Contradicting results exhibiting a significant reduction in sperm vitality after a high cholesterol diet administration were reported in previous studies conducted on mice and rats, which was suggested to be due to the earlier effect of the high cholesterol diet on the epididymal tissue than its effect on the testicular tissue (Ouvrier et al., 2011; Shalaby, 2004).

Table 3. Effects of 1% cholesterol diet, Trihoney and atorvastatin on percentages of sperm vitality, sperm morphology and sperm concentration

| Parameters          | Groups  | Live sperm (%) | Dead sperm (%) | Normal sperm (%) | Abnormal sperm (%) | Concentration (Sperm×10⁶/mL) |
|---------------------|---------|----------------|----------------|------------------|-------------------|-----------------------------|
|                     | C       | 89.50±4.51ᵃ     | 10.50±4.51ᵃ    | 95.25±3.13ᵃ      | 4.75±3.13ᵃ        | 85.93±44.21ᵃ               |
|                     | CH      | 89.67±3.53ᵃ     | 10.33±3.53ᵃ    | 92.08±8.07ᵃ      | 7.92±8.07ᵃ        | 86.18±33.29ᵃ               |
|                     | HCD     | 64.80±32.03ᵇ,ᵇ  | 35.20±32.03ᵇ   | 64.22±25.23ᵇ     | 35.78±25.23ᵇ      | 12.43±12.74ᵇ               |
|                     | DA1     | 55.00±44.85ᵇ    | 45.00±44.85ᵇ   | 63.60±39.89ᵇ     | 36.40±39.38ᵇ      | 18.94±24.23ᵇ               |
|                     | DH1     | 76.75±30.59ᵇ,ᵇ  | 23.25±30.59ᵇ   | 82.33±16.06ᵇ     | 17.67±16.06ᵇ      | 37.71±43.59ᵇ               |
|                     | DH2     | 86.58±6.75ᵇ     | 13.42±6.75ᵇ    | 91.00±4.87ᵇ      | 9.00±4.87ᵇ        | 45.46±18.90ᵇ               |

Data were analysed using one-way analysis of variance (ANOVA). A Post Hoc test (LSD) was used to test the significant difference between the groups. Values are given as mean ± standard deviation of mean. ᵁᵇ Values not sharing a common superscript letter within the same column differ significantly at p<0.05. C: commercial pellet; CH: commercial pellet plus 600 mg/kg/day Trihoney; HCD: 1% cholesterol diet; DH1: 1% cholesterol diet plus 300 mg/kg/day Trihoney; DH2: 1% cholesterol diet plus 600 mg/kg/day Trihoney; DA1: 1% cholesterol diet plus 2 mg/kg/day atorvastatin.
There was no significant difference between CH group and the control group in any of the tested sperm parameters. These comparable results indicate that Trihoney has no negative impacts on sperm parameters. It also showed that Trihoney has no enhancing effects on the tested parameters in the normocholesterolemic rabbits.

The deleterious impacts of a high cholesterol diet and hypercholesterolemia on sperm quality parameters could be induced via their negative impacts on testicular tissue. Hypercholesterolemia induces testicular degenerative changes that render seminiferous tubules atrophied and non-functioning with arrest of spermatogenesis (Mohamed et al., 2020a). These degenerative changes possibly caused by an oxidative stress damage (Ashrafi et al., 2013; Shalaby, 2004). High cholesterol diet and hypercholesterolemia interrupt hypothalamic-pituitary-gonadal axis with a subsequent disruption of spermatogenesis (Hamad Mohamed et al., 2020; Bashandy, 2007). The reduction in the sperm concentration and motility in a high cholesterol diet fed animals may be attributed to the impairment of Sertoli and Leydig cells secretory function which subsequently affects spermatogenesis and epididymal sperm maturation. Epididymal dysfunction is another contributory factor in the reduction of sperm motility and cytostructural modifications that affect sperm morphology (Yamamoto et al., 1999). The epididymis was suggested as an early target of dietary cholesterol overload. The alteration induced by hypercholesterolemia in epididymal function causes a dramatic reduction of sperm motility and vitality and an increase in sperm morphological abnormalities (Ouvrier et al., 2011).

Concurrent supplementation of Trihoney with a high cholesterol diet improved the percentages of sperm progressive motility (p<0.05), total motility (p<0.05) and sperm with normal morphology (p<0.05) and reduced the percentages of immotile sperm (p<0.05) and sperm with abnormal morphology (p<0.05) when compared to the high cholesterol diet group; meanwhile, their levels were comparable to the control as illustrated in Tables 2 and 3 and Figure 1. More improvements were achieved by the Trihoney dose of 600 mg/kg/day than the dose of 300 mg/kg/day. Even though sperm concentration increased with Trihoney supplementation, it remained significantly lower than the control (p<0.05). To the best of our knowledge, no previous study has been conducted to determine the effects of honey against the changes in sperm parameters that are induced by

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**Figure 1.** Eosin-Nigrosin stain of sperm morphology and vitality. The smears of the slides from the different groups were examined with ×1000 magnification (oil lens). C: commercial pellet; CH: commercial pellet plus 600 mg/kg/day Trihoney; HCD: 1% cholesterol diet; DH1: 1% cholesterol diet plus 300 mg/kg/day Trihoney; DH2: 1% cholesterol diet plus 600 mg/kg/day Trihoney; DAT: 1% cholesterol diet plus 2 mg/kg/day atorvastatin.
a high cholesterol diet. However, there are numerous studies that have been conducted to determine the importance of honey in abating the impacts of other toxicants on sperm parameters. Administration of honey to rats exposed to cigarette smoke improved sperm count, percentage of motile sperm and the percentage of sperm with normal morphology (Mahaneem et al., 2011). Supplementation of honey to nicotine-treated male rats improved fertility through improvements in sperm concentration, percentage of motile sperm and the number of normal sperm (Aisyah et al., 2011). The same effects on sperm parameters were achieved by honey in rats fed with a high sucrose diet (Oyelowo et al., 2014) and in diabetic rats (Michael et al., 2015). Moreover, sperm progressive motility and post insemination pregnancy rate in mice were improved upon addition of 10% of honey to IVF media (Hadi, 2017). In human, honey supplementation to oligospermic men improved sperm concentration, motility and morphology (Ismail et al., 2014). Supplementation of 10% of honey to cryoprotectant solution results in an enhancement of sperm quality post-thawing (Fakhridin & Alsaadi, 2014).

The likely underlying mechanisms behind the positive effects of Trihoney on sperm parameters of high cholesterol diet-fed rabbits are its ability to maintain testicular integrity and optimize neuroendocrine gonadal axis and in turn enhancement of spermatogenesis, which were suggested to be due to Trihoney antioxidant activity as published recently (Hamad Mohamed et al., 2020; Mohamed et al., 2020a). The antioxidant activity of honey reduces lipid peroxidation and restores the antioxidant system of the testicular tissue (Mohamed et al., 2011).

The other possible mechanisms could be via enhancement of spermiogenesis (Mohamed et al., 2012) and spermatogenesis through the decrease in testicular lactate dehydrogenase and increase in sorbitol dehydrogenase which are testicular marker enzymes for spermatogenesis (Abdul-Ghani et al., 2008). It possible that honey acts as a physiologic modulator of spermatogenic cells proliferation which influences the cell cycle of the seminiferous epithelium and increases spermatogenesis (Syzana et al., 2011). Furthermore, honey enhances spermatogenesis and sperm vitality via abating apoptosis and necrosis in testicular cells which could be due to the antioxidant properties of honey. The antioxidant activity may neutralize the patterns of expression of apoptosis related genes and proteins or controlling anti-apoptotic patterns (Saki et al., 2013). Honey is a source of glucose, fructose, minerals and vitamins that stimulates sperm motility. Glucose and fructose are considered to be a fuel source for sperm motility (Hadi, 2017).

Treatment of the animals with atorvastatin showed better percentages of sperm PM and sperm concentration than using a high cholesterol diet alone; however, it did not reach the statistical significance. For percentages of sperm total motility, immotile sperm, vitality and normal morphology, atorvastatin treatment caused the worst results among the groups including the group that received high cholesterol diet alone. In a study carried out on healthy men, atorvastatin treatment resulted in a reduction of sperm concentration and vitality coupled with an increase in the percentage of abnormal sperm. Conversely, total sperm motility showed a significant improvement with no effects of atorvastatin observed on progressive motility (Pons-Rejraji et al., 2014). Use of atorvastatin in the treatment of hypercholesterolemic patients has been noticed as a cause of reduction of sperm motility. This was suggested to be due to the inhibition of coenzyme Q (10) (CoQ10) (Niederberger, 2005). Inhibition of cholesterol biosynthesis also inhibits the synthesis of CoQ10 as they share the same biosynthetic pathway. A brief exposure to atorvastatin causes a marked reduction of CoQ10 (Rundek et al., 2004). The negative impact of atorvastatin on sperm parameters could also be through reduction of serum and/or testicular testosterone. The reduction of serum and testicular testosterone with atorvastatin was reported both in animal and human studies (Hamad Mohamed et al., 2020; Bustan & Jawad, 2017; Kanat et al., 2009). Atorvastatin was suggested as one of the statins that might induce primary hypogonadism even at low doses (Corona et al., 2010). Statins reduce testosterone via reduction of cholesterol, inhibition of steps of steroidogenesis process or inhibition of de novo synthesis of cholesterol in Leydig cells (Schooling et al., 2013).

IV. CONCLUSION

Trihoney showed its effectiveness as a potential protective natural product that minimizes the negative impacts of a high cholesterol diet on sperm quality parameters. The protective
effects of Trihoney might be attributed to its high antioxidants constituents, which is suggested to be explored in future studies. On the other hand, treatment of rabbits with atorvastatin failed to reverse any of the changes induced by the high cholesterol diet in the sperm parameters.

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