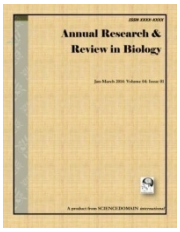

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Beneficial Effects of Ethanol Extract of *Zingiber officinale* (Ginger) Rhizome on Epididymal Sperm and Plasma Oxidative Stress Parameters in Experimentally Cryptorchid Rats

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AOA and IAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author TAO managed the analysis of the study and literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: While antioxidant effect of ginger rhizome in reducing the oxidative stress in many diseases is well reported, there are limited studies on its effect in improving testicular function of cryptorchid rats. The present study was therefore carried out on cryptorchid rats given ethanol extract of ginger rhizome (EEG) to evaluate the effect on epididymal sperm and plasma oxidative stress parameters.
Methodology: Twenty-four male Sprague-Dawley rats (170g-210g) were randomly divided in a blinded fashion into 3 groups (n=8). Group A was sham-operated and treated with vehicle (corn-oil). Groups B and C were rendered cryptorchid and treated with vehicle and EEG respectively.
Results: Cryptorchid rats demonstrated significant decline in testicular weight leading to reduced epididymal sperm count, motility and percentage of morphologically normal sperm. Plasma oxidative stress was evident as there was rise in malondialdehyde (MDA) levels but decrease in the activity of the antioxidant enzyme superoxide dismutase (SOD). EEG

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treatment however, significantly ($p<0.05$) improved all the above parameters.
Conclusion: The above findings indicate that EEG treatment helped to improve the testicular function in cryptorchid rats probably by counteracting the rise in oxidative stress in the plasma.

Keywords: Antioxidants; Cryptorchidism; Epididymal sperm parameters; Oxidative stress; Zingiber officinale.

1. INTRODUCTION

Cryptorchidism results from the failure of the testis to descend from the abdomen into the scrotal sac. It occurs naturally [1], can be induced experimentally [2] and may be unilateral or bilateral. It can be congenital, or acquired, whereby testes that were in scrotal position at birth later ascends [3,4]. It usually results from hormonal abnormalities, which could be either deficiency or insensitivity to androgen or anti-mullerian hormone [5]. Several studies have described low birth weight and preterm delivery as the major risk factors for cryptorchidism [6]. In prospective studies using similar and clearly defined criteria of cryptorchidism, the incidence of cryptorchidism at birth has varied between 1.6 and 9.0% in USA [7], Denmark [8,9], Finland [8], Italy [10], UK [3,11], India [12], Lithuania [13], and Malaysia [14]. It is the most significant risk factor for testicular cancer increasing the risk 2.5-11 fold [15]. Its aetiology is for the most part unknown and appears to be multifactorial [16].

Cryptorchidism induces apoptosis, cell death and large scale removal of germ cells from the seminiferous epithelium [17]. Recent studies have shown that testicular testosterone production is acutely reduced in a number of conditions like cryptorchidism, which is associated with Reactive Oxygen Species (ROS) production and oxidative stress in the testis [17,18]. In most mammals, the testis is kept between 3-5ºC below body temperature. A slight increase in temperature for a short or long period results in a rapid loss of mature germ cells. The increased testicular temperature in cryptorchidism has long been associated with increased testicular oxidative stress [2,19,20]. Moreover, cryptorchidism has also been shown to induce an increase in ROS, which correlated with increased germ cell apoptosis and alterations in the expression of a number of genes associated with energy and lipid metabolism, stress response, and redox reactions [21]. Testis tissue under increased temperature in vitro also showed an increased susceptibility to oxidative stress and germ cell apoptosis [22]. In addition, cryptorchidism was reported to reduce sperm count in rats [2,23-25], mice [26,27] and humans [28]. Sperm motility was also reported to be reduced in cryptorchid rats [24,29,30] and humans [28]. Sperm morphological abnormalities were also reported to be increased in the cryptorchid rats [24].

Ginger (Zingiber officinale) rhizome (ginger root) is widely used as a spice or condiment [31] and medical treatment for certain diseases [32-34]. Ginger contains several compounds such as gingerol, gingerdiol, and gingerdione that possess strong antioxidant activity [35]. *Zingiber officinale* (ginger) has been used in India, China, Arabia and other parts of Asia as a medicinal plant for aiding digestion and treating stomach upset, nausea and diarrhea for more than 2000 years [36]. It has also been used to treat arthritis, colic diarrhea and heart conditions [37]. Its root is widely used as a digestive aid for mild stomach upset and is commonly recommended by health care professionals to help treat or prevent nausea and vomiting which is associated with motion sickness, pregnancy and cancer chemotherapy [32]; although, there is less evidence to support its use for motion sickness or other types of

nausea and vomiting. Ginger has a long traditional history of being effective in reducing symptoms of gastrointestinal distress. It is regarded as an excellent carminative, which prevents the elimination of intestinal gas, and intestinal spasmolytic, which relaxes and soothes the intestinal tracts [38]. Modern scientific research has revealed that ginger possesses numerous therapeutic properties including antioxidant [39,40] and anti-inflammatory effects [41].

Since oxidative stress has been well reported as the major cause of many symptoms sequel to cryptorchidism, and ginger rhizome has been reported to possess antioxidant effects, studies on the antioxidant effects of ginger in cryptorchidism-induced oxidative stress was of interest to us. The present study was thus designed to investigate whether ginger extract can improve sperm and plasma oxidative stress parameters in the experimentally cryptorchid rat.

2. MATERIALS AND METHODS

2.1 Animals

Twenty four (24) male Sprague-Dawley rats (170-210g) were purchased from the Institute of Medical Research and Training, University of Ibadan College Hospital, Nigeria and were acclimated to their new environment. They were fed a standard laboratory diet (Bova Jay Feeds Nig. Ltd, Ogbomoso) with free access to tap water ad libitum. The rats were kept under condition of uniform humidity and temperature on a 12-h light-dark cycle.

2.2 Selection of *Zingiber officinale* (ginger) and Preparation of Ethanolic Extract

The rhizomes of *Zingiber officinale* (ginger) were bought from same farmer at Oja Oba market in Ilorin, Nigeria and authenticated at the Botany section of the department of Pure and Applied Biology, Ladoke Akintola University of Technology, Nigeria. They were air-dried and ground into powdery form.

In a previous study investigating the efficiency of various pure solvents on pressurized liquid extraction of ginger, 70% ethanol was reported to give the best performance in terms of yield of total extract complete constituent profile and recovery of most gingerol-related components [42]. Moreover, anti-oxidant activity has been reported to be more in ethanol extract of ginger than in other solvent extracts [40]. So, we prepared ethanol extract of ginger (EEG) by soaking 250g of the powder in 70% ethanol for 72 hours. It was filtered and the filtrate was poured into a round bottom conical flask which was fixed with a rotary evaporator. Water in the extract dried up gradually by evaporation. The cooled extract was measured so as to determine the concentration. The dried yield of the extract was 2.8g.

2.3 Experimental Protocol

After two weeks acclimatization to their new environment with standard laboratory diet and water given ad libitum, animals were randomly divided into three groups, 8 rats per group receiving treatments as described below:

a. Pre-treated with 10ml of corn-oil (vehicle) /kg b.w [43] for 21 days, sham-operated on the 22nd day and orally post-treated with same dose of corn-oil for 7 days.

b. Pre-treated with 10ml of corn-oil (vehicle) /kg b.w [43] for 21 days, rendered cryptorchid on the 22nd day and orally post-treated with same dose of corn-oil for 7 days.
c. Pre-treated with 1g/kg b.w of ethanol extract of ginger rhizome (EEG) [44] dissolved in corn-oil for 21 days, rendered cryptorchid on the 22nd day and orally post-treated with same dose of EEG solution for 7 days.

A solution containing EEG dissolved in corn-oil was freshly prepared daily in such a way that all animals received 10ml/kg b.w of either corn-oil alone or the solution depending on the group as described above. The extract and the vehicle were administered by oral gavage between the hour of 9:00am and 10:00am daily. Corn oil of chemical reagent grade was purchased from Nacalai Tesque, Inc. (Japan). It has been conveniently used as one of the most common vehicles to administer lipophilic chemicals to rodents in toxicity studies. It has about 60% polyunsaturated fatty acid; therefore, it is one of the oils that have been recommended as a replacement for saturated fat [45].

Unilateral cryptorchidism was induced as previously described [23]. Briefly, under strict aseptic conditions, the animals were anaesthetized with ketamine (75 mg/kg b.w). The testis was mobilized through a transverse inguinal incision and the gubernacula of the testes severed. The freed testis was pushed back into the abdomen through the internal inguinal ring which was subsequently closed with 2-0 chromic sutures. The sham-operation followed the same procedure but the testis was left in the scrotum. All the animals subsequently recovered fully.

On the 30th day of the experiment, each rat was weighed and sacrificed by cervical dislocation. Blood sample from each rat was collected (by cardiac puncture) into lithium heparinized capillary tubes. It was centrifuged at the rate of 3000 revolutions per minute for 15 min. Plasma was collected from each sample and preserved. The testis of each rat was harvested and preserved in separate formalin bottles. The testis was removed, washed in the washing buffer and weighed with electronic weighing balance to know the ratio of the homogenizing buffer to the organ. The constituent of the washing buffer is 11.5g of KCl in 1000ml of distilled water. The homogenizing buffer {pH=7.4} contains 11.5g of KCl and 7.88g of Tris HCl in 1000ml of distilled water. NaOH was added drop wise to correct the pH. The homogenizing buffer was added at a ratio of 1:4. The testis was grounded in the homogenizing buffer, centrifuged and the homogenate was refrigerated. All authors hereby declare that “principles of laboratory animal care” (NIH publication No. 85-23, revised 1985) were followed. All experiments have been examined and approved by our institutional ethics committee.

2.4 Determination of Epididymal Sperm Parameters

For each separated epididymis, the caudal part was removed and placed in a beaker containing 1ml of normal saline solution. It was macerated with a pair of sharp scissors and left for a few minutes to liberate the sperm cell into the normal saline. Sperm suspension drops were placed on the clean grease-free glass slide and two drops of warm 2.9% sodium citrate were added. Improved Neubauer counting chamber was used to count the sperms [23].

Sperm motility, estimated as the percentage of sperm that manifest progressive motility, was determined as previously described by Quill and Garbers [46]. Briefly, the sperm suspension was diluted in 1ml of normal saline solution. About 10μL was pipetted onto a clean grease-

free glass slide. A cover slip was lowered onto the sample on the slide, avoiding air bubbles, and the slide was examined using a microscope with a 40X objective. At least, six widely spaced fields were examined to provide an estimate of the percentage of the progressively motile sperm cells. The sperms with progressive motility were estimated and recorded as (N) while the total number of all the sperm cells counted; those with slow progressive motility, non-progressive motility and those that were immotile were added up with the estimated sperm with progressive motility. The total number was recorded as (T). Sperm motility (%) was calculated using (N/T× 100%).

Percentage of morphologically normal sperm was estimated by the method previously described by Darszon et al. [47]. The principle is based on the ability of morphologically normal sperm to appear white in color as the plasma membrane will prevent the dye to enter, while abnormal sperms take up the dye and stain dark color. The microscope slides and the eosin stain were pre-warmed to room temperature. One ml of the sperm suspension -normal saline solution was transferred to a test tube and 2 drops of 1% eosin was added and mixed gently for agitation. This was incubated for 45-60mins to allow its proper staining and then re-suspended with a Pasteur pipette. A clean grease-free glass slide was used. Potential damage to the sperm cells should be avoided. One or 2 drops of the stained sperm were placed approximately 1cm from the end of the slide lying on a flat surface. A second slide was held with the slide's long edge gently touching across the width of the sperm slide and pulled across to produce a sperm smear. After air drying the slide, using a microscope at 100X objective, the sperm cells were examined. The sperm along the periphery were normally excluded from the examination because there is a greater tendency for artifacts to occur in these regions. At least, five fields were viewed covering the whole slide. Examples of morphological abnormalities are double-headed, elongated head, pyriform head, bent head, bent tail, bent mid-piece, coiled tail, double tail, headless, tailless, etc. All those with normal morphology were recorded as N while the total number of the counted spermatozoa was recorded as T. The percentage sperm morphology was calculated as (N/T X100%).

2.5 Determination of Total Protein and Oxidative Stress Related Parameters

Superoxide dismutase (SOD) estimation was done by the method of Misra and Fridovish, (1972) [48]. The principle is based on the ability of SOD to inhibit the auto-oxidation of adrenaline at pH of 10.2. Superoxide radical {O^-} generated causes the oxidation of adrenaline to adrenochrome. The yield of adrenochrome increases per O^- introduced with increasing concentration of adrenaline. Briefly, 0.1ml of blood plasma was diluted with 0.9ml of distilled water. 0.1ml of the resulting solution was added to 2.5ml of the carbonate buffer. 0.3ml of the adrenaline was added. This was read in a spectrophotometer at wave-length of 480nm. Blank cuvette contained 2.5ml of carbonate buffer, 0.3ml of adrenaline and 0.1ml of distilled water. The absorbance at 0sec and 150sec were recorded.

Malondialdehyde (MDA) was estimated by the method of Ohkawa et al. (1979) [49]. The principle is based on the reaction of malondialdehyde {MDA} with thiobarbituric acid {TBA}, forming a MDA-TBA complex which absorbs strongly at a wave-length of 532nm. Small amounts of MDA are produced during lipid peroxidation, which react with TBA to give a pink colored complex and absorb light when in an acidic solution at 532nm. Briefly, 0.4ml of the blood plasma was mixed with 0.5ml of 30% TCA, and 1.6ml of Tris KCl was added. TBA (0.5ml) was then added and the solution was incubated for 45mins at 80^0c. This produced pink colored reaction mixtures which were read at 532nm.

Estimation of total protein (TP) was based on the biuret colorimetric method [50] using the clinical kit. Proteins give an intensive violet blue complex with copper salts in an alkaline medium. Iodide is included as an antioxidant. The formed color intensity is proportional to the total protein on which this method is based. The spectrophotometer was adjusted to zero with distilled water. The blank was 1.0ml of the biuret solution. The calibrator was 1.0ml + 25µL of biuret solution. For each sample, 1.0ml of the biuret solution and 25µL of the blood plasma were put into the cuvette, mixed, incubated for 10 min at room temperature and read at 540 nm.

2.6 Data Processing

Data were analyzed using Microsoft excel statistical package. All values given were the Mean±S.D. of the variables measured. Significance was assessed by the analysis of variance (ANOVA), followed by a post-hoc Tukey multiple range test for multiple comparisons. P-Values of 0.05 or less were taken as statistically significant.

3. RESULTS

3.1 EEG Intervention Improves Testis Weight and Sperm Parameters in Cryptorchid rats

Testicular weight was significantly low ($p<0.001$) in vehicle-treated, cryptorchid rats (0.26±0.03g) compared to sham operated control rats (1.71±0.15g). This showed that cryptorchidism caused a significant testicular weight loss in rats. The testicular weight in the EEG-treated cryptorchid rats (0.57±0.07g) improved significantly ($p<0.01$) than the vehicle-treated, cryptorchid rats. The above data showed that ginger rhizome augmented testicular weight in the cryptorchid rats (Table 1).

Epididymal sperm count was significantly low ($p<0.001$) in vehicle-treated, cryptorchid rats (8.71±0.70 10^6/ml) compared to sham operated control rats (68.63±4.72 10^6/ml). This showed that cryptorchidism induced a significant sperm loss. The epididymal sperm count in EEG-intervened cryptorchid rats was (34.06±2.71 10^6/ml) compared to vehicle treated cryptorchid rats (8.71±0.70 10^6/ml) indicating the fact that there was augmentation of sperm production in the testis (Table 1).

Percentage of motile sperm too was significantly low ($p<0.001$) in vehicle-treated, cryptorchid rats (16.71±2.93%) compared to sham operated control rats (82.43±2.86%). However, with EEG intervention the percentage of motile sperms (66.57±1.66%) in the epididymis increased considerably (Table 1).

Similarly, percentage of morphologically normal sperm was significantly low ($p<0.001$) in vehicle-treated, cryptorchid rats (21.57±2.21%) compared to sham operated control rats (75.00±5.02%). EEG intervention to cryptorchid rats reversed the trend (Table 1) as the percentage of morphologically normal sperm increased in number (59.43±0.90%).

Table 1. Ethanolic extract of ginger (EEG, 1g/kg b.w) intervention improves testicular weight and sperm parameters in cryptorchid rats. Values are expressed as Mean±SD (n=8)

Parameters	A (Sham operated, corn-oil treated)	B (Cryptorchid, corn-oil treated)	C (Cryptorchid, EEG treated)
Testicular weight (g)	1.71 (±0.15)	0.26 (±0.03)***	0.57 (±0.07) $^{***, \#\#}$
Sperm count (10^6/ml)	68.63 (±4.72)	8.71 (±0.70)***	34.06 (±2.71) $^{***, \#\#\#}$
Sperm motility (%)	82.43 (±2.86)	16.71 (±2.93)***	66.57 (±1.66) $^{***, \#\#\#}$
Morphologically normal sperm (%)	75.00 (±5.02)	21.57 (±2.21)***	59.43 (±0.90) $^{**, \#\#\#}$

$^{(**, ***)}$ signify p<0.01, p<0.001 respectively vs. group A rats while $^{(\#\#\#)}$ signifies p<0.001 vs. group B rats

3.2 EEG intervention counteracts the rise in plasma oxidative stress

Plasma SOD levels was significantly low (p<0.001) in vehicle-treated, cryptorchid (0.04±0.01 mMol/mg protein) rats compared to sham operated control rats (0.42±0.03 mMol/mg protein). EEG treatment to cryptorchid rats improved the plasma SOD levels (0.24±0.01 mMol/mg protein, Table 2).

Plasma MDA level was significantly high (p<0.001) in vehicle-treated, cryptorchid rats (4.25 ±0.03 mMol/mg protein) compared to sham operated control rats (1.79±0.07 mMol/mg protein). This showed that cryptorchidism caused a significant increase in the plasma MDA level in rats. The rise in plasma MDA levels was significantly reduced (2.10±0.03 mMol/mg protein) with EEG intervention to cryptorchid rats. The data established that ginger rhizome administration decreased the plasma MDA level in cryptorchid rats (Table 2).

Total protein concentration in the plasma similarly demonstrated a very much identical trend. It was low (p<0.001) in vehicle-treated, cryptorchid rats (1.6±0.10 mg/ml) compared to sham operated control rats (4.1±0.22 mg/ml) but significantly improved after EEG supplementation (2.23±0.07 mg/ml) to cryptorchid rats (Table 2).

Table 2. EEG intervention (1g/kg b.w) counteracts the rise in plasma oxidative stress. Values are expressed as Mean±S.D (n=8)

Parameters	A (Sham operated, corn-oil treated)	B (Cryptorchid, corn-oil treated)	C (Cryptorchid, EEG treated)
SOD (mMol/mg protein)	0.42 (±0.03)	0.04 (±0.01)***	0.24 (±0.01) $^{***, \#\#\#}$
MDA (mMol/mg protein)	1.79 (±0.07)	4.25 (±0.03)***	2.10 (±0.03) $^{**, \#\#\#}$
TP (mg/ml)	4.1 (±0.22)	1.6 (±0.10)***	2.23 (±0.07) $^{***, \#\#\#}$

$^{(**, ***)}$ signify p<0.01, p<0.001 respectively vs. group A rats while $^{(\#\#\#)}$ signifies p<0.001 vs. group B rats

4. DISCUSSION

A previous study by Duru et al. [24] showed that cryptorchidism reduces sperm count, sperm motility, sperm morphology, superoxide dismutase (SOD) and increase malondealdehyde (MDA) in rats. Moreover, secondary degeneration of the cryptorchid testes has been

associated with high temperature related oxidative stress. The present study investigated the effects of ginger extract intervention on sperm and biochemical parameters in experimentally induced crypt orchid rat.

The observed reduction in testicular weight in the cryptorchid rats in the present study is similar to earlier published reports [26,27]. Declined intratesticular testosterone, elevated temperature and high oxidative stress following cryptorchidism probably affect cell viability and trigger a fast pace cell removal through giant cell formation [17]. Huff et al. [51-53] have shown that maturation of gonocytes to type A spermatogonia, which is the first step in postnatal spermatogenic development, is deficient in cryptorchid infants. The reduction in testicular weight in cryptorchids could be attributed to the loss of spermatocytes and spermatids. The present study also showed that ethanol extract of ginger (EEG) significantly increased the testicular weight in the cryptorchid rats. The findings support the contention that EEG intervention has the potential in reversing the testicular weight loss associated with cryptorchidism.

Decline in sperm count in cryptorchid conditions has been reported in rats [2, 23-25], mice [26,27] and humans [28]. This is the outcome of the impairment of spermatogenesis associated with cryptorchidism [2,54-56]. Moreover, the impairment of spermatogenesis has been reported to be more severe in patients with bilateral cryptorchidism compared with unilateral cryptorchidism or retractile testes [57]. Oxidative stress is a mediator of sperm cell dysfunction [58]. Excessive production of ROS reduces the antioxidant capacity of sperms and seminal plasma, inducing oxidative stress which damages sperm membrane and causes infertility [58]. The present study not only confirmed the declined sperm count in the testis as measured from epididymal preparations but also confirmed that EEG intervention stimulates spermatogenesis leading to an improved sperm number in the epididymis.

The observed reduction in sperm motility in cryptorchid rat testis in the present study is consistent with the previous findings from studies in rats [24,29,30] and humans [28]. Increase in sperm motility in epididymal preparations from cryptorchid rats pre-treated with EEG indicates that EEG intervention improved sperm survival in these rats. Previous study by Moretti et al. (2007) [28] showed that there are more healthy spermatozoa in fertile controls than in either unilaterally or bilaterally cryptorchid patients. They further reported that spermatozoa with pathologies like immaturity, necrosis and apoptosis are more in number in either unilaterally or bilaterally cryptorchid patients than in the fertile controls.

Similarly, spermatozoal morphological abnormalities were significantly higher in the cryptorchid rats compared to healthy controls [24]. The observed reduction in the proportion of sperm with normal morphology in cryptorchid rats in the present study is identical with the previous report [24]. Our study further showed that EEG administration to cryptorchid rats helped to raise the proportion of sperm with good morphology in the epididymal preparations.

The attenuation in the plasma SOD level in the cryptorchid rats as observed in the present study is consistent with report of Duru et al. [24]. The enzyme is responsible for quenching superoxide free radicals and is an integral part of the internal defense mechanism for favorable modulation of the redox state in any physiological system. Testicular damage due to cryptorchidism, results in excessive generation of free radicals, indirectly through the elevated temperature of the abdominal testis [2]. However, EEG supplementation to cryptorchid rats supported the restoration of the enzyme activity which significantly ($p<0.001$) improved compared to cryptorchid controls.

Previous studies have shown that testicular tissue under increased temperature as in cryptorchidism has an increased susceptibility to oxidative stress, leading to increased level of lipid peroxidation [20,22,24]. The present study confirmed the earlier findings as MDA levels in plasma demonstrated a significant rise in the cryptorchid rats. However, like other parameters, EEG administration to cryptorchid rats is found effective in reversing the trend. Identical effect is also seen with respect to total protein concentration in the plasma.

Though the mechanism of cryptorchidism-induced testicular oxidative stress is inconclusive, secondary degeneration of the cryptorchid testes is presumed to be related to a higher temperature (35–37°C) compared with the normal location in the scrotum (33°C) [59-61]. The sensitivity of the testicular enzymes to elevated testicular temperature was also suggested [2,19,20]. Li et al. [21] examined reactive oxygen species (ROS) production and gene expression patterns after the induction of cryptorchidism in adult mice. Those investigators reported that cryptorchidism induced an increase in ROS, which was correlated with increased germ cell apoptosis and alterations in the expression of a number of genes associated with energy and lipid metabolism, stress response, and redox reactions. Testis tissue under increased temperature in vitro also shows an increased susceptibility to oxidative stress and germ cell apoptosis (GCA) [22]. The increase in ROS during cryptorchidism has also been correlated with a decline in testosterone [17] and oxidative stress. Specifically an increase in NO levels subsequent to eNOS overexpression, has been linked to germ cell apoptosis in a mouse model of cryptorchidism [62]. The anti-oxidant potential of ginger in the present study may be a result of its previously identified anti-oxidant components such as gingerol, gingerdiol, and gingerdione [35].

Recent studies have shown that testicular testosterone production is depleted in a number of conditions like cryptorchidism, which is associated with ROS production and oxidative stress in the testis [17,18]. Apart from being a rich source of antioxidants, ginger has also been shown to boost testosterone level in male rats [63]. Though testosterone was not measured in the present study along with other reproductive hormones, one such limitation in the present study, the potency of ginger in enhancing testicular sperm parameters may not be solely due to its anti-oxidant boosting ability, but may also be due to enhanced testosterone production in the Leydig cells which need further elucidation in future studies.

5. CONCLUSION

In conclusion, this study shows that ethanol extract of ginger rhizome has the protective effect against the testicular dysfunction induced by experimental cryptorchidism in adult rats. This beneficial effect may be due to the anti-oxidative property of the extract that counteracted the rise in oxidative stress in cryptorchid testis.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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