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Fertility Enhancing Potential of *Mucuna pruriens* Seeds in Female Sprague-Dawley Rats

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Authors' contributions

This work was carried out in collaboration between all authors. Author OTN wrote the first part of the manuscript, managed the analysis of the study and performed the statistical analysis. Author GSC designed the study, performed literature search and wrote the final manuscript in accordance with the guideline of this journal. Author OAA wrote the protocol, supervised the study and edited the manuscript for submission. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To determine the effect of oral administration of methanolic seed extract of *Mucuna pruriens* (*M. pruriens)* on oestrous cycle, ovulation, reproductive hormones and oxidative stress in the ovary of cyclic Sprague-Dawley rats.
Design: Prospective animal study related to *M. pruriens* in reproductive area.
Place and Duration: Animal Facility of the Department of Anatomy, Faculty of Basic Medical Sciences, College of Medicine of the University of Lagos, Nigeria between the months of June 2012 and August, 2012.
Methodology: Forty female Sprague-Dawley rats with regular 4 days cycle averagely weighing 145 g were used. Methanolic extract of *M. pruriens* was given orally at 50, 100 and 200 mg/kg body weight. Oestrous cycle was monitored daily. At the end of the experiment animals were sacrificed by cervical dislocation. Oocytes were counted, blood and ovaries were assayed for hormonal and biochemical studies respectively.
Results: Oestrous cycle remained unchanged in the treatment groups. Catalase and superoxide dismutase levels were increased slightly compared to control. A dose dependent increase in FSH and LH ($p < 0.05$ at 200 mg/kg) levels were observed with an

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increase in the number of oocytes released at ovulation compared to control.
Conclusion: *M. pruriens* seed extract has the potential to enhance fertility by increasing serum levels of FSH and LH which in turn increases the number of oocytes released at ovulation possibly through its antioxidant properties.

Keywords: Mucuna pruriens; ovulation; oxidative stress markers; FSH; LH.

1. INTRODUCTION

Human health is of prime importance to a country's development and progress. Herbal preparation and medications have been in use for the treatment of diseases and various ailments since ancient times in many parts of the world. In developed countries, despite newer formulations of effective conventional drugs, the treatment of diseases and other ailments with herbal remedies is still very popular [1]. In developing countries, the use of herbal remedies as alternatives to modern medicine is on the increase. In Nigeria, many indigenous plants have been used in herbal medicinal preparations to cure sicknesses and diseases and to heal injuries [2,3]. *M. pruriens* is one such plant; it is a tropical legume known as velvet bean, belonging to the family *Fabaceae*. The plant is an annual climbing shrub with long vines that can reach over 15 m in length. When the plant is young, it is almost completely covered with fuzzy hairs but when it becomes older; it is almost completely free of hairs.

It is found in Africa, India and the Caribbean's; where it is widely known for its uses in various ailments as reported in literature [4-6]. Phytochemical screening of the plant revealed that it contains alkaloids, flavonoids, tannins saponins, cardiac glycosides, anthraquinones and carbohydrates [6-9]. It is a constituent of more than 200 indigenous drug formulations [6,10]. Some authors have reported that all the various parts of the plant possess valuable medicinal properties [6,11,12]. Following the discovery, that *Mucuna* seeds contain L-Dopa which is used in the treatment of Parkinson's disease; its demand even in the international market has increased considerably [6]. This demand has motivated Indian farmers to start commercial cultivation of the *Mucuna* plant. It has widespread cultivation over most of the subcontinent and is found in bushes, hedges and dry deciduous low forests throughout the plains of India [10,13,14].

M. pruriens has been reported to enhance fertility in male rats [15-21] however; there is a dearth of literature on the effect of *M. pruriens* on the function of the female reproductive system. This study was carried out to evaluate the effect of *M. pruriens* on the reproductive function of the mature female Sprague-Dawley rats.

2. MATERIALS AND METHODS

2.1 Plant Source

The *M. pruriens* plant with mature seeds was harvested from Mowe area of Lagos, Nigeria. Both plant and seeds were identified and authenticated by Professor J.D. Olowokudejo of the Department of Botany of the University of Lagos. Voucher specimen with accession number LUH 4922 was deposited in the herbarium of the Department of Botany.

2.1.1 Seed extraction

The extraction was carried out in the Pharmacognosy Department of the Faculty of Pharmacy, University of Lagos. Briefly, seeds were obtained from the pods, air-dried and grounded into fine powder using the mortar and the pestle. 450 g of fine powder was mixed with alcohol and placed in the Soxhlet apparatus. The mixture was heated at 60℃ and the extract was obtained by distillation. The powder obtained (107.6g, 23.9% yield) was stored at room temperature of 25℃ before use. All dilutio ns of the extract were made in distilled water.

2.1.2 Dose selection

Our choice of dosage selection was based on a previous study conducted in India in which the author reported a significant increase in fertility indices when *M. pruriens* was administered to male albino rats [18]. Following the enhanced-fertility indices reported with males, we decided to use the same dosage options in this study on female rats: 50, 100 and 200 mg/kg body weights of the seed extract.

2.2 Animals

Forty, two months old female Sprague-Dawley rats of Wistar strain weighing between 140 - 150 g obtained from the Animal House of the College of Medicine, University of Lagos, Nigeria were used in this study. They were housed five animals per cage at the Animal Facility of the Department of Anatomy, College of Medicine of the University of Lagos, Nigeria. The animals had free access to water and standard commercial rat chows purchased from Pfizer Nigeria Limited and were maintained at 12-h light/12-h dark cycle and at temperatures between 25 to 28℃. The animals wer e allowed to acclimatize for two weeks before the commencement of the experiment. Throughout the duration of the experiment, the animals were observed for adverse effects such as fur loss, diarrhea, bleeding, ataxia, morbidity and mortality resulting from administration of the extract. All procedures were approved by the Departmental Committee on the use and care of animals and tissue collection.

2.3 Determination of the Oestrous Cycle

Oestrous cycle was monitored for 24 days. Oestrous cyclicity was determined daily between 8 a.m. and 9:30 a.m. using the vaginal smear method. Vaginal secretion was collected with a plastic pipette filled with 10 µl of normal saline (NaCl 0.9%). The vagina was flushed two or three times with the pipette and the vaginal fluid was placed on a glass slide. A different slide was used for each animal. The unstained secretion was observed under a light microscope. Only animals with a 4-day oestrous cycle were selected for this study.

2.3.1 Oestrous cyclicity study

Twenty rats divided into 4 groups of 5 rats in each were used for this study. *M. pruriens* was administered orally using an oro-gastric tube daily for 24 days at 50, 100 and 200 mg/kg body weights while control animals received distilled water. Animals were sacrificed by cervical dislocation. Laparotomy was performed; ovaries were removed, trimmed of fat and stored at -80ºC for biochemical analysis.

2.3.2 Ovulation study

Twenty animals were used for this study. The animals received a single oral dose of *M. pruriens* at 50, 100 and 200 mg/kg body weight at 9 a.m. on the day of proestrus using an oro-gastric tube. Distilled water was given to the control animals. The rats were sacrificed by cervical dislocation the next day (estrus) at 10 a.m. A ventral laparotomy was performed and the oviduct was dissected out, placed on glass slides with a drop of saline and covered with cover-slips. This was squeezed with both sides being gently rocked and each ovum found in the distended ampulla was counted under a light microscope [22].

2.4 Biochemical Analysis

The right ovaries were homogenized using a Potter–Elvehjem homogenizer. A 20% (1/5 w/v) homogenate of the tissue was prepared in 50m MTris-HCl buffer (pH 7.4) containing 1.15% potassium chloride and centrifuged at 10,000 rpm at 4℃ for 10 min.

Superoxide dismutase was assayed utilizing the technique of [23]. A single unit of enzyme was expressed as 50% inhibition of Nitrobluetetrazo-lium (NBT) reduction/min/mg/protein.

Catalase was assayed colorimetrically at 620 nm and expressed as µmoles of H_2O_2 Consumed/min/mg/protein as described by [24].

2.5 Hormonal Assay Studies on Follicle Stimulating Hormone and Luteinizing Hormone

Blood was obtained from the angular vein of the eye of the Sprague-Dawley rats at 6 p.m. in the evening of proestrus and collected into heparinised bottles. Each blood sample was spun at 2,500 rpm for 10 minutes in an angle-head desktop centrifuge at temperatures of 25℃. Serum samples were assayed in batches with control sera at both physiological and pathological levels by Standard Quantitative Enzyme- Linked Immunosorbent Assay (ELISA) technique with Micro well kits from Syntro Bioresearch Inc., California, USA.

2.6 Statistical Analysis

Results were analyzed and expressed as Mean ± SD and were subjected to one-way ANOVA with Newman-Kenls post hoc test version 5.0 for windows. Statistical significance was considered at P=.05.

3. RESULTS

All the treated rats showed normal behaviour throughout the study. No signs of adverse effects were observed.

3.1 Oestrous Cycle

Analysis of the oestrous cycle revealed that oral administration of 50, 100 and 200 mg/kg body weight of methanolic seed extract of *M. pruriens* did not produce any irregularity/derangement in the cycle pattern. Also, length of cycle remained unchanged in all the treated rats; animals showed a regular four days cycle as shown (Table 1).

Table 1. Effect of the oral administration of *M. pruriens* for 24 days on the length of the oestrous cycle in sprague-dawley rats

Treatment groups	Length of oestrous cycle in days
Control	4.0±0,00
50 mg/kg	4.0±0.10
100 mg/kg	4.0±0.20
200 mg/kg	4.0±0.40

n = 5. Values are expressed as mean ± standard deviation

3.2 Antioxidant Status of Catalase and Superoxide Dismutase

The extract exhibited a dose dependent increase in catalase and superoxide dismutse activities in the treatment groups compared to the control group however; this increase was not statistically significant (Table 2).

Table 2. Effect of the oral administration of *M. pruriens* on the enzymatic antioxidant activities of catalase and superoxide dismutase in the ovary of sprague-dawley rats

Treatment groups	SOD (min/mg protein)	CAT (Mmol/min/mg protein)
Control	1.50±0,30	60.17±16.50
50 mg/kg	1.65±0.37	60.83±16.57
100 mg/kg	1,67±0,56	61.14±15.30
200 mg/kg	1.88±0.90	62.67±17.40

n = 5. Values are expressed as mean ± standard deviation

3.3 Serum concentrations of follicle stimulating hormone and luteinizing Hormone

A dose dependent increase in serum concentrations of follicle stimulating hormone and luteinizing hormone was observed. This increase was significant for luteinizing hormone at 200 mg/kg (Table 3).

Table 3. Effect of the oral administration of *M. pruriens* on serum concentrations of follicle stimulating hormone and luteinizing hormone at 6.00 p.m. on proestrus

Treatment groups	Follicle stimulating hormone (mlU/ml)	Luteinizing hormone (mlU/ml)
Control	1.83±0.77	1.13±0.15
50 mg/kg	1.87±0.04	1.56±0.81
100 mg/kg	1.95±0.63	1.90±0.51
200 mg/kg	2.01±0.02	2.03±0.76*

*n = 5. Values are expressed as mean ± standard deviation. * P < 0.05*

3.4 Ovulation and Number of Ova Shed

A slight increase in the number of oocytes released in the oviduct was observed in the treated animals compared to the control (Table 4).

Table 4. Effect of the oral administration of a single dose of *M. pruriens* on the number of ova shed in the oviduct in the morning of estrus in sprague-dawley rats

Treatment groups	Number of ova shed in the oviduct
Control	7.5±2.40
50 mg/kg	7.6±1.30
100 mg/kg	7,6±1.50
200 mg/kg	8.1±2.50

n = 5. Values are expressed as mean ± standard deviation

4. DISCUSSION

Estrogens and progesterone are important in the normal functioning of the female reproductive system. They are responsible for the development and maturation of reproductive organs and also provide the proper environment required for the transport of gametes and nidation. The balance in hormonal interplay between estrogens and progesterone is responsible for a normal regular cycle [25,26]. This study revealed that the oral administration of *M. pruriens* seed extract did not alter the oestrous cycle in all the treated animals throughout the treatment period of 24 days. The treated animals maintained a normal cycle pattern and cycle length that was comparable with the control animals. Although authors did not determine the levels of progesterone and estrogens in this study however, we can only deduce from our findings that *M. pruriens* did not produce any negative effect either directly on the pituitary or indirectly on the hypothalamus to disrupt the intricate balance in hormonal interplay between progesterone and estrogens levels that is necessary to maintain a normal cycle.

Literature is rife with studies reporting that *M. pruriens* has an excellent scavenging ability that mops up excessive production of reactive oxygen species and free radicals [8,20,27-29]. Reactive oxygen species plays both a physiological as well as a pathological role in the female reproductive tract. Numerous animal and human studies have demonstrated the presence of reactive oxygen species in the female reproductive tract such as in the ovaries [30-32], the fallopian tubes [33] and in embryos [34]. Reactive oxygen species is involved in the modulation of an entire spectrum of physiological reproductive functions such as oocyte maturation, ovarian steroidogenesis, corpus luteal function and luteolysis [30,32,35]. On the other hand, the pathological effects are exerted by various mechanisms including lipid damage, inhibition of protein synthesis, and depletion of ATP [36]. Reactive oxygen species have been implicated in more than 100 diseases [37-39]. The superoxide radical is formed when electrons leak from the electron transport chain [40]. Superoxide dismutase decomposes superoxide anion into hydrogen peroxide and oxygen at very high rates. Superoxide radical is involved in diverse physiological and pathophysiological processes [41]. Catalase catalyses the decomposition of hydrogen peroxide to water and oxygen. High concentration of hydrogen peroxide is deleterious to cells such as DNA, proteins, and lipids, leading to mutagenesis and cell death [42].

The slight increase in the activities of superoxide dismutase and catalase observed in the ovary in this study is an indication of the antioxidant properties inherent in *M. pruriens*. The upregulation in these markers of oxidative stress is in response to reactive oxygen species and free radicals. As earlier stated, both animal and human studies have demonstrated the presence of reactive oxygen species in the ovary. Phytochemical analysis has shown that *M. pruriens* seeds contain flavonoids and tannins (6-9). Flavonoids and tannins are phenolic compounds, and plant phenolics are a major group of compounds that act as primary

antioxidants or free radical scavengers [43]. In addition, *M. pruriens* seeds are a rich source of L-Dopa and its metabolites. *In vitro* antioxidant assays have supported the antioxidant property of L-Dopa [44]. Dopamine, a product of L-Dopa metabolism, has also been found to possess strong anti-oxidant capacity and free radical scavenging activity [45,46]. Antioxidants prevent oxidative stress caused by free radicals which damage cells and vital biomolecules. They terminate chain reactions triggered by free radicals by removing free radical intermediates and inhibit other oxidation reactions [47]. The antioxidant capacity of the extracts may be attributed to the presence of L-Dopa and its metabolite, dopamine and also, the identified phytochemicals.

Our study showed a dose dependent increase in the levels of follicle stimulating hormone and luteinizing hormone compared to the control. Increase in luteinizing hormone was significant at 200 mg/kg body weight of the extract. Treatment with *M. pruriens* significantly improved blood levels of dopamine, adrenaline and noradrenaline in infertile males [16]. L-Dopa and its metabolite dopamine have been reported to stimulate the hypothalamus and forebrain to secrete gonadotropin-releasing hormone (GnRH) [16,20,48]. This ultimately will activate the anterior lobe of the pituitary gland to secrete follicle stimulating hormone and luteinizing hormone. The report of this study is in agreement with studies carried out by elegant researchers in other parts of the world on both animal and human males in which follicle stimulating hormone and luteinizing hormone levels increased significantly following the administration of *M. pruriens*. [6,17,18,28].

Luteinizing hormone is critical to ovulation because it is responsible for all the processes and events that accompany ovulation. The rapid surge of luteinizing hormone that occurs between 5 to 7 p.m. in the evening of proestrus induces follicular rupture and ovulation in rats [49]. The present study showed a dose dependent increase in luteinizing hormone levels and a slight increase in oocyte number at 50 and 100 mg/kg body weights. However, at the highest dosage of 200 mg/kg we recorded a significant increase in the levels of circulating luteinizing hormone and also a concomitant increase in the number of oocytes released at ovulation compared to the control. Increase in testosterone levels resulting from increase in circulating luteinizing hormone levels have been recorded following treatment with *M. pruriens* in both human and animal studies. This in turn has increased fertility indices such as sperm count, sperm motility, sperm morphology and libido [15,19,20,28]. Therefore, the report of this study suggests that the increasing levels of circulating luteinizing hormone from the anterior pituitary produced by the administration of *M. pruriens* was responsible for the increase in the number of oocytes released at ovulation. This study failed to investigate the effect of *M. pruriens* on the histology of the ovary. The reported increases in the circulating levels of follicle stimulating hormone and luteinizing hormone could have reflected in increased number of growing follicles and matured graafian follicles thereby substantiating the fact that this extract could be used in the treatment of anovulation caused by hormonal imbalance.

4. CONCLUSION

M. pruriens enhances fertility in female Sprague-Dawley rats by producing a dose dependent increase in follicle stimulating hormone and luteinizing hormone which in turn increased the number of oocytes released at ovulation possibly through its rich source of L-Dopa and its metabolite, dopamine. From this study, it could be inferred that at higher dosages than was administered in this study, the number of ova shed at ovulation may be significantly increased. Thus, the use of *M. pruriens* in the treatment of female infertility caused by anovulation as a result of hormonal imbalance seems promising.

CONSENT

Not applicable.

ETHICAL APPROVAL

All authors hereby declare that “Principles of laboratory animal care” (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

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COMPETING INTERESTS

Authors declare that no competing interests exist.

REFERENCES

1. Qureshi S, Shah AH, Tariq M, Ageel AM. Studies on herbal aphrodisiacs used in Arab system of medicine. Am J Med. 1989;17:57–63.
2. Sofowora A. Medicinal Plants and Traditional Medicine in Africa. 2nd ed. Ibadan, Nigeria: Spectrum Books Ltd; 1993.
3. Agboola A. Contraception, textbook of Obstetrics and Gyneacology for Medical Students. Gynecology. 1998;1:189–90.
4. Brain KR. Accumulation of L-DOPA in cultures from *Mucuna pruriens*. Plant Sci Letters. 1976;7:157–61.
5. Campbell NA, Reece LA, Urry ML, Cain SA, Wasserman PV, Jackson RB. Biology. 8th ed. California: Pearson Benjamin Cunnings; 2008.
6. Vadivel V, Janardhanan K. Nutritional and Anti-nutritional Composition of Velvet Bean: an Under-Utilized Food Legume in South India. Inter J Food and Sci Nutr. 2000;51:279–87.
7. Nebedum JO, Udeafor PC, Okeke CU. Comparative effects of ethanolic extracts of *Ficus carica* and *Mucuna pruriens* leaves on haematological parameters in albino rats. Biokemistri. 2010;22:77–84.
8. Agbafor KN, Nwachukwu N. Phytochemical analysis and antioxidant property of leaf extracts of *Vitex doniana* and *Mucuna pruriens*. Biochem Res Inter. 2011;Article ID 459839, 4 pages.
9. Nwaoguikpe RN, Braide W, Ujowundu CO. The Effects of Processing on the Proximate and Phytochemical Compositions of *Mucuna pruriens* Seeds (Velvet Beans). Pakistan J Nutr. 2011;10:947–51.
10. Agharkar MS, Qureshi AQ, Iqbal J. Antidiabetic evaluation of *Mucuna pruriens*, Linn seeds. J Pak Med Assoc. 1991;40:147–50.
11. Manyam BV, Dhanasekaran M, Hare TA. Neuroprotective effects of *Mucuna pruriens*. Phytother Res. 2004;18:106–67.
12. Sathiyanaranyan L, Arulmozhi S. *Mucuna pruriens* Linn: a comprehensive review. Pharmacog Rev. 2007;1:157–62.

13. Sharma ML, Chandhoke N, Ray G, Jamwal KS, Gupta OP, Singh GB. Pharmacological screening of Indian medicinal plants. Indian J Exper Biol. 1978;16:228–35.
14. Siddhuraju P, Vijayakuma K, Janardhanan K. Chemical Composition and Protein quality of the Velvet Bean (*Mucuna pruriens*). J Agric Food Chem. 1996;44:2636–41.
15. Ahmad MK, Mahdi AA, Shukla KK, Islam N, Jaiswar SP, Ahmad S. Effect of *Mucuna pruriens* on semen profile and biochemical parameters in seminal plasma of infertile men. Fertil Steril. 2008;90:627–35.
16. Shukla KK, Mahdi AA, Ahmad MK, Shankhwar SN, Rajender S, Jaiswar Sp. *Mucuna pruriens* improves male fertility by its action on the hypothalamus-pituitary-gonadal axis. FertilSteril. 2009;92:1934–40.
17. Gupta A, Mahdi AA, Ahmad MK, Shukla KK, Bansal N, Jaiswar SP et al. A proton NMR study of the effect of *Mucuna pruriens* on seminal plasma metabolites of infertile males. J Pharm Biomed Anal. 2011;55:1060–6.
18. Jayanthi Abraham. Effect of *Mucuna pruriens* Seeds on Fertility of Male Abino Rats *Rattus norvegicus.* J Pharma Res. 2011;4:233–36.
19. Mahajan GK, Mahajan AY, Mahajan RT. Efficacy of aphrodisiac plants towards improvement in semen quality and motility in infertile males. J complement Integr Med. 2011;9:Article 6.
20. Singh AP, Sarkar S, Tripathi M, Rajender S. *Mucuna pruriens* and Its Major Constituent L-DOPA Recover Spermatogenic Loss by Combating ROS, Loss of Mitochondrial Membrane Potential and Apoptosis. PLOS ONE. 2013;8(1):54655.
21. Suresh S, Prithiviraj E, Lakshmi NV, Ganesh MK, Ganesh L, Prakash S. Effect of *Mucuna pruriens* (Linn.) on mitochondrial dysfunction and DNA damage in epididymal sperm of streptozotocin induced diabetic rat. J Ethnopharmacol. 2013;145:32–41.
22. Kim CY, Wakabayashi K, Nobunaga T. Time-dependent ovulation-blocking effect of ether anesthesia differs from pentobarbital in rats. Tohoku J Exp Med. 1994;172:237–42.
23. Kakkar P, Dos B, Viswnathan PN. A modified spectrophotometric assay of superoxide dismutase. Indian J Biochem. 1984;21:130−2.
24. Sinha AK. Colorimetric assay of catalase. Anal Biochem. 1972;47:389−94.
25. Leung PC, Armstrong DT. Interactions of steroids and gonadotropins in the control of steroidogenesis in the ovarian follicle. Ann Rev Physiol. 1980;42:71–82.
26. Boubekri A, Gernigon-Spychalowicz T, Khammar F, Exbrayat J-M. Morphometry and immunohistochemistry of follicles growth and steroidogenesis in saharian wild sand rat, Psammomysobesus, ovary. Folia Histochem Cyto. 2009;47:59–66.
27. Tripathi YB, Upadhyay AK. Effect of the alcohol extract of the seeds of *Mucuna pruriens* on free radicals and oxidative stress in albino rats. Phytother Res. 2002;16:534–8.
28. Shukla KK, Mahdi AA, Ahmad MK, Jaiswar SP, Shankwar SN, Tiwari SC. *Mucuna pruriens* reduces stress and improves the quality of semen in infertile men. Evid Based Complement Alternat Med. 2010;7:137–44.
29. Suresh S, Prithiviraj E, Prakash S. Effect of *Mucuna pruriens* on oxidative stress mediated damage in aged rat sperm. Int J Androl. 2010;33:22–32.
30. Sabatini L, Wilson C, Lower A, Al-Shawaf T, Grudzinskas JG. Superoxide dismutase activity in human follicular fluid after controlled ovarian hyperstimulation in women undergoing in vitro fertilization. Fertil Steril. 1999;72:1027–34.
31. Suzuki T, Sugino N, Fukaya T, Sugiyama S, Uda T, Takaya R. et al. Superoxide dismutase in normal cycling human ovaries: Immunohistochemical localization and characterization. FertilSteril. 1999;72:720−6.

32. Behrman HR, Kodaman PH, Preston SL, Gao S. Oxidative stress and the ovary. J Soc GynecolInvestig. 2001;8(1 Suppl):40−42.
33. El Mouatassim S, Guerin P, Menezo Y. Expression of genes encoding antioxidant enzymes in human and mouse oocytes during the final stages of maturation. Mol Hum Reprod. 1999;5:720–5.
34. Guerin P, El Mouatassim S, Menezo Y. Oxidative stress and protection against reactive oxygen species in the pre-implantation embryo and its surroundings. Hum Reprod Update. 2001;7:175–89.
35. Ishikawa M. Oxygen radicals-superoxide dismutase system and reproduction medicine. Nippon Sanka Fujinka Gakkai Zasshi. 1993;45:842–8.
36. Ray SD, Lam TS, Rotollo JA, Phadke S, Patel C, Dontabhaktuni A, et al. Oxidative stress is the master operator of drug and chemically-induced programmed and unprogrammed cell death: Implications of natural antioxidants in vivo. Biofactors. 2004;21:223−32.
37. Aitken RJ and Baker MA. Oxidative stress and male reproductive biology. Reprod Fertil Dev. 2004;16:581−8.
38. Gibson GE, Huang HM. Mitochondrial enzymes and endoplasmic reticulum calcium stores as targets of oxidative stress in neurodegenerative diseases. J Bioenerg Biomembr. 2004;36:335–40.
39. Madamanchi NR, Vendrov A, Runge MS. Oxidative stress and vascular disease. Arterioscler Thromb Vasc Biol. 2005;25:29–38.
40. Halliwell B, Gutteridge JM, Cross CE. Free radicals, antioxidants, and human disease: where are we now? J Lab Clin Med. 1992;119:598−620.
41. Johnson F, Giulivi C. Superoxide dismutases and their impact upon human health. Mol Aspects Med. 2005;26:340–52.
42. Chelikani P, Fita I, Loewen PC. Diversity of structures and properties among catalases. Cellular and Mol Life Sci. 2004;61:192–208.
43. Potterat O. Antioxidants and free radical scavengers of natural origin. Current Organic Chemistry. 1997;1:415–40.
44. Gulcin I. Comparison of *In vitro* antioxidant and antiradical activities of L-tyrosine and L-Dopa. Amino Acids. 2007;32:431–8.
45. Gow-Chin Y, Chiu-Luan H. Antioxidant effects of dopamine and related compounds. Biosci Biotech Biochem. 1997;61:1646–9.
46. Kazuki K, Hiroyuki S. High content of dopamine, a strong antioxidant, in Cavendish banana. J Agric Food Chem. 2000;48:844–8.
47. Sies H. Oxidative stress: Oxidants and antioxidants. Expr Physiol. 1997;82:291–5.
48. Vermes I, Toth EK, Telegdy G. Effects of drugs on brain neurotransmitter and pituitary testicular function in male rats. Horm Res. 1979;10:222–32.
49. Freeman ME. The ovarian cycle of the rat. In: Knobil E, Neil J, editors. Physiology of Reproduction. New York: Raven Press Ltd; 1988.

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