Indian Journal of Animal Sciences **93** (9): 843–852, September 2023/Review Article
https://doi.org/10.56093/ijans.v93i9.113326

Herbal remedies for male infertility and spermatogenic activity in animals: A review

CHETNA GANGWAR[1], GURURAJ KUMARESAN[2]✉, ANIL KUMAR MISHRA[2], ASHOK KUMAR[2], R POUROUCHOTTAMANE[1] and BHUVANESHWAR RAI[3]

ICAR-Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh 281 122 India

Received: 30 July 2021; Accepted: 9 August 2023

ABSTRACT

Male infertility is becoming an important untouched area that needs immediate attention due to the increasing demand for breeding strategies, keeping in view the production and increasing per animal productivity. Many additives and antioxidants have been tried for enhancing the seminal quality, but still there is no evidence of full-proof effect on the conception rates in female animals. However, herbal preparations which promise multi-factorial effect in the breeding male animals can be explored, and in turn could prove to be a better tool to encounter the problem of male infertility holistically. The herbal preparations and its effect at the cellular, molecular and metabolic level still needs to be understood. However, the advantage of using the herbal ingredients could be, use of available local herbal ingredients which are more economical, affordable, can reduce the use of hormonal therapy, have less side effects on long term usage, and have greater acceptability by the farmers. These herbal ingredients will be useful in breeding programmes for improvement of germplasm in terms of productivity. The current review covers how the herbs can be utilized in improving the semen quality and quantity, enhancing function of sertoli and leydig cells, mating behaviour, fecundity, seminal antioxidant status, hypophyseal adrenal gonadal axis cum endocrine regulation, microcirculation of testes, as well as in semen cryopreservation and post thaw quality of different species.

Keywords: Herbal preparations, Male infertility, Male reproductive behaviour, Semen quality, Spermatogenic activity

Male reproduction in animals is a key area that needs more attention for effective implementation of the breeding programmes. Quality males having superior germplasm are essential, but on the other side, elite animals with good reproductive parameters are equally paramount in triggering their growth potential. Good quality male germplasm can be spread over the large population through artificial insemination, but the fertility of cryopreserved semen is not up to the mark (Gangwar *et al.* 2023). To predict the fertility status of male animals, the parameters like spermatogenesis, semen quality, sperm functions, fertility, etc. must be considered (Gangwar *et al.* 2016). Spermatogenesis depends on intra-testicular and extra-testicular endocrine governing processes, and physiology of the inter-tubular microcirculation (Holstein *et al*. 2003). Seminal characteristics including spermatozoa concentration, viability, mobility, morphology, sperm abnormalities, sperm capacitation, etc. are used to predict the semen quality (Huynh *et al*. 2000, Rodriguez-Martinez, 2003, 2006, Gangwar *et al.* 2020). Male infertility issues needs more attention in the current scenario, owing to the fact that good quality male germplasm is difficult to obtain while planning for breeding to improve productivity, and it also requires boost in the form of supplementation of synthetic additives in the feed.

The medicinal plants are quite often used for improvement in litter size and fecundity, prevention and treatment of reproductive disorders (Ayoka *et al*. 2008, Gangwar *et al.* 2019). Several plants have male fertility regulatory potentials and can improve the sexual desire and fecundity (Thakur *et al*. 2012), endocrine effect (Ajuogu *et al*. 2019), semen quality characteristics (Ajuogu *et al*. 2019, 2020, Patel *et al.* 2022), etc. Moreover certain plants with medicinal characteristics are reported to have anti-fertility effects that encompass an impaired spermatogenic activity and decreased semen quality (Olugbenga *et al*. 2011, Shaik *et al*. 2017, Ajuogu *et al*. 2018). Application of herbal formulations often has been advocated immensely due to convenience, low cost and desired effects (Saleh *et al*. 2015). Earlier studies mostly focussed on reactive oxygen species and its effect pertaining to antioxidant and their application in male reproduction (Chatterjee and Chatterjee 2009, Gangwar *et al.* 2014, Gangwar *et al.* 2018). Therefore, this review addresses the role of various herbs in directly enhancing the performance of male reproductive activity or by improving the seminal characteristics during cryopreservation. This review also discusses various herbal preparations that have potential

Present address: [1]ICAR-Central Institute for Research on Goats, Makhdoom, Uttar Pradesh. ✉Corresponding author email: guruvet@gmail.com

role in modulating the male animal fertility.

Endocrine regulation of reproductive system

Endocrinological regulation is important in modulating the reproduction in domestic animals by its feed-back mechanisms. An effective interplay of hormone, receptors and its metabolites would result in favourable outcomes in reproduction, and in turn harvesting the best germplasm. But, there are few studies that helped to decipher the encouraging effects of herbal preparation in the male reproduction, which are discussed in this section.

Tribulus terrestris and its effects on hormonal function were analyzed in non-human primates, and other laboratory animals to mitigate the erectile dysfunction (ED) (Adaikan *et al*. 2000). *T. terrestris* extract was given at specified doses orally to primates for short term effect, and to rabbits and rats for eight weeks to assess its long term effect. The study also assessed its effect on castrated rats treated with biweekly doses of testosterone cypionate for two months along with *T. terrestris* oral preparation for the same period in another group. When the blood samples were analysed for testosterone and its other analogues, all were significantly increased in the species studied. Even castrated rats showed a significant hike in the testosterone levels which may be due to the active principle '*protodioscin*' in the *T. terrestris* herbal preparation, and the same is also the reason for effectively improving the cases of erectile dysfunction (Kalamegam *et al*. 1988). A study by Haeri *et al*. (2006) also indicated the effectiveness of SKEO (*Satureja Khuzestanica* essential oil) in significantly increasing the concentrations of Follicular Stimulating Hormone (FSH) and testosterone in the treated groups.

The favourable effect of the extract of *Pedalium murex* fruits in male rats on the levels of serum testosterone for 28 days was studied and the male rats responded well with the increase in testosterone levels on administration of the extract with dose rate of 150 mg/kg. It was also well recorded that with the progression of treatment, the serum testosterone levels gradually increased, and further, the containment of treatment did not decrease the raised serum testosterone levels (Sharma *et al*. 2012). Another herb, namely *G. tessmannii* significantly increased the plasmatic testosterone gradually from 7 to 56 days post-treatment (Defo *et al*. 2017), while some other herbs like *Mucuna pruriens, Astercantha longifolia* and *Curculigo orchioides*, were found to effectively modulate the secretion of pituitary hormones, viz. FSH and Luteinizing Hormone (LH) (Chauhan *et al*. 2010).

Improving the libido and mating behaviour

Herbal aphrodisiacs, when used judiciously, could improve the overall libido and mating behaviour of the animals. Male sexual behaviour is governed by various parts of the brain in the form of a neural circuit (Tsai *et al*. 2009). Haeri *et al.* (2006) reported that the vigour and prolificacy of the male rats administered with *Satureja khuzestanica* essential oil (SKEO) at certain doses could significantly improve when compared to the controls. The same ingredient while supplemented in diet also could have a positive effect on fertility indices and litter size. Post implantation losses were also reduced significantly in the female counterpart. Moreover the numbers of live foetuses were also increased by treatment of the same herbal preparation in dams possibly due to decreased blood ROS generation and its increased scavenging activity. Further, it can be explained by the fact that presence of certain active principles including carvacrol and flavonoids attribute to the anti-oxidant and scavenging activity of *Satureja* spp. (Haeri *et al*. 2006). Certain important libido parameters like mount latency, intromission latency, ejaculation latency and post ejaculatory interval were significantly decreased by the ethanolic extract of *Pedalium murex*. On the contrary, this extract significantly improved the penile erection index, mounting frequency and intromission frequency and serum testosterone level ($P<0.05$) (Sharma *et al.* 2012) in wistar albino rats. On the other hand, herbal extracts from date palm were found to improve the fertility and health in rabbits (Khalifa *et al*. 2018). Locally available herbs like *Moringa oleifera* were found to have desirable effects on libido and live spermatozoa concentration when used orally at certain doses (100, 200 and 500 mg/kg) with no toxicity or other adverse effects in experimental animals (Varsha *et al.* 2013). Oral administration of ethanolic extract of *Alpinia galanga* significantly increased sperm percentage, viability, motility, mating behaviour and testosterone hormone in rats (Mazaheri *et al*. 2014).

Stimulating the function of sertoli cells and leydig cells

Leydig cells influence the seminiferous tubule via high testosterone levels in the testes through the LH. Similarly, FSH influences the sertoli cells, and supports spermatogenesis (Kretser 1982). The role of sertoli cells and leydig cells thus can be augmented by the use of certain herbs, which increase the aphrodisiac activity and androgenic stimulation. Hence, the aphrodisiac herbs were evaluated for their natural induction of the FSH and testosterone secretion with positive influence on the function of accessory sex organs and testes. In this context, the effect of SKEO at the dose of 225 mg/kg on the increased testicular weight, seminal vesicles, and ventral prostate was studied by Haeri *et al*. (2006). As per the finding in the male rats administered with SKEO, the histopathological analysis showed an increase in the number of germinal cells, leydig cells, seminiferous tubules. Further, in the treatment groups, the sertoli cells were found hypertrophic. Thus, it is obvious that the continuous androgenic stimulation has a positive effect on the physiological functions of the epididymis and accessory sex organs due to SKEO. *Mucuna pruriens* extract increase the weight of the accessory sex organs probably due to the result of increased secretory activity, which was evident from an increase in the activities of alkaline phosphatase in epididymis, protein levels in the testis and epididymis (Mutthu *et al*. 2011).

It was observed that certain herbs were used to reverse the toxic effects on the testes as reported by Okaily *et al*. (2016). In this case, they tapped the favourable effects of the extract of *Eruca sativa* seeds to reverse the toxic effects caused by cadmium chloride, another important research done by El Ghazzawy *et al*. (2011) also focussed on a similar pattern, in which pomegranate juice was found to have the ability to counteract structural changes in the rat epididymis caused by plasticizer bisphenol by increasing the number of sperm in cauda epididymis, reducing sperm abnormalities and improving male fertility.

Preventing oxidative stress

Balance between ROS and ROS-scavenging system and its inter-play is very vital to male animal reproduction system (Agarwal *et al*. 2008, Gangwar *et al*. 2018, Gangwar *et al*. 2019). Free radical-induced oxidative stress compromises the animal reproductive efficiency, and it requires antioxidant therapy to alleviate the oxidative stress. Herbal therapeutics offer good scope in combating the ill effects of free radicals. Plant derived antioxidants can display favourable or harmful effects in male reproduction functions including spermatogenesis and seminal parameters (Zhong and Zhou 2013). Herbal or medicinal plants contain many active ingredients which are reported to have flavonoids, carotenes, tannins, polyphenols etc. (Gupta and Sharma 2006, Nagulendran *et al*. 2007, Sen *et al*. 2010). Sperm immobilization occurs due to fair increase in ROS concentrations by depleting the cellular ATP and decrease in phosphorylation, whereas ROS levels above physiological break-points could lead to lipid-peroxidation and spermicidal activity (Misro *et al*. 2004). This spermicidal activity can also be attributed to free radical induced damage in the spermatozoa plasma membranes, which have high PUFA along with anti-oxidant enzymes in sub-optimal concentrations (Sawyer *et al*. 2001, Maneesh and Jayalekshmi 2006). Further, spermatogenesis being a very active process, with a high rate of cell division, leads to generation of excess ROS due to increased mitochondrial respiration (Aitken and Roman 2008). All these reasons contribute to change in balance between the ROS generation and de-toxification, that culminates to cellular stress, and damage of cellular components and motifs in the sperm and testes. This eventually leads to poor semen quality cum infertility in male animals, and on the other side accounts to fertilization failure and failed embryogenesis and abortions in females (Rabbani *et al*. 2010, Enciso *et al*. 2011). ROS are also generated from semen processing steps including cryopreservation in addition to the spermatogenesis (Bucak *et al*. 2008, 2009) and further the freezing/thawing procedures leads to cold shock/injuries and lipid peroxidation (Bucak *et al*. 2012). Moreover, other environmental factors like high temperature, toxins, chemicals and microbial contamination (Gangwar *et al*. 2021, Kumaresan *et al.* 2022) attribute to ROS production thereby affecting the reproduction system.

The effect of aqueous extract of *Rhodiola sacra* (RS) was studied for its antioxidant activity post-cryopreservation with its antioxidant scavenging activity against superoxide anion radical on boar semen characteristics (Zhao *et al.* 2009). RS concentration used in extender ranging between 4 to 8 mg/L was found to have a significant correlation with GSH and MDA concentration in spermatozoa in the frozen thawed boar semen (Zhao *et al*. 2009). Natural tea extracts from *Camellia sinensis* at 10 mg/L level significantly decreased the MDA concentration (Mehdipour *et al*. 2016). While, Wen *et al*. (2019) reported that the addition of grape seed extracts (GSE) to the diluter improved the sperm quality in goats along with better antioxidant capacity during preservation at refrigerated temperature.

Modulating the proliferation and apoptosis of germ cells

Lower numbers of sperm cells and sperm defects are one of the major factors of male infertility. Furthermore, spermatogenesis is an extremely orchestrated process to produce sperm at a magnifying rate. At this rate, there are possible chances of acquiring apoptotic spermatozoa, if testicular environment is not favourable. Patel *et al*. (2017) reported that compared to the control, *Bacopa monnieri* (Brahmi) extract treatment resulted in a significant increase ($P<0.05$) in spermatogenic cell count, tubular diameter, and in steroidogenic indices in the testis. It also increased the sperm viability in cauda epididymidis of the treated mice at 80 mg dosage. Conversely, with the same extract in the dosage of 80 mg, there was an appreciable decrease ($P<0.05$) in abnormal sperm morphology and lipid peroxidation levels in testis of the treated mice compared to the controls.

Mehdipour *et al.* (2016) reported that tea extract (*Camellia sinensis*) when used at a dose of 10 mg/L level increased the proportion of viable spermatozoa, and lowered the apoptotsis in sperm when compared to other treatments ($P<0.05$), and also the levels of MDA were significantly decreased. Another multi-herbal formulation called Hatch-up that includes *Glycyrrhiza glabra, Curculigo orchioides*, *Tribulus terrestris Withania somnifera*, etc. increased the total sperm concentration in the cauda epididymis, with reduced abnormalities in sperm on comparison to rats that received vehicle alone (Ananda Kumar *et al*. 2013). *Eruca sativa* seeds extract were also reported to have beneficial effects in improving seminal parameters by alleviating the toxic effects of cadmium chloride in testes (Okaily *et al*. 2016).

Ameliorating the microcirculation of the testis

Testicular microcirculation is an important parameter in the male reproductive physiology because of its transportation of nutrients and other secretory products for spermatogenesis. Hormones like LH and functional entities like Leydig cells are influenced by the microcirculation in the testes (Bergh *et al*. 1987). Besides the hormonal influences on microcirculation, there are the herbal therapeutics that improve the microcirculation in the testes. *Ficus caria* (Fc) leaf extract increased the sperm

count, motility of spermatozoa, etc. in the formaldehyde treated testes. Moreover, seminiferous tubule with arrested spermatogenesis was hardly observed, showing that Fc had positive effects on sperm characteristics when exposed with formaldehyde (Naghdi *et al*. 2016). Sahoo *et al*. (2014) investigated the aphrodisiac potential of herbal preparations from various components of *Curculigo orchioides, Mucuna pruriens, Cucurbita pepo*, *Tribulus terrestris, Allium tuberosum, Argyreia nervosa*, etc. in albino rats in specified proportion. It was found that 600 mg/kg of the herbal formulation improved the mating behaviour, mating performance, serum hormonal levels and sperm count. Muthu *et al.* (2011) reported that the *Mucuna pruriens* extracts significantly improved the testicular metrics and physiology and epididymal alkaline phosphatase activity with possible androgenic activity. These positive effects might be due the improved circulation of endocrine regulators towards the testes.

Herbal preparation as source of trace elements

Organic minerals can support optimum reproductive function by improving semen production, sperm motility and male fertility (Arthington *et al*. 1995). Trace elements including copper and zinc supplementation in animal feed influences production and reproduction positively (Rowe *et al*. 2013). Herbal preparations are known to combat the sperm membrane from the ill effects of damage during freezing. Amino acids like proline protects the membrane structure during stress; and along with cysteine it doubles into an antioxidant scavenging the ROS through glutathione formation during freeze-thawing. Certain vitamins including C (Gangwar *et al*. 2015), E and minerals like Zn, Cu and Se and other essential oils of herbs have reported to have protective effects on cell membrane. The study reported that dietary azolla supplementation improves the mating behaviour, semen volume and semen quality in bucks as azolla is very rich in trace minerals and vitamins (Gangwar *et al*. 2019). Addition of semen diluent with 10 to 20% pomegranate juice that has high amount of vitamins, minerals and anti-oxidants has showed encouraging findings in terms of post thaw semen quality in bulls (El-Sheshtawy *et al*. 2016).

Improvement in semen quality and quantity

Male reproduction depends on both physical and behavioural development, and with proper nutrition there is always a way to improve the seminal quality and quantity. There are other resources that can be used to improve these parameters. The effect of certain herbal extracts from *Tribulus terrestris, Eurycoma longifolia,* and *Leuzea carthamoides* was analysed for vigour and semen quality in boars (Frydrychová *et al*. 2011). In this study, various spermatozoa and fertility parameters were assessed, and significant differences in libido, semen volume, sperm concentration, morphologically abnormal spermatozoa were observed. The herbal preparation treated boars showed an increase of 20% in all these aforesaid parameters after the experiment. Other anti-oxidant herbs were also explored including the Chinese herb *Rhodiola rosea*, for its antioxidant potential (Ohsugi *et al*. 1999). Further, Zhao *et al*. (2009) studied that aqueous extract of *Rhodiola sacra* positively influenced the biochemical and sperm quality parameters in cryopreserved boar-sperm. Another popular perennial herb Rosemary (*Rosmarinus officinalis*) was also found to have antioxidant properties due to certain substances including flavonoids, diterpenes, triterpenes, polyphenols, etc. (Samotyja and Matecka 2010). The same was studied for its effect on sperm quality and was found to improve the sperm motility and fertility post-crypreservation (Malo *et al*. 2011). Aphrodisiac herbs that tend to improve the libido like *Ferula hermonis* is known for its antioxidant effects in both gender (Hanafi *et al*. 2010) was used as an extract supplementing the semen extender that increased the post-thaw motility, viability and decreased lipoperoxidation during cryo-preservation in boar semen Malo *et al*. (2012). Simple disaccharide like trehalose obtained from seaweed extract has been known to combat ROS and thermal shock during free-thaw process of semen in various domestic species (Bucak *et al*. 2007, Reddy *et al*. 2010).

In our previous study (Gangwar *et al*. 2019), it was found that dietary azolla supplementation in bucks significantly improved the libido, semen quality and semen volume. Similarly, *Spondias mombin* leaf extract was used to stabilize the bucks which were studied before and after treatment with oral administration of 800 mg/kg body weight for two weeks. The following spermiogram analysis by castrating the selected goats that are processed for histology of testicular and epididymis tissue showed significantly higher ($P \leq 0.05$) morphological abnormalities in pre-treated animals compared to the post-treated animals (Oloye *et al*. 2017). Further it was observed that certain morphological abnormalities including curved mid-piece, bent tail etc., were higher in pre-treated animals compared to tis post-treated counterpart. Other functional attributes like sperm motility, viability were elevated in post-treatment group. Similarly, another herb *Cynomorium songaricum* when administered in animals showed highly significant epididymal sperm count, and it considerably improved the testicular weight as compared to the control groups (Yang *et al*. 2010).

Preparations having herbs like *Enantia chlorantha, Zingiber officinale, Sesame radiatum, Asparagus racemosus, Cynomorium coccineum, Mucuna pruriens, Piper longum, Tribulus terrestris, Withania somnifera,* etc. are reported to improve the semen quality in rats (Morakinyo *et al*. 2008, Shittu *et al*. 2008, Khaki *et al*. 2009).

Effect on semen cryopreservation

The freeze-thaw process reduces the spermatozoa quality through exerting physical and chemical stressors, thereby decreasing the semen quality, sperm viability and fertilization efficiency. A study was conducted on boar

Table 1. Effect of herbs on aphrodisiac activity of male animals

Herb used	Part used	Form used	Physiological function	Animal tested	Reference
Rhodiola sacra	Root	Aqueous extract	Improved the antioxidant capacity of semen	Boar semen	Zhao *et al*. (2009)
Satureja khuzestanica	Arial part	Esssential oil	Increased the sperm count and sertoli cell function	Wistar rats	Haeri *et al*. (2006)
Rosmarinus officinalis	Leaves	Aqueous extract	Improved the post thaw semen quality	Boar	Malo *et al*. (2010)
Camellia sinensis	Leaves	Aqueous extract	Increased the sperm viability and decrease the sperm apoptosis	Ghezel rams	Mehdipour *et al*. (2016)
Mucuna pruriens	Seed	Ethanolic extract	Improved the sexual behaviour of males	Rats	Suresh *et al*. (2009)
Cynomorium songaricum	Stem	Aqueous extract	Increased the testicular weight and sperm count	Rats	Yang *et al*. (2010)
Pedalium murex	Fruit	Ethanolic extract	Improved the sexual behaviour and serum testosterone	Wistar rats	Sharma *et al*. (2012)
Eurycoma longifolia	Roots	Methanolic extract	Improved spermatogenesis	Rats	Low *et al*. (2013)
Bacopa monnieri	Whole plant	Ethanolic extract	Semen quality, sperm cell count and steroidogenic indices in testes was improved	Mice	Patel *et al*. (2017)
Dana racemosa	Whole plant	Whole plant powder	Increased sperm motility & viability	Rat	Khaki *et al*. (2009)
Curculigo orchioides	Rhizome	Ethanolic extract	Improved penile erection, mating performance, mount frequency and mount latency	Rat	Thakur *et al*. (2012)
Daucus carota	Seed	Ethanolic extract	Improved testosterone level	Rat	Nouri *et al*. (2009)
Zingiber officinale	Rhizome	Aqueous extract	Increased sperm count, viability and motility	Rats	Morakinyo *et al*. (2008)
Zingiber officinale	Rhizome	Rhizome powder	Increased sperm count, viability, motility and fertility	Rats	Khaki *et al*. (2009a)
Lactuca sativa, Petroselinum hortense, Bacopa monniera	Leaf	Ethanolic extract	Increased testicular function	Mice	Patil *et al*. (2009)
Lannea acida	Stem bark	Methanolic extract	Protected testicular morphology and decrease sperm abnormality	Rats	Ahmed *et al*. (2010)
Withania somnifera	Whole plant	Whole plant powder	Regulated serum androgen levels	Rats	Kiassalari *et al*. (2009)
Lepidium meyenii	Hypocotyls	Aqueous extract	Improved testicular function and sperm motility	Rats	Chung *et al*. (2005)
Hylocereus co-staricensis	Pulp	Ethanolic extract	Increased spermatogenesis, sperm count and sperm viability	Mice	Aziz and Noor (2010)
Citrus sinensis	Fruit peel	Ethanolic extract	Improved sperm quality parameters	Rat	Khaki *et al*. (2011)
Kigelia africana	Fruit	Methanolic extract	Improved semen quality and seminal antioxidant status	Rat	Azu *et al*. (2010)
Raphanus sativus	Seed	Seed powder	Improved semen quality and performance	Rabbit	El-Nattat and El-Kady (2007)
Pomegranate	Fruit	Juice	Improved frozen-thawed semen quality	Bull	El-Sheshtawy *et al*. (2016)
Mucuna pruriens	Seed	Methanolic extract	Improved serum testosterone level and testicular cholesterol and protein	Wistar Rat	Muthu and P Krishnamoorthy (2011)
Spondias mombin	Leaf	Ethanolic extract	Improved semen quality	Bucks	Oloye *et al*. (2017)
Camellia sinensis	Leaf	Methanolic extract	Improved post-thawed spermatozoa motility, viability and membrane integrity	Bull	Khan *et al*. (2017)

Continued...

Table 1. (*Concluded*)

Herb used	Part used	Form used	Physiological function	Animal tested	Reference
Grape seed	Seed	Procyanidin extract	Improved sperm motility, acrosome membrane integrity, mitochondrial activity, plasma membrane integrity and total antioxidative capacity	Buck	Wen *et al*. (2019)
Phoenix dactylifera	Fruit	Aqueous extract	Improved the antioxidant potential, testosterone level and sperm parameters	Rabbit	Khalifa *et al*. (2018)
Thymus vulgaris	Whole plant	Ethanolic extract	Improves the quality of ram sperm after freezing and thawing	Moghani ram	Vahedi *et al*. (2018)
Aloe barbadensis	Gel	Aqueous extract	Adversely affected the spermiogram of bucks	Bucks	Olugbenga *et al.* (2011)
Alpinia galanga	Rhizomes	Methanolic extract	Increased sperm percentage, viability, motility and testosterone hormone	Wistar Rats	Mazaheri *et al*. (2014)
Sesamum indicum		Ethanolic extract	Improved testosterone level and antioxidant status	Wistar Rats	Ashamu *et al*. (2014)
Green tea		Catechin	Improved sperm DNA integrity and antioxidant activity	Bulls	İNANÇ *et al*. (2019)
Ficus asperifolia	Fruit	Aqueous extract	Increased the weight of sexual organs and androgenic capacity	Wistar Rats	Watcho *et al*. (2017)
Tribulus terrestris	Fruit	Aqueous extract	Improved seminal attributes	Afshari rams	Pour *et al*. (2015)
Moringa oleifera	leaf	Powder	Increased testosterone level and improved seminal parameters	Rabbits	Ajuogu *et al*. 2019)
Azolla	leaf	Pellet	Improved libido, semen quality and semen volume.	Bucks	Gangwar *et al*. (2019)
Cyathula prostrata	Whole plant	Whole plant powder	Decreased sperm motility and morphology	Rabbits	Ajuogu *et al*. (2020)
Allium cepa	Bulb	Crude extract	Improves post thaw sperm quality	Sirohi bucks	Patel *et al.* (2022)
Aloe perfoliata	Leaf pulp	Crude extract	Improves post thaw sperm quality	Sirohi bucks	Patel *et al.* (2022)

spermatozoa to assess the positive effects of Rosemary herb (*Rosmarinus officinalis*) at various concentrations on total motility, livability, integrity of acrosome, response to Hypo-Osmotic Swelling Test (HOST) and malonaldehyde levels. Rosemary is another herb that has increased the sperm motility, and showed positive effect on HOST, and reduction in MDA concentration (Malo *et al.*, 2012). The same herb was also tested in bull and ram semen, which showed the encouraging results (Daghigh-Kia *et al*. 2014, Mascaró *et al*. 2016). İNANÇ *et al*. (2019) investigated the effect of green tea extract 'catechin (CT)', on semen quality parameters in the frozen-thawed bull sperm as a supplement to Tris extender. It was observed that the CT supplementation offered protection to cryodamage of morphological and DNA integrity of bull spermatozoa by enhancing the total antioxidant activity depending of the dose. Green tea extract supplemented in semen dilutor was found to show significant effect on post-thaw sperm motility, livability and integrity of membrane (Khan *et al*. 2017) in bull. Likewise, Pour *et al*. (2015) reported that supplementation of 5% *T. terrestris* extract in diluter improved the seminal attributes of Afshari ram at 5°C.

Mehdipour *et al*. (2016) reported that tea extract (*Camellia sinensis*) used at a dose of 10 mg/L improve significantly ($P<0.05$) the sperm motility compared to the untreated controls. Further the extract used at doses of 5 and 10 mg/L influenced higher membrane integrity, mitochondrial activity and antioxidant capacity in comparison to control group ($P<0.05$). *Camellia sinensis* extract at 10 mg/L level influenced spermatozoa viability and reduced the apoptotosis of spermatozoa ($P<0.05$) compared to all other treatments. Also the MDA formation that aids in oxidative stress was highly reduced at similar concentrations ($P<0.05$). Wen *et al.* (2019) assessed certain male reproductive parameters including sperm motility, acrosome membrane integrity and related anti-oxidant activities due to the effect of grape seed extract which were significantly elevated compared to control group, whereas MDA levels were found to be lesser than the control group ($P<0.05$). Grape seed extract (GSE) when treated @ 30 mg/L significantly improved the sperm quality. Furthermore, higher litter sizes were obtained through artificial insemination (AI) at the same dose of GSE.

Malo *et al*. (2011) reported that inclusion of rosemary

extract into the extender has positive effects on embryogenesis through improved fertilization efficiency. Also in another experiment, a similar herb called Garden thyme (*Thymus vulgaris*) improved the ram semen quality and post-thaw quality, with notable effects on sperm morphology and functional characteristics (Vahedi *et al*. 2018).

Conclusion

There is a gradual increase in the use of chemical antimicrobial agents as well as hormones leading to the infertility or subfertility in the animals. The current review has tried to consolidate the various herbal formulations that can specifically solve the problem of male infertility or improve the semen characteristics, thereby addressing its potential in male reproduction. The damage created by chemical agents can be reverted by the application of herbal remedies thereby improving the reproductive health of the wealthy germplasm of our country. The herbal preparations and its effect at the cellular, molecular and metabolic level still needs to be understood, which in turn requires more advanced studies and trials using the active ingredients responsible for improving the andrological effect. More futuristic work needs to be done for adapting the male reproductive behaviour to the changing trends of intensification, which leads to production stress and the herbal based additives or therapies can aid in this transition.

ACKNOWLEDGEMENT

The reasearch was carried out for the NLM funded project (Project number-ANSC CIRG SOL 2023 00100319).

REFERENCES

Adaikan P G, Gauthaman K, Prasad R N and Ng S C. 2000. Proerectile pharmacological effects of *Tribulus terrestris* extract on the rabbit corpus cavernosum. *Annals of the Academy of Medicine, Singapore* **29**(1): 22–26.

Agarwal A, Makker K and Sharma R. 2008. Clinical relevance of oxidative stress in male factor infertility: an update. *American Journal of Reproductive Immunology* **59**(1): 2–11.

Ahmed M K, Anuka J A, Attahir A, Tanko Y, Wawata A U and Yusuf M S. 2010. Studies of the effect of methanolic stem bark extract of Lannea acida on fertility and testosterone in male Wistar rats. *Asian Journal of Medical Sciences* **2**(6): 253–8.

Aitken R J and Roman S D. 2008. Antioxidant systems and oxidative stress in the testes. *Oxidative Medicine and Cellular Longevity* **1**: 15–24.

Ajuogu P K, Ere R, Nodu M B, Nwachukwu C U and Mgbere O O. 2020. The influence of graded levels of *Cyathula prostrata* (Linn.) Blume on semen quality characteristics of adult New Zealand white bucks. *Translational Animal Science* **4**(2): 1134–9.

Ajuogu P K, Herbert U, Ibeh P C, Nodu M B, Ukpabio U H, Onyegbule C G and Akintola A O. 2018. Semen quality characteristics and testosterone levels of rabbit bucks fed Costus afer leaf. *African Journal of Biotechnology* **17**(2): 24–8.

Ajuogu P K, Mgbere O O, Bila D S and McFarlane J R. 2019. Hormonal changes, semen quality and variance in reproductive activity outcomes of post pubertal rabbits fed *Moringa oleifera* (Lam.) leaf powder. *Journal of Ethnopharmacology* **233**: 80–6.

Al-Okaily B N and Al-Shammari Z M. 2016. The impact of Eruca sativa seeds on Leydig's cells number and hormonal profile in cadmium exposed rats. *Kufa Journal for Veterinary Medical Sciences* **7**(2): 241–53.

Arthington J D, Johnson K R, Corah L R, Willms C L and Hill D A. 1995. The effect of dietary zinc level and source on yearling bull growth and fertility. *Kansas Agricultural Experiment Station Research Reports* **1**: 109–10.

Ashamu E A, Salawu E O, Oyewo O O, Alhassan A W, Alamu O A and Adegoke A A. 2010. Efficacy of vitamin C and ethanolic extract of *Sesamum indicum* in promoting fertility in male Wistar rats. *Journal of Human Reproductive Sciences* **3**(1): 11.

Ayoka A O, Akomolafe R O, Akinsomisoye O S and Ukponmwan O E. 2008. Medicinal and economic value of *Spondias mombin*. *African Journal of Biomedical Research* **11**(2): 129–36.

Aziz F A and Noor M M. 2010. Ethanol extract of dragon fruit and its effects on sperm quality and histology of the testes in mice. *Biomedical Research* **21**(2):126–30.

Azu O O, Duru F I, Osinubi A A, Noronha C C, Elesha S O and Okanlawon A O. 2010. Preliminary study on the antioxidant effect of *Kigelia africana* fruit extract (Bignoniacieae) in male Sprague-Dawley rats. *African journal of Biotechnology* **9**(9): 1374–81.

Bergh A, Rooth P, Widmark A and Damber J E. 1987. Treatment of rats with hCG induces inflammation-like changes in the testicular microcirculation. *Reproduction* **79**(1): 135–43.

Bucak M N, Ateşşahin A and Yüce A. 2008. Effect of anti-oxidants and oxidative stress parameters on ram semen after the freeze–thawing process. *Small Ruminant Research* **75**(2-3): 128–34.

Bucak M N, Ateşşahin A, Varışlı Ö, Yüce A, Tekin N and Akçay A. 2007. The influence of trehalose, taurine, cysteamine and hyaluronan on ram semen: microscopic and oxidative stress parameters after freeze–thawing process. *Theriogenology* **67**(5): 1060–7.

Bucak M N, Başpınar N, Tuncer P B, Coyan K, Sarıözkan S, Akalın P P, Büyükleblebici S and Küçükgünay S. 2012. Effects of curcumin and dithioerythritol on frozen-thawed bovine semen. *Andrologia* **44**: 102–09.

Bucak M N, Tuncer P B, Sarıözkan S and Ulutaş P A. 2009. Comparison of the effects of glutamine and an amino acid solution on post-thawed ram sperm parameters, lipid peroxidation and anti-oxidant activities. *Small Ruminant Research* **81**(1): 13–7.

Chatterjee A and Chatterjee R. 2009. How stress affects female reproduction: An overview. *Biomedical Research* **20**: 79–83.

Chauhan N S and Dixit V K. 2010. Effects of *Bryonia laciniosa* seeds on sexual behaviour of male rats. *International Journal of Impotence Research* **22**(3): 190–95.

Chung F, Rubio J, Gonzales C, Gasco M and Gonzales G F. 2005. Dose–response effects of *Lepidium meyenii* (Maca) aqueous extract on testicular function and weight of different organs in adult rats. *Journal of Ethnopharmacology* **98**(1-2): 143–7.

Daghigh-Kia H, Olfati-Karaji R, Hoseinkhani A and Ashrafi I. 2014. Effect of rosemary (*Rosmarinus officinalis*) extracts and glutathione antioxidants on bull semen quality after cryopreservation. *Spanish Journal of Agricultural Research* (1): 98–105.

De Kretser D M. 1982. Sertoli cell—Leydig cell interaction in the regulation of testicular function. *International Journal of Andrology* **5**: 11–17.

Defo P B, Wankeu-Nya M, Ngadjui E, Fozin G R, Kemka F X, Kamanyi A, Kamtchouing P and Watcho P. 2017. The methanolic extract of *Guibourtia tessmannii* (Caesalpiniaceae) improves sexual parameters in high fat diet-induced obese sexually sluggish rats. *Asian Pacific Journal of Reproduction* **6**(5): 202.

El Ghazzawy I F, Meleis A E, Farghaly E F and Solaiman A. 2011. Histological study of the possible protective effect of pomegranate juice on bisphenol-A induced changes of the caput epididymal epithelium and sperms of adult albino rats. *Alexandria Journal of Medicine* **47**(2): 125–37.

El-Nattat W S and El-Kady R I. 2007. Effect of different medicinal plant seeds residues on the nutritional and reproductive performance of adult male rabbits. *International Journal of Agriculture and Biology* **9**: 479–85.

El-Sheshtawy R I, Gamal A and El-Nattat W S. 2016. Effects of pomegranate juice in Tris-based extender on cattle semen quality after chilling and cryopreservation. *Asian Pacific Journal of Reproduction* **5**(4): 335–39.

Enciso M, Cisale H, Johnston S D, Sarasa J, Fernández J L and Gosálvez J. 2011. Major morphological sperm abnormalities in the bull are related to sperm DNA damage. *Theriogenology* **76**(1): 23–32.

Frydrychova S, Opletal L, Macáková K, Lustyková A, Rozkot M and Lipenský J. 2011. Effects of herbal preparation on libido and semen quality in boars. *Reproduction in Domestic Animals* **46**(4): 573–8.

Gadea J and Matas C. 2000. Sperm factors related to *in vitro* penetration of porcine oocytes. *Theriogenology* **54**(9): 1343–57.

Gangwar C, Kharche S D, Kumar Satish and Jindal S K. 2016. Cryopreservation of goat semen: Status and prospects. *Indian Journal of Small Ruminants* **22**(1): 1–10

Gangwar C, Kharche S D, Mishra A K, Saraswat S, Kumar N and Sikarwar A K. 2020. Effect of diluent sugars on capacitation status and acrosome reaction of spermatozoa in buck semen at refrigerated temperature. *Tropical Animal Health and Production* **52**: 3409–15.

Gangwar C, Kharche S D, Ranjan R, Kumar S, Goel A K, Jindal S K and Agarwal S K. 2015. Effect of vitamin C supplementation on freezability of Barbari buck semen. *Small Ruminant Research* **129**: 104–07.

Gangwar C, Mishra A K, Gururaj K, Kumar A, Kharche S D, Saraswat S, Kumar R and Ramachandran N. 2021. Semen quality and total microbial load: An association study in important Indian Goat breeds during different seasons. *Andrologia* **53**(4): 13995.

Gangwar C, Ranjan R, Kharche S D, Pourouchottamane R and Rai B. 2023. Success of artificial insemination in goats: An overview. *Indian Journal of Small Ruminants* **29**(1): 1–10

Gangwar C, Ranjan R, Kumar Satish, Karche S D, Goel A K, Ramachandran N and Jindal S K. 2014. Use of chelating agent for optimum post thaw quality of buck Semen. *Indian Journal of Animal Sciences* **84**(8): 839–41.

Gangwar C, Ravindra K, Kharche S D, Jindal S K, Chaudhary U B and Mishra A K. 2019. Effect of azolla supplementation in feed on semen freezability in bucks. *Indian Journal of Animal Sciences* **89**(4): 398–401.

Gangwar C, Saxena A, Patel A, Singh S P, Yadav S, Kumar R and Singh V. 2018. Effect of reduced glutathione supplementation on cryopreservation induced sperm cryoinjuries in Murrah bull semen. *Animal Reproduction Science* **192**: 171–8.

Gauthaman K and Ganesan A P. 2008. The hormonal effects of *Tribulus terrestris* and its role in the management of male erectile dysfunction–An evaluation using primates, rabbit and rat. *Phytomedicine* **15**(1-2): 44–54.

Gupta V K and Sharma S K. 2006. Plants as natural antioxidants. *Natural Product Radiance* **5**: 326–34.

Haeri S, Minaie B, Amin G, Nikfar S, Khorasani R, Esmaily H, Salehnia A and Abdollahi M. 2006. Effect of *Satureja khuzestanica* essential oil on male rat fertility. *Fitoterapia* **77**(7-8): 495–99.

Hanafi E M, Raouf A A, Kassem S S, Abdel-Kader M M and Elkadrawy H H. 2010. A novel herbal remedy to alleviate drawbacks of heat stress in rats with special references to some reproductive and molecular alterations. *Global Journal of Biotechnology and Biochemistry* **5**(3): 145–52.

Holstein A F, Schulze W and Davidoff M. 2003. Understanding spermatogenesis is a prerequisite for treatment. *Reproductive Biology and Endocrinology* **1**(1): 1–6.

Hu J H, Zan L S, Zhao X L, Li Q W, Jiang Z L, Li Y K and Li X. 2010. Effects of trehalose supplementation on semen quality and oxidative stress variables in frozen-thawed bovine semen. *Journal of Animal Science* **88**(5): 1657–62.

Huynh P N, Hikim A P, Wang C, Stefonovic K, Lue Y H, Leung A, Atienza V, Baravarian S, Reutrakul V and Swerdloff R S. 2000. Long-term effects of triptolide on spermatogenesis, epididymal sperm function, and fertility in male rats. *Journal of Andrology* **21**(5): 689–99.

İnanç M E, Çil B, Yeni D, Avdatek F, Orakçı D, Tuncer P B, Türkmen R and Taşdemir U. 2019. The effect of green tea extract supplementation in bull semen cryopreservation. *Kafkas Universitesi Veteriner Fakultesi Dergisi* **25**(5): 703–08.

Khaki A R, Fathiazad F, Ahmadi-Ashtiani H R, Rastgar H and Rezazadeh S. 2009. Effects of *Danae racemosa* on spermatogenesis in rat. *Journal of Medicinal Plants* **8**(31): 87–92.

Khaki A, Fathiazad F, Nouri M, Afshin Khaki A, Ozanci C C, Ghafari-Novin M and Hamadeh M. 2009. The effects of Ginger on spermatogenesis and sperm parameters of rat. *International Journal of Reproductive BioMedicine* **7**(1): 7–12.

Khaki A, Ouladsahebmadarek E, Javadi L, Farzadi L, Fathiazad F and Nouri M. 2011. Anti-oxidative effects of citro flavonoids on spermatogenesis in rat. *African Journal of Pharmacy and Pharmacology* **5**(6): 721–5.

Khalifa A W, El-Sisy G A, El-Nattat W S, Mourad A A and Maghraby N. 2018. Effect of water extract of dates palm (*Phoenix dactylifera*) on semen characteristics and oxidative status in serum of male New Zealand rabbits under heat stress. *Asian Pacific Journal of Reproduction* **7**(1): 22–26.

Khan H, Khan M, Qureshi MS, Shakoor A, Gohar A, Ullah H, Hussain A, Khatri P, Shah S S, Rehman H and Khan A. 2017. Effect of green tea extract (*Camellia sinensis*) on fertility indicators of post-thawed bull spermatozoa. *Pakistan Journal of Zoology* **49**(4): 1243–49.

Kiasalari Z, Khalili M and Aghaei M. 2009. Effect of *Withania somnifera* on levels of sex hormones in the diabetic male rats. *International Journal of Reproductive BioMedicine* **7**(4): 163–68.

Kumaresan G, Gangwar C, Mishra A K, Kumar A, Kharche S D, Singh N P and Pachoori A. 2022. Occurrence, molecular characterization and antimicrobial-resistance pattern of *Staphylococcus* species isolates from buck semen. *Archives of Microbiology* **204**(2): 135.

Low B S, Das P K and Chan K L. 2013. Standardized quassinoid-rich *Eurycoma longifolia* extract improved spermatogenesis

and fertility in male rats via the hypothalamic–pituitary–gonadal axis. *Journal of Ethnopharmacology* **145**(3):706–14.

Malo C, Gil L, Cano R, González N and Luño V. 2012. Fennel (*Foeniculum vulgare*) provides antioxidant protection for boar semen cryopreservation. *Andrologia* **44**: 710–15.

Malo C, Gil L, Cano R, Martínez F and Galé I. 2011. Antioxidant effect of rosemary (*Rosmarinus officinalis*) on boar epididymal spermatozoa during cryopreservation. *Theriogenology* **75**(9): 1735–41.

Maneesh M and Jayalekshmi H. 2006. Role of reactive oxygen species and antioxidants on pathophysiology of male reproduction. *Indian Journal of Clinical Biochemistry* **21**(2): 80–89.

Mascaró F, Gil L, Malo C, González N, Martínez F and de Blas I. 2016. Effect of pasteurized egg and *Rosmarinus officinalis* supplementation on quality of cryopreserved ram semen. *Cryoletters* **37**(4): 422–31.

Mazaheri M, Shahdadi V and Boron A N. 2014. Molecular and biochemical effect of alcoholic extract of *Alpinia galanga* on rat spermatogenesis process. *Iranian Journal of Reproductive Medicine* **12**(11): 765–70.

Mehdipour M, Kia H D, Najafi A, Dodaran H V and García-Álvarez O. 2016. Effect of green tea (*Camellia sinensis*) extract and pre-freezing equilibration time on the post-thawing quality of ram semen cryopreserved in a soybean lecithin-based extender. *Cryobiology* **73**(3): 297–303.

Misro M M, Choudhury L, Upreti K, Gautam D, Chaki S P, Mahajan A S and Babbar R. 2004. Use of hydrogen peroxide to assess the sperm susceptibility to oxidative stress in subjects presenting a normal semen profile. *International Journal of Andrology* **27**(2): 82–87.

Morakinyo A O, Adeniyi O S and Arikawe A P. 2008. Effects of *Zingiber officinale* on reproductive functions in the male rat. *African Journal of biomedical research* **11**(3): 329–34.

Muthu K A and Sharma P. 2011. Molecular and morphological characters: An appurtenance for antagonism in *Trichoderma* spp. *African Journal of Biotechnology* **10**(22): 4532–43.

Naghdi M, Maghbool M, Seifalah-Zade M, Mahaldashtian M, Makoolati Z, Kouhpayeh S A, Ghasemi A and Fereydouni N. 2016. Effects of common fig (*Ficus carica*) leaf extracts on sperm parameters and testis of mice intoxicated with formaldehyde. *Evidence-Based Complementary and Alternative Medicine*.

Nagulendran K R, Velavan S, Mahesh R and Begum V H. 2007. *In vitro* antioxidant activity and total polyphenolic content of *Cyperus rotundus* rhizomes. *E-journal of Chemistry* **4**(3): 440–49.

Nouri M, Khaki A, Fathiazar F and Rashidi M R. 2009. The protective effects of carrot seed extract on spermatogenesis and cauda epididymal sperm reserves in gentamicin treated rats *Yakhteh Medical Journal* **11**: 327–33.

Ohsugi M, Fan W, Hase K, Xiong Q, Tezuka Y, Komatsu K, Namba T, Saitoh T, Tazawa K and Kadota S. 1999. Active-oxygen scavenging activity of traditional nourishing-tonic herbal medicines and active constituents of *Rhodiola sacra*. *Journal of Ethnopharmacology* **67**(1): 111–9.

Oloye A A, Ola-Davies O E, Ajayi O L, Oyeyemi M O, Olurode S A and Emikpe B O. 2017. Spermiogram and testicular morphological studies of the buck after treatment with ethanol leaf extract of *Spondias mombin*. *Sokoto Journal of Veterinary Sciences* **15**(1): 72–76.

Olugbenga O M, Olukole S G, Adeoye A T and Adejoke A D. 2011. Semen characteristics and sperm morphological studies of the West African Dwarf Buck treated with Aloe vera gel extract. *Iranian Journal of Reproductive Medicine* **9**(2): 83–88.

Patel D K, Chaudhari C F, Modi L C, Chaudhari N F, Chaudhary M M, Tyagi K K and Kunvar S V. 2022. Effect of different egg yolk levels in tris extender with and without aloe vera and onion crude extracts on surti buck semen at refrigerated temperature. *Indian Journal of Veterinary Sciences and Biotechnology* **18**(4): 44–49.

Patel S K, Singh S, Singh H K and Singh S K. 2017. Effect of standardized extract of *Bacopa monnieri* (CDRI-08) on testicular functions in adult male mice. *Journal of Ethnopharmacology* **197**: 101–09.

Patil R B, Vora S R and Pillai M M. 2009. Antioxidant effect of plant extracts on phospholipids levels in oxidatively stressed male reproductive organs in mice. *International Journal of Reproductive BioMedicine* **7**(1): 35–39.

Pour S S, Pirestani A, Alirezai M and Shafiyei K. 2015. The effect of adding different levels of aqueous extract of *Tribulus terrestris* in the extender on sperm motility Afshari rams at 5 C. *Journal of Chemical and Pharmaceutical Research* **7**(4): 957–59.

Rabbani S I, Devi K and Khanam S. 2010. Effect of rosiglitazone on the nicotinamide-streptozotocin induced type-2 diabetes mellitus mediated defects in sperm abnormalities and oxidative defense system in male Wistar rats. *Acta Pharmaceutica Sciencia* **52**(2): 121–28.

Raji Y, Gbadegesin M A, Osonuga O A, Rahmat A A, Akinsomisoye O S, Awobajo F O, Kunle-Alabi O T, Esegbue P R, Osonuga I O and Lamidi A F. 2006. Reproductive, Hematological and Biochemical profiles of male rats treated with aqueous extract of *Spondias mombin* bark. *International Journal of Pharmacology* **2**(1): 126–30.

Reddy N S, Mohanarao G J and Atreja S K. 2010. Effects of adding taurine and trehalose to a tris-based egg yolk extender on buffalo (*Bubalus bubalis*) sperm quality following cryopreservation. *Animal Reproduction Science* **119**(3-4): 183–90.

Rodriguez-Martinez H. 2003. Laboratory semen assessment and prediction of fertility: Still utopia? *Reproduction in Domestic Animals* **38**(4): 312–18.

Rodríguez-Martínez H. 2006. Can we increase the estimative value of semen assessment? *Reproduction in Domestic Animals* **41**(2): 2–10.

Rowe M P, Powell J G, Kegley E B, Lester T D, Williams C L, Page R J and Rorie R W. 2013. Influence of organic versus inorganic trace mineral supplementation on bull semen quality. *AAES Research Series* **597**: 11–13.

Sahoo H B, Nandy S, Senapati A K, Sarangi S P and Sahoo S K. 2014. Aphrodisiac activity of polyherbal formulation in experimental models on male rats. *Pharmacognosy Research* **6**(2): 120–26.

Saleh H, Jafarikukhdan A, Hosseini A and Armand R. 2015. The application of medicinal plants in traditional and modern medicine: A review of *Thymus vulgaris*. *International Journal of Clinical Medicine* **6**(9): 635–42.

Saleh R A and Agarwal A. 2002. Oxidative stress and male infertility: from research bench to clinical practice. *Journal of Andrology* **23**(6): 737–52.

Samotyja U and Małecka M. 2010. Antioxidant activity of blackcurrant seeds extract and rosemary extracts in soybean oil. *European Journal of Lipid Science and Technology* **112**(12): 1331–36.

Sawyer D E. Roman S D and Aitken R J. 2001. Relative

susceptibilities of mitochondrial and nuclear DNA to damage induced by hydrogen peroxide in two mouse germ cell lines. *Redox Report* **6**(3): 182–84.

Sen S, Chakraborty R, Sridhar C, Reddy Y S R and De B. 2010. Free radicals, antioxidants, diseases and phytomedicines: Current status and future prospect. *International Journal of Pharmaceutical Sciences Review and Research* **3**(1): 91–100.

Shaik A, Yalavarthi P R and Bannoth C K. 2017. Role of Anti-fertility medicinal plants on male and female reproduction. *Journal of Complementary and Alternative Medicine* **3**: 1–22.

Sharma P, Huq A U and Singh R. 2013. Cypermethrin induced reproductive toxicity in male Wistar rats: Protective role of *Tribulus terrestris*. *Journal of Environmental Biology* **34**(5): 857–62.

Sharma V, Thakur M and Dixit V K. 2012. A comparative study of ethanolic extracts of *Pedalium murex* Linn. fruits and sildenafil citrate on sexual behaviors and serum testosterone level in male rats during and after treatment. *Journal of Ethnopharmacology* **143**(1): 201–06.

Shittu Lukeman A J, Shittu Remilekun K, Adesite Samson O, Ajala Oluwole M, Bankole Munir A, Benebo Benebo A S, Tayo A O, Ogundipe Olufemi A and Ashiru Oladapo A. 2008. Sesame radiatum phytoestrogens stimulate spermatogenic activity and improve sperm quality in adult male Sprague Dawley rat testis. *International Journal of Morphology* **26**(3): 643–52.

Singh S, Nair V and Gupta Y K. 2012. Evaluation of the aphrodisiac activity of *Tribulus terrestris* Linn. in sexually sluggish male albino rats. *Journal of Pharmacology & Pharmacotherapeutics* **3**(1): 43–47.

Suresh S, Prithiviraj E and Prakash S. 2009. Dose-and time-dependent effects of ethanolic extract of *Mucuna pruriens* Linn. seed on sexual behaviour of normal male rats. *Journal of Ethnopharmacology* **122**(3): 497–501.

Thakur M, Chauhan N S, Sharma V, Dixit V K and Bhargava S. 2012. Effect of *Curculigo orchioides* on hyperglycemia-induced oligospermia and sexual dysfunction in male rats. *International Journal of Impotence Research* **24**(1): 31–37.

Tsai H W, Chen J C, Yeh K Y, Tai M Y and Tsai Y F. 2009. Male sexual behavior and brain catecholamine levels in middle-aged rats. *Chinese Journal of Physiology* **52**(4): 215–22.

Vahedi V, Hedayat Evrigh N, Behroozlak M and Dirandeh E. 2018. Antioxidant effects of Thyme (*Thymus vulgaris*) extract on ram sperm quality during cryopreservation. *Iranian Journal of Applied Animal Science* **8**(2): 263–69.

Varsha S Z, Dabhadkar D K, Thakare V G and Pare S R. 2013. Effect of aqueous extract of *Moringa oleifera* seed on sexual activity of male albino rats. *Biological Forum – An International Journal* **5**(1): 129–40.

Watcho P, Watio H M, Wankeu-Nya M, Ngadjui E, Defo P D, Nkeng-Efouet P A, Nguelefack T B and Kamanyi A. 2017. Androgenic effects of aqueous and methanolic extracts of *Ficus asperifolia* in male Wistar rats. *BMC Complementary and Alternative Medicine* **17**(1): 42.

Wen F, Li Y, Feng T, Du Y, Ren F, Zhang L, Han N, Ma S, Li F, Wang P and Hu J. 2019. Grape seed procyanidin extract (GSPE) improves goat sperm quality when preserved at 4°C. *Animals* **9**(10): 810.

Yang W M, Kim H Y, Park S Y, Kim H M, Chang M S and Park S K. 2010. *Cynomorium songaricum* induces spermatogenesis with glial cell-derived neurotrophic factor (GDNF) enhancement in rat testes. *Journal of Ethnopharmacology* **128**(3): 693–96.

Zhao H W, Li Q W, Ning G Z, Han Z S, Jiang Z L and Duan Y F. 2009. *Rhodiola sacra* aqueous extract (RSAE) improves biochemical and sperm characteristics in cryopreserved boar semen. *Theriogenology* **71**(5): 849–57.

Zhong R Z and Zhou D W. 2013. Oxidative stress and role of natural plant derived antioxidants in animal reproduction. *Journal of Integrative Agriculture* **12**(10): 1826–38.