

Musk-Deer in Wildlife Crime: A Forensic Approach

Mithilesh Jha¹, AK Jaiswal²

Abstract

An attempt has been made to present the scientific study related with identification of wildlife crime exhibits derived from Musk deer (Scheduled animal). Musk pod is one of the common wildlife crime exhibits. International as well as domestic regulations prescribe very serious provisions for this endangered species. To meet worldwide huge demand of musk for perfumery & medicinal purposes, it has been used illegally in trade. Several seizures have been made by one or other enforcement agencies under certain laws & legislations. An illegal shipment of Chinese musk from the musk deer was seized in Japan in 1987, an amount corresponding to approximately 100,000 deer killed. Species identification from the seized suspected contraband exhibits is necessary for further proceedings & prosecution. The article summarizes the identification techniques of derivatives of this endangered fauna, which will be helpful for the enforcement agencies and related scientific society. The present article focuses on the morphological identification, chemical examination including Gas-chromatographic method & microscopic findings in derivative of musk deer (*Moschus* spp.).

Keywords: Musk Deer Cites; WI (P) Act; Forensic; Identification; Musk Deer; Musk Pod; Hair Examination; Gas Chromatography; Wildlife Crime etc.

Introduction

'Kasturi mriga' is well known deer for its unique scent producing gland that yields Musk (Kasturi). Normal life span of Musk deer is of 12-20 years [32], but they are killed before they attain normal life-span for their quality 'musk'. Musk is a substance with a stringent and pleasant smell obtained from a gland of the male musk deer (*Moschus* spp.). Literally, the name of 'musk' i.e., a Sanskrit word meant for 'testicles', has come to encompass a wide variety of substances with somewhat similar odour, which include glandular secretions of from animals other than that of musk deer, numerous plant emitting similar fragrances & artificial substances with some odors. In fact, Musk is a secretion used by adult males for scent-marking. Highly valued for its scent, fixative, and medicinal properties, musk has been used in traditional medicines and perfumery from as far back as 3,500 BC [30]. Traditionally it is obtained by killing the animal

and removing the musk gland, depicted here, but musk can be milked from live males, as practiced in Chinese musk deer farms. The perfumer uses musk principally in the scenting of soap, sachet powder & in making for liquid perfumery.

Flower (1875) [8] and Heptner & Naumov (1961) [13] classified the species in the family Cervidae, but presently a majority of scientists place the species in the separate family, the Moschidae (Brooke (1878) [2] Flerov (1952) [7] Groves & Grubb (1987) [12] & Whitehead, (1972) [34]). The systematic position of the musk deer is given in table 1.

Table 1: Position of Musk deer in biological world

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Artiodactyla
Sub-order	Ruminantia

Author's Affiliation: ¹SSA (Serology), Central Forensic Science Laboratory, (CBI) New Delhi, Delhi 110003, India. ²Chemist, Dept. of Forensic Medicine & Toxicology, All India Institute of Medical Science, New Delhi, Delhi 110029, India.

Correspondence and Reprint Requests: AK Jaiswal, Chemist, Dept. of Forensic Medicine & Toxicology, All India Institute of Medical Science, New Delhi, Delhi 110029, India.

E-mail: ashokjaiswal72@gmail.com

Infra-order	Pecora
Family	Cervidae
Genus	<i>Moschus</i>
Species	<i>M. moschiferus</i> , <i>M. berezovskii</i> , <i>M. fuscus</i> & <i>M. chrysogastr</i>

Musk deer which comprise of one of the most endangered deer species are found not only in the Indian subcontinent, but also in the whole world. An accepted agreement for the distribution of four sub species has been made (Table 2) as follows.

Table 2: Distribution of sub-species

Sl. No.	Species	Distribution [10]
1	Himalayan Musk Deer (<i>Moschus chrysogaster</i>)	Afghanistan, China, India, Nepal, & Pakistan
2	Black Musk Deer (<i>Moschus fuscus</i>)	Bhutan, China, India, Nepal, & Pakistan
3	Siberian Musk Deer (<i>Moschus moschiferus</i>)	Russia, Kazakhstan, China, Korea & Mangolia
4	Dwarf Musk Deer (<i>Moschus berezovskii</i>)	China & Vietnam

Legislations for the Protection of Musk Deer

Protective measures for the endangered population of musk deer ranges from International regulations like IUCN (International Union for Conservation of Nature and Natural Resources), CITES (Convention on International Trade of Endangered Species of Flora & Fauna) to domestic regulations like Wildlife (Protection) Act, 1972 of Govt. of India. IUCN includes this species of deer as threatened for extinction¹⁶

Table 3: Protective measures for Musk deer

Species	IUCN15	CITES3	WL(P) Act,197235
Himalayan Musk Deer (<i>Moschus chrysogaster</i>)	Lower Risk	Appendix II (1979)*	Schedule-I
Black Musk Deer (<i>Moschus fuscus</i>)	Lower Risk	Appendix II (1979)*	-
Siberian Musk Deer (<i>Moschus moschiferus</i>)	Vulnerable	Appendix II (1979)*	-
Dwarf Musk Deer (<i>Moschus berezovskii</i>)	Lower Risk	Appendix II (1979)*	-

* All species of musk deer are listed in Cites Appendix II except Himalayan populations of Afghanistan, Bhutan, India, Myanmar, Nepal, & Pakistan which are listed in Appendix-I of Cites (1983)

Physical features of Musk deer

The major physical features of the animal have been given in table 4. Overall coloration of Musk deer varies from a light yellowish to almost black. A dark brown is most common. The head is generally lighter. A pair of whitish stripes extends from the chin down the chest to the belly. A scattering of lighter spotted may be present on the back & sides. Young are born intensely white spotted on their upper body and they attain the adult Colouration by the age one and half years. This species of deer does not have Antlers; however the sharp upper canines of male grow very long measuring about [10] centimeter and project well below the chin in older individuals. These weapons are used in displays and fights between males; performing a similar function to the antlers of true deer.

Canine of female musk deer is not visible. The tail is very small and is often hidden in thick, bristly, pithy hair coat [27]. A fully mature male deer bears a "Musk pod" between the genitalia & umbilicus, which release a strong smelling, dark brown semi fluid substance for attraction of females during the onset of the rut. The active chemical constituent of musk pod is known as Muscone, which has well known use in perfumes or in medicines or as aphrodisiacs and fertility drugs [31].

Table 4: Physical features of an adult Musk deer\

Sl.No	Features	Range
1	Body length	86-100 cm
2	Shoulder Height	52-55 cm
3	Tail length	4-6 cm
4	Weight	13-18 kg.

Musk secretion in Musk deer

The Musk synthesis is probably regulated by androgens from the testes, as castrated males produce a negligible amount [24]. From the age of 12 to 18 months, musk is secreted from a single layer of columnar epithelial cells that lines the vesicles of the gland. The inner wall of the musk sac is lined with thirty or more keratinized layers of epithelium that slough and become mixed with musk³⁰. Musk takes about thirty days or even more to mature in the sac where it changes from being creamy white and pasty (with no remarkable scent into a powerful scented, granular, dark reddish-brown substance. Musk gets synthesized seasonally, prior to the rut and may influence oestrus cycling.

Chemical constituent of Musk pod

Musk yields by distillation with steam and subsequent purification a small percentage of viscid colorless oil with a very powerful and agreeable odour of musk, this oil appears to be ketone and is termed as Muscone [22]. The granules of musk contain moisture, fatty acids, resins, proteins and inorganic substances. Musk-contents are more water soluble in comparison to alcohol. Studies suggest that water can dissolve musk grain about from 50-75% but in alcohol only 10-12%. It should not contain more than 15% of moisture or yield on incineration more than 8% of ash. The odorous component of musk is muscone which is 0.5-2.0% of musk [26]. It consists of a 15-membered ring ketone with one methyl substituent in the 3-position.

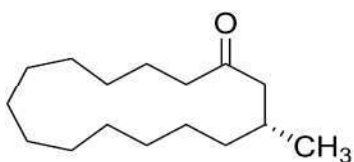


Fig. 1: Muscone (3-Methylcyclopentadecanone)



Fig. 2: A Musk Pod



Fig. 3: Dried Musk Grains librated from musk pod

Figure 1: <https://en.wikipedia.org/wiki/Muscone>
 Photograph1: https://upload.wikimedia.org/wikipedia/commons/c/c7/Moschus_chrysogaster.jpg
 Photograph 2 & 3: Wildlife Crime Control Bureau (ER) Kolkata

Musk deer in Illegal trade

Musk deer are not hunted for meat and fur skin but they are killed primarily for trade of musk glands. The musk pod is highly valued for its cosmetic and alleged pharmaceutical properties, and can fetch U.S. \$ 45,000 per kilogram¹⁰ on the international market. Musk is used for medicinal purposes mostly but perfume industry is also important sector where this derivative is in heavy demand and expansive. In Hong-Kong, the International centre for musk (despite a ban on imports), musk is valued at US\$ 50,000 per kilogram, while its value in India is four times its weight in gold [39]. Although this musk, produced in a gland of the males, can be extracted from live animals, most "musk-gatherers" kill the animals to remove the entire sac, which yields only about 25 grams (1/40 of a kilogram) of the brown waxy substance. Such poaching is relatively easy to accomplish and difficult to stop. The clandestine use of derivative of musk deer is achieved in the following steps [32].

- A. The deer is hunted by various methods.
- B. The musk gland of the killed deer is removed.
- C. Musk pod is dried either in direct sunlight, on a hot stone (this is the best way, no singing of hairs occur), or by immersion in hot oil (quality of musk is affected adversely, as it gets either completely baked or fried) [29].
- D. On drying, the reddish-brown paste turns into a black granular matter called "musk grain", which is used for alcoholic solutions.

- E. The fragrance of the tincture becomes more stringent during storage and gives a pleasant odor only after it is considerably diluted.

Use of Musk pod

Use of Musk can be traced back to the Tang dynasty in China in the eighth century. The cosmetic industry uses more than 900 types of artificially synthesized musk, but only 30 are economically important [14]. The use of musk in medicine was recorded by Aetius, the Greek Physician, in Circa 520 AD. [11,28]. In China and India Musk has been considered a superior medicine since the fifth century AD. According to Pharmacopoeia of the People's Republic of China, musk can revive unconscious patients, stimulate circulation of vital energy and blood and it also possesses anti-inflammatory- analgesic effects. It has been used in the treatment of delirium, stroke, and unconsciousness and miscarriage, ejection of stillborn fetus, acute angina pectoris, acute abdominal pain, skin infection, sore throat, sprained joints, trauma and paralysis [28]. There are 398 patented Chinese medicines using musk as ingredients. In India and Nepal musk is used in Ayurvedic medicine as a stimulant to cure bronchitis, pneumonia, impotence, typhoid, typhus and as a sedative to treat asthma, epilepsy, hysteria and other nervous disorders. As anti-inflammatory agent, Musk is a more effective antidote for snake venom than hydrocortisone. In Japan, both 'Stamina' drinks and children's tonic are made from plant and animal derivatives, of which the most important is musk [9].

Forensic Examination of Musk pod

There is heavy demand of musk pod in the international market due to various alleged properties and high costs. For meeting this huge demand, Musk deer are hunted by various methods. As such, not only musk-pod containing males are killed but even younger and female individuals (having no musk pod) are being killed. The original musk pod obtained from male are mixed with fake musk pod which are made by putting some extraneous similar grains and small portion of musk granules (to impart the musky odour) in small part of cut skin of musk deer. Sometimes, illegal traders cut the young pods, containing no musk at all and fill them with the liver and blood of the animal, mixed with a small portion of genuine musk, fill and sew them up in the skin and dry on hot stove [29]. In such a situation forensic examination is an

ultimate need to identify the species from suspected exhibit. Such forensic examinations may range from morphological comparison with standard one including shape, size, weight, colouration and pattern of hair to chemical examination of musk grains / materials of the questioned pods. Microscopic analysis of the fur of the skin portion gives a landmark decision in ascertaining the pod being genuine and derived from Musk deer. However DNA fingerprinting may be of immense use but need a lot of sophistication, skill and standard data.

(A) Physical examination

(1) *Smell*: Normally, the musk has a remarkable diffusive and subtle scent that is characteristic of its own. Everything in its vicinity soon becomes affected by it, and long retains its odour, although not in actual contact with it. For this, the East India Company ordered that no musk be brought in the same ship with tea [29]. It has been reported that the musk of young musk deer has no as strong as of older ones. Also, difference of food, climate or situation has no impact on quality of musk.

(2) *Shape & Size of Musk pod*: The musk pods are spherical to pyriform in shape. Size of the pod varies according to species, age of Musk deer and the season in which the pods are collected. Normally they are 3-7 centimeter in diameter; 2-4 centimeter deep [6]. The amount of water contained in natural musk varies according to time of year, local environment, food, the way the musk is handled after it is collected and how long it has been stored. Musk collected in summer (Summer Musk) is moist and contains 52-57% water and Musk collected in winter (winter musk) contains 28-30% water [38]. A male musk deer of poorer physical condition secretes musk that is only 41-46% of the musk secreted by a healthy male musk deer [37], although sometimes it will secrete no musk [36].

(3) *Weight of Musk pod*: The weight of musk pod and the amount of musk obtained from a single musk pod vary. A musk pod may weigh between 10-15 gram although as much as 50 gm. The percentage of musk grain to weight musk pods reportedly varied from 44% [28] to around 50% [33]. In the 1990s; the medicinal companies calculate the weight of musk grain (W) obtained from musk pods using the following formula. Accordingly, 100 gm of Musk pods would yield 64 gm. of dry musk grain [36].

$W = \text{Wt. of Musk pod} \times 80 \% (\text{ for shell pod}) \times 80 \% (\text{ for water in musk})$

(4) *Musk grains*: The musk grains are of irregular shape, but generally round or oblong, a dark reddish-brown colour, but when taken out of the pod and kept for any length of time, becomes nearly black [29]. In autumn and winter the grains are firm, hard and nearly dry, but in summer they become damp and soft, probably the green foods the animals then eat.

(5) *Colouration of hair on Musk Pod*: As musk pod belongs to abdominal region of the animal, it shows white dominant colour with slight yellow-black shade. The tendency of hair is also peculiar, if it is not chopped.

(B) Chemical examination

(1) *Solubility test*: Water can dissolve from 50-75% of musk grains but alcohol only 10-12%. It should not contain more than 15% of moisture.

(2) *Gas Liquid Chromatography*: It is an efficient technique involves a sample being vaporized and injected onto the head of the Chromatographic column. The sample is transported through the column by the flow of inert, gaseous mobile phase. The column itself contains a liquid stationary phase which is adsorbed onto the surface of an inert solid. The technique has been found suitable for the accurate L-muscone assay [25].

a. *Extraction of sample*: Prior to chromatographic analysis, it is essential to extract L-muscone from complex of aqueous matrix. Solvent extraction technique 40 and Solid phase extraction (SPE) methods using a suitable solid sorbent 17-20 have been reported to be employed for extraction of the L-muscone. Of the two extraction methods, SPE provides highly purified extracts with excellent precision & satisfactory recovery & offers the possibility of automation [5].

b. *GC Condition: DB-5MS fused*: silica capillary column (15m×250 μm I.D., 0.25 μm film thickness), initially at 80°C for 2 min, raised to 190°C at a rate of 30°C /min and to 210°C at 10°C /min. and finally at 30°C /min to 300°C (3 min): 1.0 μL sample injected in the pulsed splitless injection mode (purge delay time 42 sec); Helium as carrier gas at 0.8 ml/min in constant flow mode; injector and detector temperatures at 260°C & 300°C, respectively. Retention time-7.6 min for Cyclopentadecanone (Internal Standard) & 7.8 min for L-muscone [25].

(3) *Gas chromatography*: Mass spectrometry Analysis: It is particularly suitable for separating

complex organic chemical mixtures into separate components & identifying them. The technique was applied by Lin, Chang & Huang (2004) [22] for Musk deer derivatives & they acquired full-scan mass-spectrometric data for the m/z 50-500 range. They reported the Selective Ion Monitoring (SIM) data with m/z 238, 223 & 209 for Muscone; m/z- 231, 120 & 107 for Muscopyridine & m/z- 234, 280 & 193 for Imipramine.

Condition: A Hewlett-Packard 5890 gas chromatograph/5972 mass selective detector (GC-MSD) equipped with HP-G1034C Chemstation software for study. The GC was equipped with a 12-m Hewlett-Packard (Andover, MA) HP Ultra-1 (100% dimethylpolysiloxane phase) fused silica capillary column (0.20 mm ID; 0.33 μm film thickness). The injector & interface temperature were maintained at 260 & 280°C, respectively. Oven temperature was held at 100°C for 1 minute, then programmed to 280°C at 20°C/minute, and held at the final temperature for 10 minutes. They used sample size of 3 μL, splitless injection mode & 0.75 minute as injector purging off duration.

(C) Biological examination

Besides coloration of hairs on musk pod as described in physical examinations, it is necessary to analyze the hair [21] for its microstructure under light microscope. It possess very coarse overall diameter, medulla composed of spherical cells that occupy entire hair. Diameter of the hair is constant in most part of the hair with characteristics wineglass-shaped root [4].

Anwar et al has reported seven hair characteristics viz., (i) average number of scales across mid-shaft region-14 (range 13-16) (ii) average scale diameter (μ)- 3.5 (range 3-5) (iii) diameter of hair at mid-shaft region (μ)-50 (iv) medulla diameter (μ)-28 (v) cuticular patterns- flattened (vi) medulla patterns-latticed and (vii) pigmentation in cortex-Transparent [42].

These characteristics may be utilized as reference keys which are based on studies of guard hair samples collected from the abdominal region of the musk deer. Further, Serological Examinations of exhibits either by Precipitin method and or Agar-gel diffusion method may be adopted for species determination, provided species specific antisera is made available. DNA-profiling of seized suspected musk pod material (as suggested by Malik et al) 41 will be of very useful if lab is equipped and standard database is available for the same.

Conclusion

In addition to zoological studies, forensic identification techniques related with wildlife crime exhibits are demand of time. Species determination from Suspected Musk becomes essential and for such identification, the exhibits should be subjected forensic analyses. Suspected musk pod can be identified by morphological, microscopic examination of hair, chemical examinations followed by instrumental techniques. For this, a comprehensive physical, biological and chemical analysis should be adopted for furnishing scientific opinion related with such wildlife crime exhibits. Enforcement agencies should also be sensitized for preliminary identification of such crime exhibits. Forensic Science Laboratories should also be equipped and standardized for examinations of such wildlife crime exhibits. With adaptation of comprehensive approach of forensic identification of musk-pod, not only the offenders will be prosecuted but such endangered fauna may remain conserved in natural habitat.

Reference

- Arora RB, Seth SDS, Somani P. Effectiveness of Musk (Kasturi), an indigenous drug against *Echis curinatus* (the saw - scaled viper) envenomation. *Life Sci.* 1962;9:453-57.
- Brooke V. On the classification of the Cervidae, with a synopsis of the existing species. *Proceedings of the Zoological Society of London*, 1878. pp.883-928.
- Convention on International Trade of Endangered Species of flora & fauna (2009)
- Deedrick Douglas W. & Koch Sandra L. *Microscopy of Hair part II: A Practical Guide & Manual for Animal hairs*, Forensic Science Communication (July) 2004.
- Enoch P, Putzler A, Rinne D, & Schluter J. Automated solid-phase extraction on-line coupled to gas-chromatography. *J. Chromatogr. A.* 1998;822:75-82
- Feng W, You Y, Young H, Li G & Gu Q. A Histological Examination on the Musk Gland of *Moschus berezovskii* (in Chinese), *Journal of Zoology.* 1981;2:33-35.
- Flerov CC. Fauna of the USSR, Mammala: musk deer & deer. USSR Academy of Sciences, Moscow 1952;1(2).
- Flower WH. On the structure and affinities of the musk deer (*Moschus moschiferus*, Linn.) *Proceedings of the Zoological Society of London.* 1875. pp.159-90.
- Green MJB, Taylor R. The musk connection. *New Scientist.* 1986;26:56-58.
- Green MJB, Kattle B. Musk deer: Little understood, even its scent. *The First International Symposium on Endangered Species Used in Traditional East Asian Medicine: Substitute for Tiger Bone & Musk.* 1997 Dec 7-8; Hong-Kong.
- Green MJB. The Musk Trade, with Particular Reference to its Impact on the Himalayan Population of *Moschus chrysogaster*. Paper presented at the Bombay Natural History Society Centenary Seminar on Conservation in Developing Countries, IIT, Powai, Mumbai, 1983 Dec 6-10. pp-36
- Groves CP & Grubb P. Relationships of living deer. In Wemmer, C.M. (Ed.) *The Biology & Management of the Cervidae.* Smithsonian Institution Press, Washington DC, USA 1987. pp-21-59.
- Heptner VG & Naumov NP. *Mammals of the Soviet Union.* Vysshaya Shkola Publishers, Moscow, Russia. 1961.
- Homes V. On the Scent: Conserving Musk Deer-the Uses of Musk & Europe's Role in its trade. *TRAFFIC Europe*, Brussels, Belgium. 1999.
- International Union for Conservation of Nature & Natural resources (IUCN). *Red Data Book. Mammalia.* Int. Union for Conservation of Nature & Natural Resources. Morges, Switzerland.
- Jung MW, Ahn KH, Lee Y, Kim KP, Paeng IR, Rhee JS, Park JT, & Paeng KJ. Evaluation on the adsorption capabilities of new chemically modified polymeric adsorbents with protoporphyrin IX. *J. Chromatogr. A*, 2001;917:87-93.
- Kim KR, Paik MJ, Kim JH, Dong SW, & Jeong DH. Rapid gas chromatographic profiling & screening of biologically active amines. *J. Pharm. Biomed. Anal.* 1997;15:1309-1318.
- Kim KR, Park HG, Paik MJ, Ryu HS, Oh KS, Myung SW, & Liebich HM. Gas chromatographic profiling & pattern recognition analysis of urinary organic acids from uterine myoma patients & cervical cancer patients. *J. Chromatogr. B*, 1998;712:11-22.
- Kim KR, Shin YJ, Shim WH & Myung SW. Rapid gas chromatographic profiling & screening of acidic non steroidal anti-inflammatory drugs in biological samples. *Arch. Pharm. Res.* 1994;17(3):175-81.
- Laboratory Procedure Manual Forensic Biology. DFS, Ministry of Home Affairs, GOI, 2005. pp.22-28
- Lai JH. *Pharmacognosy.* Taipei: Chuang-I Press. 1976. pp-541.
- Lin Dong-Liang, Chang Hsien-Cheh & Huang Su-Hui. Characterization of Allegedly Musk containing Medicinal Products in Taiwan. *J Forensic Sci.*, 2004 Nov;49(6):1-7
- Macatney C. The deer with a fatal scent (A report originally written for World Wildlife Fund)

- Unasylva. 1983;35:18-19.
24. Paik Man-Jeong & Kim Kyoung-Rae, Arch Pharm Res (27-V). 2004.pp.539-543
 25. Parry EJ. Parry's Cyclopedia of Perfumes. J.A. Churchill, London, 1925;2:473-86.
 26. Parter S. The Book of Indian Animals. Bombay Natural History Soc., Oxford University Press, Bombay, 1993;20:295-96.
 27. Pereira J. The Elements of Materia Medica & Therapeutics, 4th Edition, II Longman, Bron, Green, Longmans & Roberts, London, U.K. 1985.
 28. Piesse GW. Septimus. The Art of Perfumery & Method of obtaining the Odours of Plants, 3rd edition, London 1962.pp.174-187.
 29. Shreshtha MN. Animal welfare in the musk deer. Applied Animal Behav Sc. 1998;59:245-50.
 30. Shrestha TK. Mammals of Nepal: With reference to those of India, Bangladesh, Bhutan & Pakistan. Tribhuavan University, Kathmandu. 1997.
 31. Ultimateungulate.com, National Geographic, IUCN Red List.
 32. Wallis TE. Textbook of Pharmacognosy. J & A Churchill, London, UK. 1951.
 33. Whitehead GK. Deer of the World. Constable and Company Ltd. London UK. 1972.
 34. Wildlife Protection Act, 1972 of GOI, 2009.
 35. Xu H, and Sheng H. Musk deer captive breeding programme: 15 years in Shanghai. Paper presented in Traditional East Asian Medicine: Substitute for Tiger Bone and Musk, Hong-Kong, 7-8 December, 1997.
 36. Yan Y. A Preliminary study on the Factors Affecting Musk Production in Siberian Musk deer. J of Chinese medicine materials. 1985;2:11-13.
 37. Zeng C. Determination on the Colour & Water Contents of Different Types of Musk (In Chinese). Zhongyaocai Keji. 1984;4:17-18
 38. Zhang B. Musk deer, their capture, domestication and care according to Chinese experience and methods. 1983;35:16-24.
 39. Zou QG and Su JJ. Quantitative analysis of muscone in shexiang baixin pills by gas chromatography. Zhongguo Yao Za Zhi. 1994 Jul;19(7):418-19.
 40. Malik et al. Optimization of DNA from Musk Deer (*Moschus chrysogaster*) Hair Follicle: extraction, PCR Amplification for discriminatory analysis of RAPD markers; International Journal of Biosciences. 2018;13(2):255-62.
 41. Anwar et al. A Photographic Key for the Identification of Mammalian Hairs of Prey Species in Snow Leopard (*Panthera uncia*) Habitats of Gilgit Baltistan Province of Pakistan. Pakistan J. Zool. 2012;44(3):737-43.
-