International Journal of Livestock Research, Vol. 15 (4) Apr' 2025
http://www.ijlr.org
eISSN: 2277-1964
NAAS Score:4.31

Original Research

Fundus Imaging With Smartphone in Pet and Farm Animals

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How to cite this paper
Basetty, S., Rambabu, K., Suresh Kumar, R. V., Anand Kumar, A., & Nageswara Reddy, B. (2025). Fundus Imaging With Smartphone in Pet and Farm Animals. *International Journal of Livestock Research*, *15*(4), 49–59.

Received : Feb 11, 2025
Accepted : Apr 04, 2025
Published : Apr 30, 2025

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Abstract

The present study was carried out to study the ocular fundus of pet and farm animals with a smartphone and a 20D Volk digital clear field lens mounted on self-made adaptor. It was found through the present study that the most common colour of tapetum and non-tapetum in dogs was green-blue and Black, respectively. In majority of dogs, the optic disc was White, triangular and located in non-tapetum. Yellow tapetum and Black non-tapetum were found in majority of cats. Their optic discGrey was , circular and located in tapetum. The common colour of tapetum and non-tapetum in white cattle was Yellow and Grey, respectively, while that of Buffaloes was Dark-Lavander blue and Grey respectively. All the large ruminants exhibited oval optic disc located at the junction of tapetum and non-tapetum. The common colour of optic disc was Black and Light red in white cattle and buffaloes, respectively. Greenish-blue tapetum, Reddish-grey non-tapetum, and Light red, Bean shaped optic disc present at junction of tapetum and non-tapetum were found in most of the sheep examined. Yellow-blue-green tapetum, Blue non-tapetum, and Bright red coloured Oval optic disc located in tapetum were found in majority of goat. Regarding retinal vasculature, the present study revealed that veins are lower in number and darker than arteries in all the animals.

Keywords: Fundus, Optic Disc, Smartphone, Tapetum.

Introduction

Animals depend on vision and hearing to live an active and healthy life. Routine eye examination plays a crucial role in maintaining good eye health, and early detection of diseases. The imaging of the fundus during the ophthalmological examination allows detection of not only the retinal diseases (posterior segmental affections) but also some systemic diseases (Visioli *et al.*, 2023). The fundus is the only location in the body where blood vessels and central nervous system can be seen directly. The fundus of each domestic animal species has a characteristic appearance that varies greatly among species and to a lesser extent among individuals of same species, however, fundic appearance varies very little between eyes of one individual, making diagnosis of unilateral fundic changes easier (Maggs *et al.*, 2017; Sini *et al.*, 2016).

Fundus imaging is traditionally performed by using a fundus camera in a clinical setting which is very costly, heavy, and immobile. It is important to search for easy and reliable tools of fundus imaging to conduct mass screening programs for eradicating hereditary eye disease (Alina *et al.*, 2008), and to examine the fundus of a large number of animals for understanding the normal appearance of fundus (Bulut *et al*., 2023).

Over the last decade, smartphone has progressively become integral part of people's personal and professional lives. The use of smartphone in medicine is increasing as it is versatile, compact, and easy to use. The smartphones' high-resolution cameras, large data storage capacities, ease of image capture and sharing have led to its widespread use in ophthalmology (Haddock and Quin, 2015; Ryan *et al.*, 2015). In smartphone-based fundus imaging, the coaxial flashlight of the smartphone camera and a strong, high-resolution lens form an ophthalmoscopy like system capable of recording digital fundus images (Khanamari *et al.*, 2017; Gomes and Ledbetter, 2019). Fundus imaging with smartphone is a potential tool for telemedicine and is inexpensive (Shanmugam *et al.*, 2014). The present study aimed at checking the feasibility of using smart phone for fundus imaging in pet and farm animals.

Materials and Methods

The present study was carried out at the Department of Veterinary Surgery and Radiology, College of Veterinary Science, Tirupati on a total of 98 adult animals of both pet (dog and cat) and farm (White cattle, buffalo, sheep and goat) categories. The research protocol was approved by institutional animal ethics committee of CVSc Tirupati wide reference number 281/Go/ReBi/S/2000/ CPCSEA/C.V.Sc/Tirupati.

The Realme 6 smart phone which had 64MP AI quad camera set up with LED flash and a 20D Volk digital clear field lens mounted on self-made adaptor were used for imaging of fundus in the present study (Figure 1). For making the adaptor, the inner surface of PVC pipe (50 mm diameter and 24 cm length) was tightly wrapped with matte black coloured sand paper (120 grit thicknesses) using fevikwik to avoid reflection of flash light. One end of the pipe was fixed with back cover of smartphone in such a manner that the space for the main camera of the phone present exactly at the center using fevikwik and the other end of pipe was fixed with 20D Volk lens using black tape (Figure 2).

Fig.1 Different materials used in the present study

Fig.2 Adaptor with phone and 20D lens

When an animal was selected for fundus imaging, basic ophthalmic examination was conducted to rule out any abnormalities which would restrict the induction of dilatation of pupil which was done by three consecutive topical installation of a fixed combination of one drop of Tropicamide (0.8%) and Phenylephrine (0.5%) (Maxdil Plus) with a gap of five minutes. After dilatation of pupil, the animal was taken to dark room for fundus imaging. The smartphone was attached to the adopter and positioned 3 to 10 cm distance from the eye for imaging of fundus. The Realme 6 smartphone was held in the right hand while imaging the fundus of left eye, and in the left hand while imaging the fundus of right eye. Once the area of interest was seen in the real time on the phone screen, multi shot still images and video (1080P/30fps) of fundus of the eyes were captured by keeping the flash light on. Each video was converted into a series of high-quality pictures in jpeg format for the purpose of examination by using Video to image converter app (version 2.9.12) with image interval of 0.2 seconds and Ezy Capture app (version 2.5.1) in the smartphone itself. The images of fundus obtained in the present study were studied by comparing with normal images reported in Slatter's Fundamentals of Veterinary Ophthalmology E-Book (6th edition).

Results and Discussion

The results regarding colours of tapetum and non-tapetum in different species of animals were depicted in Table 1, and those regarding colour, shape and location of Optic Disc in different species of animals were presented in Table 2. The findings about retinal vasculature were given in Table 3. Some pictures of fundus taken during the present study were showed in Figures 3-14.

Colour of Tapetum

Among the observed colours of tapetum in dogs, the most common was green-blue (28.57%) followed by yellow (21.43%), yellow-orange (14.29%), yellow-green (14.29%), yellow- orange-green (10.71%), blue-green (7.14%) and yellow-blue (3.57%). These results were in accordance with those of Sini *et al.* (2016). However, Granar *et al.* (2011) reported yellow-green as major colour of tapetum in Swedish dogs. Colour distribution in the tapetal area varied among different breeds of dog. Crispin (2005) supported the finding. An uneven junction between the tapetal and non-tapetal area with scattering of tapetal cells was found in some breeds like Cairn terrier, Shih Tzu, Spitz and Pomeranian. In Pug, tapetal area was small and optic disc was inside the non-tapetum. Area centralis was seen in 35.71% animals.

The tapetum of the cats was hyper-reflective and occupied the greater portion of the fundus in comparison to dogs. Kanemaki *et al.* (2016) reported similar findings in the feline tapetum. The predominant tapetal colour in cats was yellow (83.33%). Area centralis was evident in all the observed cats.

The most common colour of tapetum in white cattle, buffaloes, sheep and goats was Yellow (60.00%), Dark-Lavander blue (91.67%), Greenish-blue (71.43%), and Yellow-blue-green (50.00%), respectively. The findings were almost similar to those of Crispin (2005) and Bulut *et al.* (2023). Area centralis was equally distributed on either side of dorsal arterioles in white cattle. Patchy melanin pigmentation and choroid end capillaries were evident in the peripheral tapetal region in buffaloes. Area centralis was evident in 85.71 per cent cases and Winslow's stars were visible throughout the tapetum, indicating the choroid end capillaries were extending into the vitreous through the retinal pigmented epithelium in sheep. The Winslow's stars were surrounded by a yellowish area in 37.50% of goats examined.

Colour of Non-tapetum

The predominant colour of non-tapetum in dogs was Black (42.86%), followed by chocolate brown (21.43%), dark brown (17.86%), grey (14.29%) and light brown (3.57%). These results were in agreement with those of Sini *et al.* (2016) and Sirin (2020). The most common colour of non-tapetum in cats was Black (77.78%) followed by Grey (22.22%). The most observed colour of tapetum in white cattle, buffaloes, sheep and goats was Grey (60.00%), Grey (91.67%), Reddish-grey (57.14%), and Blue (50.00%), respectively. These findings were in accordance with those of Maggs *et al.* (2017).

Colour of Optic Disc

Different colours of Optic Disc observed in dogs were White (64.29%), Pinkish white (28.57%), and Pink (7.14%). These findings were in agreement with those of Narfstrom and Petersen-Jones (2007). The most common colour of Optic Disc in cats was Grey (77.78%), followed by Thick red (11.11%), and Pale (11.11%). The Optic disc of white cattle was highly myelinated and is Black in colour, while that of buffaloes was light red in colour. The predominant colour of Optic disc in sheep and goats was Light red (100.00%) and Bright red (56.25%) respectively.

Shape of Optic Disc

The most common shape of optic disc in dogs was triangular (46.43%) followed by circular (32.14%) and polygonal (21.43%). The results of the present study coincided with those of Sini *et al.* (2016). It was surrounded by a pigmented ring either completely or partially. The venous circulation was complete in 46.42% of dogs.

The shape of optic disc in cats was circular (100.00%) and it was encircled by pigmented border. It was similar to the finding of Crispin (2005). No venous circulation was noticed at the center of the optic disc in all the cats that were examined. The optic disc was oval shaped in white cattle and buffaloes, and no venous circulation was noticed. It coincided with findings of Maggs *et al.* (2017). The border of the optic disc in white cattle was completely surrounded by the pigmented ring. Numerous capillaries were radiating from the optic disc center.

It was observed in buffaloes that Bergmeister's papilla was located at the center of optic disc, from which many capillaries were seen as radiating. Optic disc of sheep was kidney or bean shaped. Bergmeister's papillae and complete pigmentation around the optic disc were found in 75.00 and 62.50% of sheep, respectively. The predominant colour of Optic disc in goat was Oval (56.25%). It was surrounded by pigmented ring completely in 75.00% of the cases, and Bergmeister's papillae were found in 62.5% of goats. Bulut *et al.* (2023) observed similar results.

Location of Optic Disc

The Optic disc of dog was found to be located in tapetum, non-tapetum, and junction of tapetum and non-tapetum in 25.00, 42.86, and 32.14% of cases, respectively. Janssens (2002) supported this finding. However, Saroglu *et al.* (2005) and Aksoy *et al.* (2011) reported that the disc was located mostly in the tapetum. These variations might be due to differences in breeds of dog. In case of cat and goat, it was located in tapetum. Crispin (2005) reported similar results. It was located at junction of tapetum and non-tapetum in white cattle and buffaloes. The disc was observed to be located in non-tapetum and at junction of tapetum and non-tapetum in 42.86 and 57.14% of sheep, respectively.

Retinal Vasculature

It was found that the pattern of retinal vasculature was holangiotic type with blood vessels distributed throughout the retina. The veins were less in number, wider and darker. The most commonly observed number of primary retinal veins in dogs was three (78.58%), followed by five (14.28%) and four (7.14%). The predominant range of retinal arterioles in dogs was 10 to 15 (39.28%), followed by 5 to10 (32.14%) and more than 15 (28.57%). The number of primary retinal veins in cats was three and that of arterioles was three in 55.55% and 4 to 5 in 44.44% of cases. The range of number of primary retinal veins in white cattle was 2-4, and that of arterioles was 3-7. In buffalos, there were 3 primary retinal veins and 4 to 6 arterioles. The range of number of primary retinal veins was 2 to 3 in both sheep and goats, that of arterioles was 4 to 5 and 5 to 7, respectively. The findings were almost similar to those of Galan *et al.* (2006).

Table 1: Colours of tapetum and non-tapetum in different species of animals

S. No.	Species and sample size	Tapetum		Non-tapetum	
		Colour	**Percentage**	**Colour**	**Percentage**
1	Dogs (28)	Green-blue	28.57	Black	42.86
		Yellow	21.43	Chocolate brown	21.43
		Yellow-orange	14.29	Dark brown	17.86
		Yellow-green	14.29	Grey	14.29
		Yellow-orange-green	10.71	Brown	3.57
		Blue-green	7.14		
		Yellow-blue	3.57		
		Total	**100.00**	**Total**	**100.00**
2	Cat (18)	Yellow	83.33	Black	77.78
		Yellow-green	16.67	Grey	22.22
		Total	**100.00**	**Total**	**100.00**
3	White cattle (10)	Yellow	60.00	Grey	60.00
		Yellow-blue	40.00	Black	40.00
		Total	**100.00**	**Total**	**200.00**
4	Buffalo (12)	Dark-Lavander blue	91.67	Grey	91.67
		Blue-yellow	8.33	Dark brown	8.33
		Total	**100.00**	**Total**	**100.00**
5	Sheep (14)	Greenish-blue	71.43	Reddish-grey	57.14
		Yellowish-green	28.57	Light grey	28.57
				Black	14.29
		Total	**100.00**	**Total**	**100.00**
6	Goat (16)	Yellow-blue-green	50.00	Blue	50.00
		Yellowish-green	31.25	Dark brown	37.50
		Levander blue	18.75	Grey	12.50
		Total	**100.00**	**Total**	**100.00**

Table 2: Colour, shape and location of Optic Disc in different species of animals

S.No.	Species and sample size	Colour of Optic Disc		Shape of Optic Disc		Location of Optic Disc	
		Colour	**Percentage**	**Shape**	**Percentage**	**Location**	**Percentage**
1	Dog (28)	White	64.29	Triangular	46.43	Tapetum	25.00
		Pinkish white	28.57	Circular	32.14	Non-tapetum	42.86
		Pink	7.14	Polygonal	21.43	Junction of tapetum and non-tapetum	32.14
		Total	**100.00**	**Total**	**100.00**	**Total**	**100.00**
2	Cat (18)	Grey	77.78	Circular	100.00	Tapetum	100.00
		Thick red	11.11			Non-tapetum	0.00
		Pale	11.11			Junction of tapetum and non-tapetum	0.00
		Total	**100.00**	**Total**	**100.00**	**Total**	**100.00**
3	White cattle (10)	Black	100.00	Oval	100.00	Tapetum	0.00
						Non-tapetum	0.00
						Junction of tapetum and non-tapetum	100.00
		Total	**100.00**	**Total**	**100.00**	**Total**	**100.00**
4	Buffalo (12)	Light red	100.00	Oval	100.00	Tapetum	0.00
						Non-tapetum	0.00
						Junction of tapetum and non-tapetum	100.00
		Total	**100.00**	**Total**	**100.00**	**Total**	**100.00**
5	Sheep (14)	Light red	100.00	Bean	100.00	Tapetum	0.00
						Non-tapetum	42.86
						Junction of tapetum and non-tapetum	57.14
		Total	**100.00**	**Total**	**100.00**	**Total**	**100.00**
6	Goat (16)	Bright red	56.25	Oval	56.25	Tapetum	100.00
		Dark red	43.75	Round	25.00	Non-tapetum	0.00
				Bean	18.75	Junction of tapetum and non-tapetum	0.00
		Total	**100.00**	**Total**	**100.00**	**Total**	**100.00**

Table 3: Retinal vasculature in different species of animals

S.No.	Species and sample size	Number of veins		Number of arteries	
		Number	**Percentage**	**Number**	**Percentage**
1	Dog (28)	3	78.58	5-10	32.14
		4	7.14	10-15	39.28
		5	14.28	>15	28.58
		Total	**100.00**	**Total**	**100.00**
2	Cat (18)	3	100.00	3	55.56
				4-5	44.44
		Total	**100.00**	**Total**	**100.00**
3	White cattle (10)	2	30.00	3	50.00
		3	50.00	4	33.33
		4	20.00	7	16.67
		Total	**100.00**	**Total**	**100.00**
4	Buffalo (12)	3	100.00	4	25.00
				5	25.00
				6	50.00
		Total	**100.00**	**Total**	**100.00**
5	Sheep (14)	2	28.58	4	42.85
		3	71.42	5	57.15
		Total	**100.00**	**Total**	**100.00**
6	Goat (16)	2	25.00	5	18.75
		3	75.00	6	50.00
				7	31.25
		Total	**100.00**	**Total**	**100.00**

Fig.3 Cairn Terrier (OD)

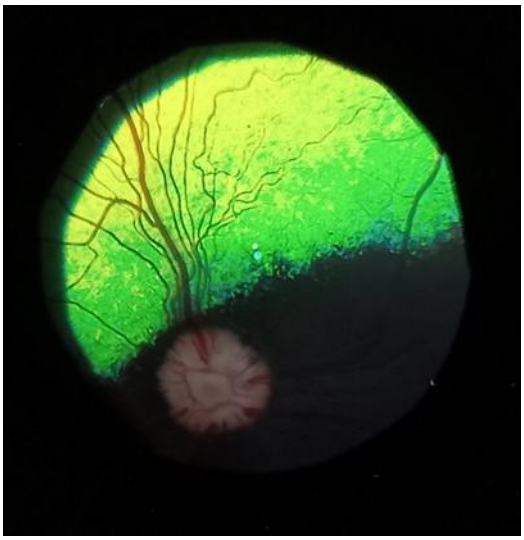

Fig.4 Dachshund (OD)

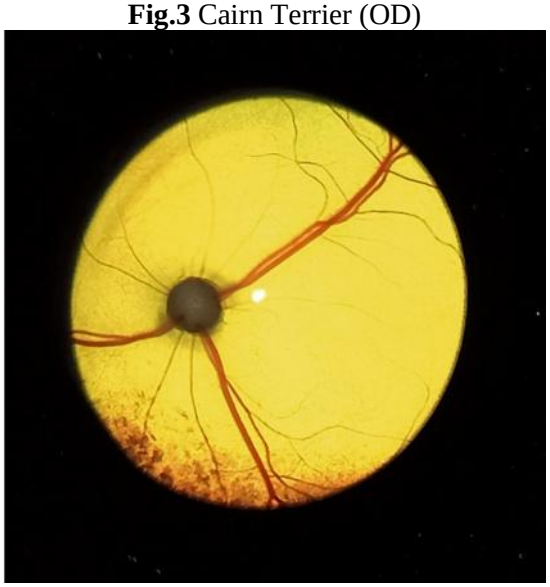

Fig.5 Persian cat (OS)

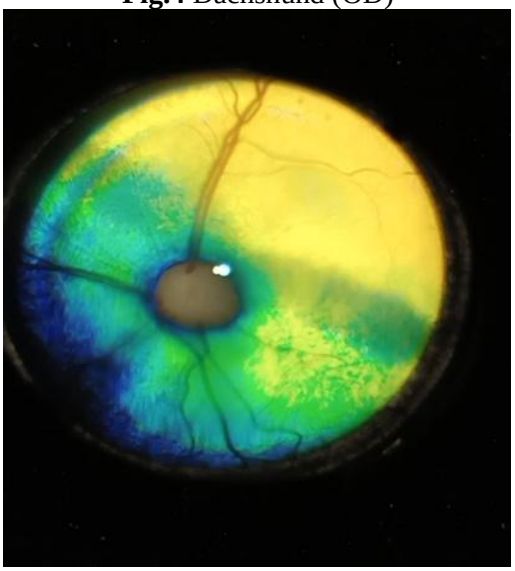

Fig.6 Non-descript cat (OD)

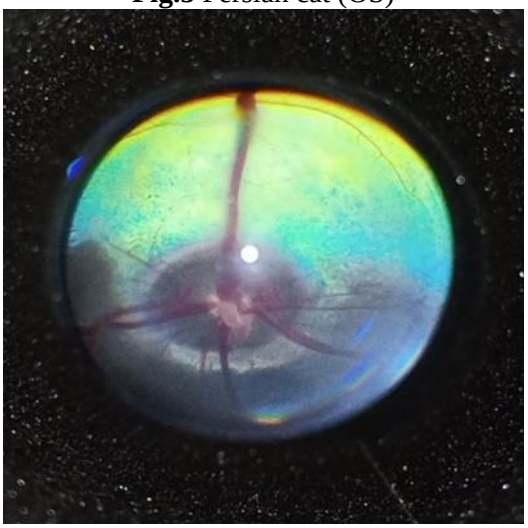

Fig.7 Jersey Cow (OS)

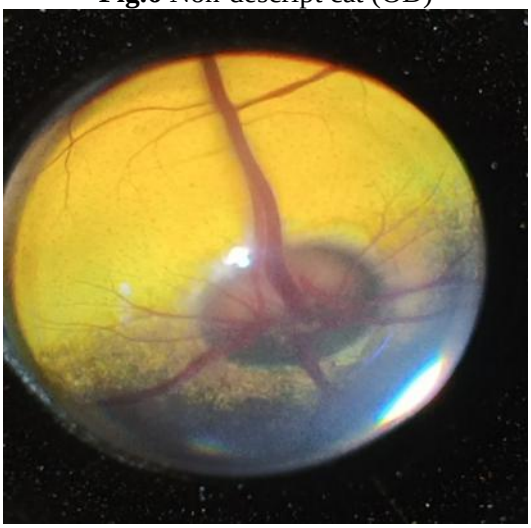

Fig.8 Ox (OD)

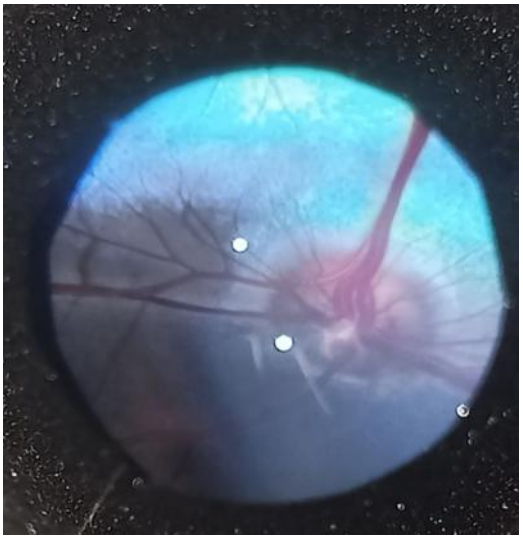

Fig.9 Non-descript Buffalo (OD)

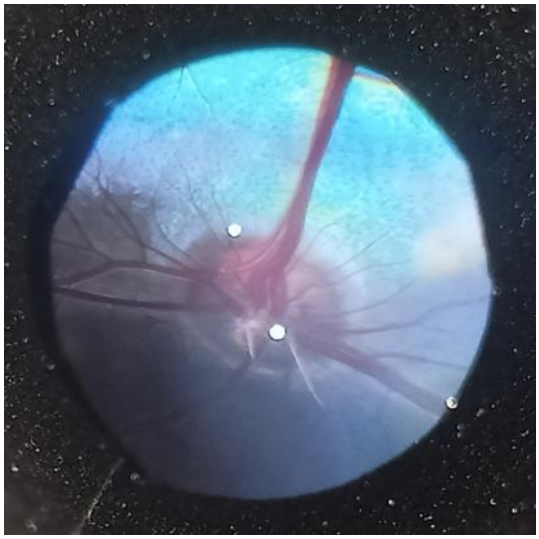

Fig.10 Non-descript Buffalo (OS)

Fig.11 Non-descript Sheep (OD)

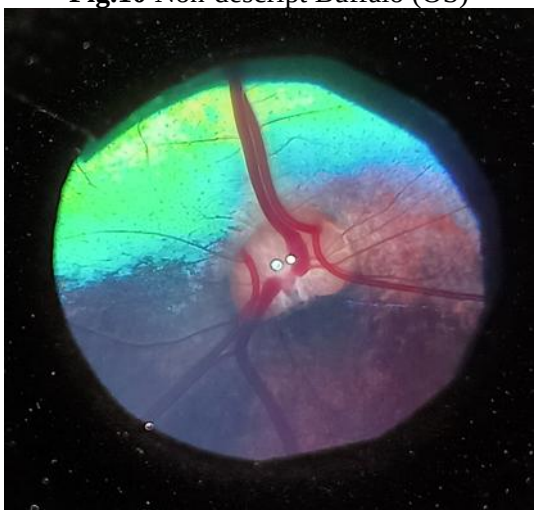

Fig.12 Non-descript Sheep (OD)

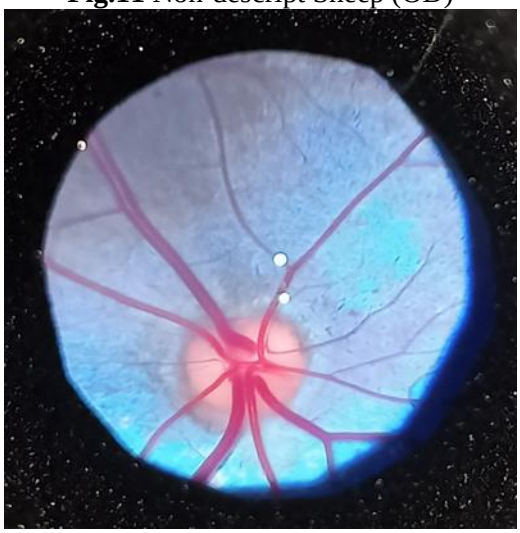

Fig.13 Non-descript Goat (OD)

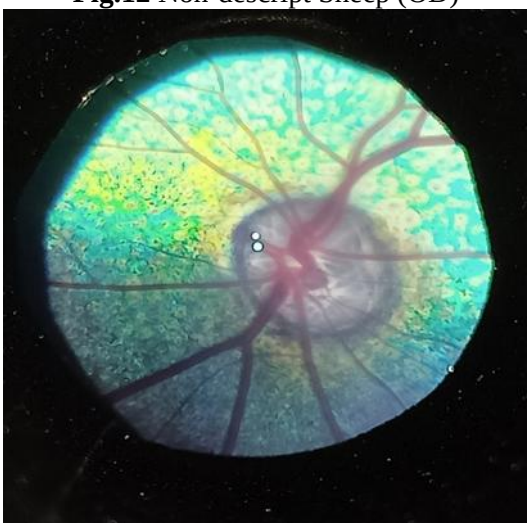

Fig.14 Non-descript Goat (OS)

Conclusions

From the results of the present study, it could be concluded that fundus imaging using a smartphone is a reliable and portable technique, it can be performed with minimal investment, and it enables client communication and education, and general teaching in veterinary ophthalmology.

Acknowledgments

The research facilities provided by Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh are acknowledged.

Contribution by Authors

All the authors contributed equally to writing the manuscript. The final manuscript was read by all authors and consented to publication.

Conflict of Interests

There is no conflict of interest.

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