



Characterization, performance and genetic diversity among goats of Odisha

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ABSTRACT

Phenotypic and biometric characterization was carried out of local goat populations of Odisha. The populations included Ganjam, Kalahandi, Ghumusar, Narayanpatnam, Raigarhi and Malkangiri goats. Ganjam goats are distinctly different from other populations because of long pointed horns. The body measurements of adult (12 months) males for heart girth, height at withers, body length, and paunch girth were measured. The coat colour of goats was recorded. The average body length, body height, chest girth, paunch girth, face length, horn length, ear length and tail length in adult female and male were measured. The biometric estimates for height at withers, body length, chest girth, paunch girth, face length, horn length, ear length and tail length indicated the average measurements. Genetic Biodiversity study includes 192 individuals of goats belonging to two recognized (Ganjam and Black Bengal) breeds and 2 lesser known goat populations (Kalahandi and Ghumusar) genotyped for a battery of 25 microsatellites. The number of observed allele for each locus ranged from 2.00 to 21.00. The highest number of allele was observed for locus OarFCB304 for Ganjam goat breed and lowest number of allele was observed for locus ETH225 for Kalahandi goat population. Polymorphic Information Content (PIC) value and bottleneck analysis were studied. Ghumusar and Kalahandi have the highest genetic distance (1.996) from the others and Ganjam and Black Bengal have minimum (0.346) genetic distance. In the neighbor joining diagram, the Ghumusar and Kalahandi goat populations plots separately from the other breeds/populations.

Key words: Characterization, Genetic diversity, Goats, Odisha

Goats, as a source of milk and meat, are one of the earliest important finds of mankind. This species of animal is capable of living in cold arid up hills or hot arid deserts or hilly terrains or ravines. Goats have served the mankind in earning its livelihood by selling live animals or its products and byproducts. The goats have increased in number from 124 million to 144 millions (2007 census) inspite of faster rate of slaughtering or mortalities but dropped to 135 million as per the latest census (LC 2012). The total contribution of goats to country's GDP is around 22,138 crores annually which included meat worth ₹ 12,000 crore, milk ₹ 5,500 crore, skin ₹ 800 crore and manure ₹ 1,600 crore. The goats are distributed though out the country, however, few states have not been on the national list of descript breeds. There are 23 recognized and registered breeds of goats (NBAGR profile 2014). The total population of goats is comprised of 35% of these 23 descript breeds while remaining are nondescript or lesser known consisting of crossbreds and other local populations. Odisha is known for its animal biodiversity while many local goat populations have been reported but are inadequately studied. There are about 63.67 million goats comprising of 22.53 million males and 41.11 million females in Odisha as per livestock census 2012.

The goat population mainly includes Ganjam breed along with many small local populations. Out of these populations only Ganjam goat breed has been registered by NBAGR (Accession No.: India_Goat_0015_Ganjam_06008). Bengal type goats are also present throughout the state. An attempt has been made to characterize some local goat populations of Odisha by conducting systematic suveys in identified areas (Fig. 1) and collecting data on phenotype, biometry and management practices. The local populations include Kalahandi, Ghumusar, Narayanpatnam, Raigarhi, Malkangiri goat populations. Genetically, Ghumusar and Kalahandi goats have been characterized and compared with Ganjam and Black Bengal goats.

MATERIALS AND METHODS

Visits were made to Koraput, Narayanpatnam, Nabrangpur, Raigarh and Malkangiri districts of Odisha state. Being on the coastal belt, the weather of Odisha is greatly influenced by the sea. The climate of the region is tropical resulting in very high temperature in the month of April and May. On the contrary, the eastern ghats experience the cold climate. The summer temperature ranges between 35–40°C and the low temperature are usually between 12–14°C. Winter is little severe in Koraput and nearing districts. The average rainfall is 150 cm. The measurements on 124 Ghumusari goats, 109 Narayanpatnam goats, 126 Raigarhi

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Fig. 1. Sampled areas of Odisha goat populations.

goat and 147 Malkangiri goats belonging to different villages of each district were recorded for height at wither, body length, chest girth, paunch girth, face length, horn length, ear length and tail length. Body weights of different age group animals were also taken. Fifty blood samples from unrelated animals belonging to different flocks were collected in EDTA coated vacutainer tubes for studying the genetic diversity. Genotyping data of Ganjam and Black Bengal goats available in the laboratory was used for comparative diversity. For genetic diversity, DNA was isolated using standard phenol extraction method (Sambrook *et al.* 1989). A battery of 25 microsatellite markers (table 5) was used on a panel of 50 animals. PCR was carried out on about 50–100 ng genomic DNA. The genotyping using PCR amplified DNA was outsourced and

data was analysed to estimate the allelic number, polymorphism information contents, heterozygosity, genetic distance and bottleneck analysis.

RESULTS AND DISCUSSION

Phenotypic characterization and biometry

Ganjam goat: Ganjam breed of goat is also called 'Gola Chheli'. The name is after the 'Gola' community who rear it since generations for meat purpose. At some places this breed is also called 'Lanka Chelli'. Ganjam goat is different from other types of Odisha goats by its prominent physical characteristics, particularly long horns. Ganjam goat is available in its purest form in Ganjam district of Odisha. The native tract of the breed lies between 19° 10'N to 20° 28'N latitude and 84° 16'E to 85° 18'E longitude over 9230 sqkm and altitude ranging from sea level to 466 meters. Ganjam is a dual purpose breed reared for meat and milk. Ghee made from Ganjam goat's milk is very costly and is used for curing asthma (Dash *et al.* 2006). Ganjam goat is a medium sized hardy animal having wide chest, long legs, well built neck and shoulders, long hair on thigh and vertebrae region (Fig. 2). The males are very strong and have comparatively longer horns. Head is convex and proportionate to body. Beard and wattles are seen both in male and female goats. Ganjam goats are found in varied coat colour i.e. black, brown, blackish brown, brownish black sometimes with white patches. Hooves, muzzle, eyelashes and horns are grayish black. Ears are medium sized and drooping. Horn size is the distinct feature of this breed. Males have stronger, twisted and curved horns while females have comparatively straight and thin horns. Horns up to 53 cm length were recorded in males. Flock size varies from few animals to over hundreds. Mixing of 4–5 flocks



Figs 2–7. 2. A flock of Ganjam goats, 3. Ghumusar goats, 4. A Kalahandi goat, 5. Narayanpatnam goats, 6. A Raigarhi goat, 7. Malkangiri goats.

of different farmers sometimes make the flock which can reach upto a size of 2,000. Majority of animals are reared under extensive system of management. No proper housing is provided to these animals. They are kept in a temporary enclosures during night, however, kids are kept in a closed cage type housing. Animals are not provided with any concentrate mixture. Majority of Ganjam goats are migratory type. They are taken up to 50–60 km distance in search of fodder. Ganjam goats are bred by natural mating. The farmers keep bucks in a ratio of 1: 10 in the flock. Castration in Ganjam goat is not practiced. The body measurements of adult (12 months) males for different traits are 66.72 ± 0.52 for heart girth, 67.23 ± 0.43 for height at withers, 59.67 ± 0.51 for body length, 62.46 ± 0.51 cms for paunch girth. The measurements for the same traits in females are 64.87 ± 0.38 , 65.62 ± 0.37 , 58.32 ± 0.36 , 61.37 ± 0.42 respectively. The body weights in male and females are $18.63 \pm$ and $16.75 \pm$ kg respectively. The average milk production in a lactation of 120 days is 45.94 liters with 3.92% fat and 14.80% SNF (Dash *et al.* 2006). Ganjam bucks attain maturity at 472 days while females show the puberty at 424 days. Age at first kidding in Ganjam goat is 583 days. Kidding interval is 337 days. Rao *et al.* (2009) also studied the morphological attributes and management of Ganjam goats.

Ghumusar goats: The survey in 16 villages of two blocks of Khandamal district revealed that Ghumusari goats are medium in size and weight and are reared for meat/mutton only. The coat colour is black, light brown, blackish brown

with dark brown belly were observed (Fig. 3). The average body weight of males at 3–6 months and 7–12 months of age was 8.60 and 13.25 kg respectively, whereas, for female the corresponding values were 8.15 and 12.07 kg respectively. The adult female and male animal (>18 months) weighed 19.88 and 20.86 kg respectively. The flock size varied from 5 to 25. A total of 132 animals of different age and sex group were recorded for different eight body measurements. The average body length, body height, chest girth, paunch girth, face length, horn length, ear length and tail length in adult female and male are given in Table 1. Animals are kept on pasture grazing. Natural service practiced. Female animals show sexual maturity at about 12–18 months of age. Ghumusar goats have lower age at first kidding than that of Ganjam goats but comparable to that of Black Bengal goats (Rao *et al.* 2002). Ghumusar goats are known for good quality meat (Patro *et al.* 2007).

Kalahandi goats: Kalahandi goats are medium sized animals mostly brown and white in colour (Fig. 4). Ears are flat, leafy and drooping. Legs are thin and cylindrical. Horns are long flat upward and backward. The biometric estimates for height at withers, body length, chest girth, paunch girth, face length, horn length, ear length and tail length indicated the average measurements (in cm) as 70.32, 69.05, 71.53, 73.84, 17.89, 15.05, 15.74 and 15.32 respectively for adult males and 65.51, 66.28, 70.36, 74.87, 15.29, 12.74, 15.01 and 13.97 respectively for females. The body weights of adult male and females were 33.42 and 30.88 kg. The results showed age-dependent sexual

Table1. Body biometry of Ghumusari goats

Age	Sex	N	Height	Length	Chest girth	Paunch Girth	Face	Horn	Ear	Tail
3	F	8	44.38±0.84	43.13±0.72	42.88±0.48	44.50±0.57	10.13±0.30	1.13±0.13	12.00±0.33	9.63±0.18
	M	5	45.60±0.81	44.40±0.81	43.80±0.92	46.20±2.22	10.60±0.40	2.40±0.24	12.00±0.00	11.20±0.37
6	F	10	47.30±1.10	48.20±1.17	47.30±1.09	48.40±1.26	11.10±0.35	2.60±0.64	12.10±0.18	10.20±0.29
9	F	7	52.29±0.47	51.29±0.81	53.86±0.88	57.57±1.51	13.00±0.00	6.14±1.03	13.00±0.31	10.86±0.14
	M	11	52.00±0.92	52.73±0.85	52.82±1.15	55.09±1.54	12.73±0.27	4.64±0.47	13.00±0.30	11.91±0.25
>18	F	75	57.33±0.36	59.09±0.42	62.96±0.57	66.80±0.65	14.00±0.12	7.40±0.32	13.29±0.11	11.80±0.13
	M	8	61.75±1.08	62.63±1.15	67.50±2.54	70.25±2.89	14.75±0.41	12.00±1.51	14.00±0.53	13.25±0.31

Table 2. Average body measurements and weight of Narayanpatnam goats

Age	Sex	Height	Length	Chest girth	Paunch Girth	Face	Horn	Ear	Tail
3M(5)	F	54.00±1.26	52.00±1.48	51.40±1.60	51.40±1.50	12.20±0.37	2.00±0.55	13.00±0.55	12.40±0.60
3M(6)	M	54.17±1.68	50.33±1.99	51.50±1.20	54.33±1.98	12.00±0.37	4.33±0.56	13.00±0.52	12.17±0.70
Overall (11)		54.09±1.03	51.09±1.25	51.45±0.93	53.00±1.30	12.09±0.25	3.27±0.52	13.00±0.36	12.27±0.45
6M (5)	F	57.60±1.91	54.60±1.99	57.60±2.25	59.00±1.67	13.40±0.60	4.80±0.58	13.00±0.32	12.60±0.51
6M (5)	M	58.60±0.81	55.00±1.30	58.80±0.92	60.80±1.53	14.20±0.58	6.00±0.63	13.40±0.51	12.60±0.68
Overall (10)		58.10±0.99	54.80±1.12	58.20±1.16	59.90±1.11	13.80±0.42	5.40±0.45	13.20±0.29	12.60±0.40
9M (5)	F	62.00±2.17	60.20±1.91	60.60±2.04	60.20±1.20	13.80±0.37	5.20±0.49	13.80±0.58	13.40±1.12
9M (5)	M	65.20±1.07	61.00±0.63	63.00±1.38	61.80±2.08	14.40±0.40	6.20±0.73	14.20±0.37	14.80±0.20
Overall (10)		63.60±1.26	60.60±0.96	61.80±1.23	61.00±1.16	14.10±0.28	5.70±0.45	14.00±0.33	14.10±0.59
A (73)	F	68.47±0.56	65.63±0.57	70.86±0.60	73.14±0.73	16.34±0.12	11.49±0.46	13.96±0.24	13.96±0.22
A (5)	M	74.40±2.77	69.60±3.71	70.60±4.39	71.40±4.07	16.00±1.05	9.60±2.38	15.20±0.86	16.20±0.37
Overall (78)		68.85±0.57	65.88±0.58	70.85±0.62	73.03±0.72	16.32±0.13	11.37±0.45	14.04±0.24	14.10±0.22

differences in the body dimensions. Like Bengal goats they are also very prolific and litter is 5.3% twins and 4.4% triplets and quadruplets. These goats are poor milkers.

Narayanpatnam goat: Ten villages of Narayanpatna and Bandhugan blocks were visited and 110 animals of different age and sex group were recorded for eight body parameters. Information on performance traits was collected through interaction with the goat keepers. Narayanpatna goats are medium in size. They are mostly brown black in colour (Fig. 5). However, brown, off white and even mixed coloured animal were also seen. These goats are reared by poor tribal (Kondhs) people for meat purpose under extensive management without any supplementation of feed and fodder. The flock size varied from 2 to 34. Breeding is through natural service. Female animals show sexual maturity at about 12–15 months of age.

The average body length, height at withers, chest girth, paunch girth, face length, horn length, ear length and tail length in adult male and female are given in Table 2. The average body weights of adult female and male animal were 27.33 ± 0.61 and 32.80 ± 6.82 kg respectively.

Nabrangpur (Raigarhi) goat: Data on biometry and management practices from 126 lesser known /local goats belonging to 40 farmers of ten villages of Nabrangpur

district were recorded. Goats are reared by marginal, small farmers and landless tribes of the area for meat purpose only. Goats are medium in size. Coat colour was light brown to dark brown and some mixed coloured animal also seen in the flocks. White or light brown colour strips extending from base of the ear to muzzle are present on either side of the nose line (Fig 6). Muzzle colour was black or brown and hooves were black or grey. These goats are reared under extensive management system with 6–10 hours grazing during the day throughout the year. The overall averages body length, height at withers, chest/heart girth, paunch girth, face length, horn length, ear length, and tail length in female and male animals are given in Table 3. The average age at sexual maturity and age at first kidding were 10–12 months and 15–18 months, respectively. Thatched houses with raised floor (2–4 ft) made up of wooden planks/bamboos are used as goat shelter. No extra concentrate or supplementations are given to the goats. Flock size varies from 2–25 animals. Natural service is practiced. These goats should be multiplied and improved for better economic return or lift the economic status of the goat keepers through goat keeping.

Malkangiri goats: A survey was conducted in eleven villages of three blocks (Matheli, Khairput and Malkangiri)

Table 3. Average body measurements of Raigarhi goats

Age	Sex	Height	Length	Chest girth	Paunch girth	Face length	Horn length	Ear length	Tail length
3	F	47.67±0.99	44.44±0.58	47.44±1.23	51.89±1.24	11.7±80.46	2.33±0.41	10.33±0.37	10.11±0.31
	M	47.88±1.09	46.0±0.12	47.6±31.27	50.75±1.16	10.63±0.32	2.50±0.38	11.00±0.38	10.75±0.37
6	F	50.43±1.59	48.43±0.84	52.14±0.94	54.57±2.21	13.86±0.26	4.43±0.57	10.57±0.37	10.29±0.29
	M	55.33±1.33	50.00±1.53	50.33±0.33	55.00±1.73	13.00±0.58	5.00±0.58	11.00±0.58	11.33±0.33
9	F	53.86±1.70	55.00±1.96	56.71±1.21	59.43±1.66	14.00±0.31	5.29±0.68	11.71±0.42	10.43±0.37
	M	55.25±1.49	55.50±1.44	58.25±2.02	61.00±2.55	14.75±0.48	7.50±0.50	11.75±0.25	11.25±0.63
12	F	58.55±0.88	57.45±1.19	59.82±0.70	62.82±1.04	14.73±0.19	6.91±0.62	11.82±0.23	11.09±0.28
	M	58.50±2.50	59.00±2.00	60.50±0.50	65.00±0.00	15.50±0.50	7.50±0.50	12.50±1.50	12.00±1.00
>18	F	61.35±0.44	60.87±0.53	65.85±0.62	70.06±0.85	15.34±0.17	9.38±0.39	13.62±0.18	12.66±0.18
	M	63.43±1.49	61.71±1.43	65.14±2.10	67.14±2.43	15.43±0.78	10.57±1.29	14.71±0.42	13.57±0.69

Table 4. Body biometry of Malkangiri goats

Age group	Height	Length	Chest girth	Paunch girth	Face	Horn	Ear	Tail
Overall	47.29±0.57	44.00±1.07	46.14±0.83	47.57±1.76	11.57±0.20	1.43±0.20	11.43±0.43	10.43±0.43
	51.33±1.67	46.33±1.33	48.67±0.33	51.00±1.53	12.67±0.67	2.33±0.33	11.67±0.33	11.33±0.33
	48.50±0.85	44.70±0.88	46.90±0.69	48.60±1.37	11.90±0.28	1.70±0.21	11.50±0.31	10.70±0.33
	50.88±1.16	47.75±0.70	50.25±1.11	53.50±1.48	12.63±0.26	2.63±0.53	12.88±0.58	11.38±0.38
	58.25±1.31	50.75±1.49	56.50±1.32	58.50±0.87	13.25±0.48	4.25±1.31	12.50±0.65	11.50±0.29
Overall	53.33±1.35	48.75±0.77	52.33±1.21	55.17±1.22	12.83±0.24	3.17±0.58	12.67±0.40	11.42±0.26
	54.80±0.79	53.00±0.77	55.90±0.50	58.70±1.51	13.40±0.16	4.40±0.48	12.90±0.57	11.70±0.56
	55.50±1.52	53.17±1.05	56.83±0.65	57.00±1.10	13.67±0.33	4.83±0.70	13.00±0.58	12.67±0.67
Overall	55.06±0.73	53.06±0.60	56.25±0.40	58.06±1.03	13.50±0.16	4.56±0.39	12.94±0.40	12.06±0.43
	58.00±1.04	54.60±0.90	59.70±0.76	60.90±1.19	14.10±0.23	6.00±0.47	13.70±0.47	12.40±0.62
	56.00±0.58	56.00±1.15	57.67±1.76	61.00±1.00	14.33±0.67	5.67±0.67	13.67±0.33	13.33±0.33
Overall	57.54±0.84	54.92±0.74	59.23±0.72	60.92±0.92	14.15±0.22	5.92±0.38	13.69±0.36	12.62±0.49
	63.20±0.39	61.79±0.37	67.37±0.51	70.69±0.61	15.62±0.10	9.64±0.33	13.94±0.24	13.80±0.18
	65.53±1.02	62.67±0.99	67.53±0.86	69.47±1.21	15.80±0.22	11.00±0.76	15.13±0.52	15.27±0.44
Overall	63.56±0.37	61.93±0.35	67.40±0.45	70.50±0.55	15.65±0.09	9.85±0.30	14.13±0.22	14.03±0.18

Table 5. Microsatellite markers, their sequences, dye labeled, type of repeat, amplified product size, location and accession numbers

Locus	Primer sequence	Dye	Type of repeat	Size range	*Ch. No	Gene bank accession No.
ILST008	gaatcatggattttctgggg tagcagtgagtgagggtggc	FAM	(CA) ₁₂	167–195	14	L23483
ILSTS059	gctgaacaatgtgatgttcagg gggacaatactgtcttagatgtgc	FAM	(CA) ₄ (GT) ₂	105–135	13	L37266
ETH225	gatcaccttgccactatttcct acatgacagccaagctgctact	VIC	(CA) ₁₈	146–160	14	Z14043
ILST044	agtcacccaaaagtaactgg acatgtgtattccaagtgc	NED	(GT) ₂₀	145–177	Ann	L37259
ILSTS002	tctatacacatgtgctgtgc cttaggggtgtattccaagtgc	VIC	(CA) ₁₇	113–135	Ann	L23479
OarFCB304	ccctaggagctttcaataaagaatcgg cgctgctgtcaactgggtcaggg	FAM	(CT) ₁₁ (CT) ₁₅	119–169	Ann	L01535
OarFCB48	gagttagtacaaggatgacaagaggcac gactctagaggatcgcaagaaccag	VIC	(CT) ₁₀	149–181	17	M82875
OarHH64	cgttcctcactatgaaagtatatatgc cactctattgtaagaattgaaatgagagc	PET	-	120–138	4	212 ^a
OarJMP29	gtatacacgtggacaccgctttgtac gaagtggcaagattcagaggggaag	NED	(CA) ₂₁	120–140	Ann	U30893
ILSTS005	ggaagcaatgaaatctatagcc tgttctgtgagtttgaagc	VIC	(nn) ₃₉	174–190	10	L23481
ILSTS019	aaggagacctcatgtagaagc acttttgaccctgtagtgc	FAM	(TG) ₁₀	142–162	Ann	L23492
OMHC1	atctgtgggctacagtcctatg gcaatgctttctaaattctgaggaa	NED	-	179–209	Not reported	228 ^a
ILSTS087	agcagacatgatgactcagc ctgcctcttttcttgagagc	NED	(CA) ₁₄	142–164	Ann	L37279
ILSTS30	ctgcagttctgcatatgtgg cttagacaacaggggtttgg	FAM	(CA) ₁₃	159–179	2	L37212
ILSTS34	aagggtctaagtcactggc gacctggtttagcagagagc	VIC	(GT) ₂₉	153–185	5	L37254
ILSTS033	tattagagtggctcagtgcc atgcagacagtttagaggg	PET	(CA) ₁₂	151–187	12	L37213
ILSTS049	caattttctgtctctccc gctgaatctgtcaaacagg	NED	(CA) ₂₆	160–184	11	L37261
ILSTS065	gctgcaaagagttgaacacc aactattacaggaggctccc	PET	(CA) ₂₂	105–135	24	L37269
ILSTSO58	gccttactaccatttccagc catcctgactttggctgtgg	PET	(GT) ₁₅	136–188	17	L37225
ILSTSO29	tgttttgatggaacacagcc tggatttagaccagggttgg	PET	(CA) ₁₉	148–191	3	L37252
RM088	gatcctcttctgggaaaagagac cctgttgaagtgaaccttcagaa	FAM	(CA) ₁₄	109–147	4	U10392
ILSTS022	agtctgaaggcctgagaacc ctacagtccttgggttgc	PET	(GT) ₂₁	186–202	Ann	L37208
OARE129	aatccagtggtgaaagactaatccag gtagatcaagatatagaatattttcaacacc	FAM	(CA) ₁₄	130–175	7	L11051
ILSTS082	ttcgttcctcatagtctgg agaggattacaccaatcacc	PET	(GT) ₁₇	100–136	2	L37236
RM4	cagcaaaatatcagcaaacct ccacctgggaaggccttta	NED	(CA) ₁₃	104–127	15	U32910

*: Chromosome number; ^a: Accession number of Arkdb data base (<http://www.thearkdb.org>).

of Malkangiri district. A total of 147 animals of different age and sex groups were recorded for 8 body parameters. Malkangiri goats are medium in size and weight and are reared for meat only. The goats were mostly light brown or black brown (Fig. 7), however, white and black colour goats were also seen. The face is having strips of white of light brown colour extending from base of the ear to nose in case of brown colour goats. The top line is black. In breeding males black ring is present around the neck. Muzzle and hooves are generally black. The flock size varied from 5 to 35. These goats are reared on semi extensive management system. The average body length, height at withers, chest girth, paunch girth, face length, horn length, ear length and tail length in adult male and female are given in Table 4. The average body weight of males at 3,6,9, 12 months of age were 9.00 ± 0.00 , 12.25 ± 0.48 , 14.50 ± 0.85 , 16.67 ± 0.33 kg respectively, whereas, for female the corresponding values were 8.14 ± 0.34 , 11.13 ± 0.52 , 13.20 ± 0.63 , 16.30 ± 0.68 kg respectively. The adult female and male animal weighed 23.93 ± 0.55 and 26.73 ± 0.90 kg respectively. Animals are kept on pasture grazing. Natural service practiced. Female animals show sexual maturity at about 12–18 month of age.

Genetic diversity among goat populations

This study includes 192 individuals of goats belonging to two recognized (Ganjam and Black Bengal) breeds and 2 lesser known goat populations (Kalahandi and Ghumusar) genotyped for a battery of 25 microsatellites (Verma *et al.* 2009, 2010, 2012, Mishra *et al.* 2013a, 2013b, Dixit *et al.* 2012). The data thus generated was pooled and a comparison was made between registered breeds (Ganjam, Black Bengal) and non-descript goats (Kalahandi and Ghumusar). All the microsatellites amplified in all the breeds/populations under study displayed high level of variability. The observed and expected number of alleles, observed and expected heterozygosities for all the populations/breeds (Kalahandi, Ghumusar, Black Bengal and Ganjam) were estimated. The number of observed allele for each locus ranged from 2.00 to 21.00. The highest number of allele was observed for locus OarFCB304 for Ganjam goat breed and lowest number of allele was observed for locus ETH225 for Kalahandi goat population. The highest number of effective allele was 8.54 at ILSTS033 for Ghumusar goat and lowest number of effective allele was 1.11 for ETH225 for Black Bengal goat breed. Average number of effective and observed allele was highest (4.29) for Kalahandi goat population and lowest 3.54 for Black Bengal goat breed. The expected heterozygosity ranged from 0.22 (ILSTS044) to 0.88 (ILSTS087) in Ghumusar goat population, 0.10 (ETH225) to 0.86 (OMHC1) in Black Bengal, 0.36 (ILSTS34) to 0.88 (OMHC1) in Ganjam and 0.10 (ILSTS044) to 0.86 (ILSTS087) in Kalahandi goat population. The average expected heterozygosity for Ghumusar, Black Bengal, Ganjam, and Kalahandi was 0.71, 0.63, 0.69 and 0.68 respectively. The observed heterozygosity ranged from 0.46 (ETH225) to 1.00 (OarFCB48, OarFCB304 and RM088) in Ghumusar goat

population, 0.16 (ILSTS22) to 0.88 (ILSTS033) in Black Bengal, 0.14 (ILSTS005) to 0.97 (ILSTS033 and OMHC1) in Ganjam and 0.11 (ILSTS044) to 0.97 (ILSTS033 and RM088) in Kalahandi goat population. The average observed heterozygosity for Ghumusar, Black Bengal, Ganjam, and Kalahandi was 0.73, 0.67, 0.54 and 0.52 respectively. Highest Polymorphic Information Content (PIC) value was 0.95 and lowest was 0.78 in overall populations (Ghumusar, Kalahandi, Ganjam and Black Bengal).

Allelic pattern across the loci in Kalahandi, Ghumusar, Black Bengal and Ganjam goat populations/breeds: The allelic patterns across the populations, the mean expected heterozygosity, mean number of private alleles and expected number of alleles is given in figure 8. The mean number of alleles was maximum in Kalahandi (10.24), followed by Ghumusar (9.88) while the mean number of alleles was lowest in Black Bengal (4.16). The effective number of alleles was maximum in Ghumusar goat (0.703) and minimum in Black Bengal goat breed (0.624). The number of private alleles was highest in Kalahandi (4.88) and least in Black Bengal goat (1.40).

Population differentiation: A great genetic differentiation between all breeds/populations (FST) was 0.19 significantly different from zero ($P > 0.05$), which means about 19% of

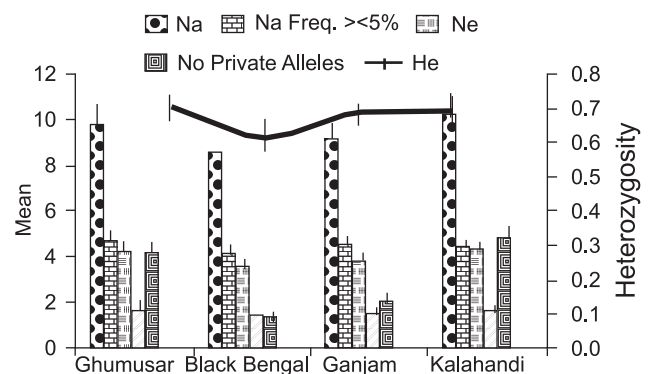


Fig. 8. Allelic pattern across Kalahandi, Ghumusar, Black Bengal and Ganjam goat populations/breeds. Na- observed allelic number, Ne- effective allelic number, He- effective heterozygosity.

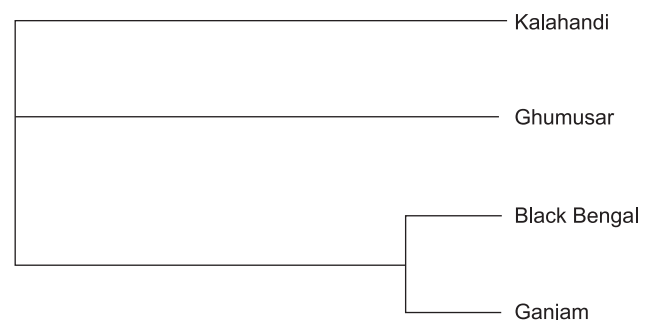


Fig. 9. NJ tree with Nei's genetic distance DA of Kalahandi, Ghumusar, Black Bengal and Ganjam goat breeds/ populations of Odisha.

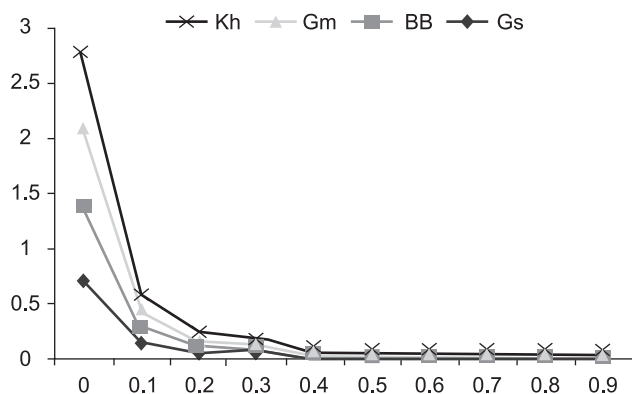


Fig. 10. L- shaped curve shown by all four populations.

Table 6. Genetic distance among four goat populations

Pop/breed	Ghumusur	Black Bengal	Ganjam	Kalahandi
Ghumusur	1.000			
Black Bengal	0.240	1.000		
Ganjam	0.245	0.713	1.000	
Kalahandi	0.364	0.151	0.201	1.000

the total genetic variation was explained by population differences and 81% corresponds the differences among individuals within each breed. The overall FIS value (0.94) was higher and significantly different from zero indicating departure from random mating and suggested that some of the studied loci were homozygous in the populations. Bottleneck analysis showed L shaped curve (Fig. 10) indicating absence of any bottleneck in all populations/ breeds in the recent past.

Nei's standard genetic distance: Nei's DS genetic distances for the four breeds were calculated and presented in Table 6 and dendrogram is depicted in Fig. 9. The Nei's DS standard genetic distance matrix was given in the lower diagonal for these breeds. According to the Table 6, Ghumusur and Kalahandi have the highest genetic distance (1.996) from the others and Ganjam and Black Bengal have minimum (0.346) genetic distance. In the neighbor joining diagram (Fig. 9), the Ghumusur and Kalahandi goat populations plots separately from the other breeds/ populations.

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