Phenotypic characterization of G*addabolli* sheep

M. Kondapu[1], S. Krovvidi[1*], V. Regula[1], N. Dhulipalla[2], B. Maachepalli[3]

[1]Department of Animal Genetics and Breeding, [2]Department of Poultry Science, NTR College of Veterinary Science, Sri Venkateswara Veterinary University, Gannavaram 521102, Andhra Pradesh, India, [3]Veterinary Assistant Surgeon, Veterinary Dispensary, Botlapalem, Prakasam District, Andhra Pradesh, India
*Corresponding author email: vetsreesudha@gmail.com

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Abstract

Indian sheep breeds, originated by generations of natural selection and domestication across diverse agro-climatic zones, exhibit specific characteristics and adaptations to their local environments, contributing to biodiversity. Characterization of lesser-known, autochthonous genetic groups those demonstrating strong adaptation within their specific local climates is vital to ensure their recognition as distinct breeds. Phenotypic characterization of *Gaddabolli*, a lesser known indigenous sheep of Andhra Pradesh, was undertaken on randomly sampled 3675 sheep from 27 sampled flocks from 15 villages in the breeding tract. These sheep were medium to large in size with two different coat colour patterns; patchy (75.4 %) and other were plain white. The body hair coat colour type was white, with brown patches around the orbital region of eye, neck and shoulder region, back, knee, hock and pastern region. The animals were with hairy coat type. Rams were horned with either characteristic curved shaped (54.7 %) or Cork screw or Spiral shaped. Among adult ewes with horns, 92.1 % of them possess rudimentary horns. The ears were either tubular (44.85%) or rudimentary (44.85 %), and only few were pendulous. The head profile was convex and muzzle was brownish white colored. The overall least-squares mean for height at withers for rams was 81.4 ± 0.2 and ewes 80.6 ± 0.1cm. The body length and chest girth at full mouth of age pooled over sex of the animals was 86.0 ± 0.1 cm and 87.5 ± 0.1 cm respectively. The pooled means for body weight at birth, three months, six months, nine months and 12 months of age were 2.8 ± 0.1, 14.2 ± 0.1, 18.1 ± 0.10, 22.2 ± 0.1 and 25.01 ± 0.1 kg respectively and adults weighed 40.9±0.3kg for males and 40.1±0.1 kg for females. The zootechnical indices determined this genetic group as meat type.

Key words: **B**iodiversity; Characterization; Gaddabolli sheep; Phenotype; zootechnical indices

Introduction

Farm animal genetic diversity is imperative in global perspective and the rationale behind to maintain is to withstand the future challenges *viz*., increased demand for livestock products, reducing environmental impact and climate change (FAO, 2011). Sheep husbandry provides substantial and sustainable source of livelihood to the marginal society of Africa (Djimon et al., 2024), Russia (Milchevskiy et al, 2020), South America (Rebollo-Morales et al 2021), and Asia (Bhateshwar et al, 2022).

Sheep breeds habituated in different agro-climatic zones of India have evolved over several generations of natural selection and domestication each with specific characteristics, thus creating rich biodiversity with 46 recognized breeds (ICAR-NBAGR**,** 2025). Conversely, FAO World Watch list (Scherf, 2000) reports **60** breeds in the subcontinent. Most of these are well-suited to their local climates and are known by traditional or geographic names (Iyue, 2011), necessitating their characterization. Lanari et al. (2003) emphasized characterization of livestock breeds as the first approach for sustainable use of animal genetic resources.

Andhra Pradesh is the highest sheep populous state in India having about 24 per cent of the nation's sheep population, but sixty-six per cent of which is still under non-descript breeds (Report, 2019). The state which mostly falls in the semi-arid climatic region has only two recognized sheep breeds: Nellore (Acharya, 1982) and a recently characterized Macherla sheep (Reddy et al., 2021: Mishra et al., 2021) with Accession No.: India_Sheep_0100_Macherla _14045 (ICAR-NBAGR, 2025). Another such lesser-known genetic group is *Gaddabolli* sheep, with its home tract in the dry land areas of Prakasam, Bapatla, Guntur and Palnadu districts of Andhra Pradesh, are distinct in their phenotype and are distinguishable from Nellore breed. The local farmers prefer this sheep to Nellore due to growth and twinning rate which is about 20 to 25 per cent in the flocks that is uncommon in most of the Indian sheep breeds. Phenotypic characterization, referring to identifying distinct breed populations and describing their characteristics within a given production environment (FAO, 2012) is more important for livestock thriving well under changing climatic conditions (FAO, 2015). Identification of populations involves the description and documentation of the physical traits of a breed (Rege, 1992) and is the first phase of characterization (Gizaw et al., 2007). The analysis of the different zootechnical indices pave the way for the classification of livestock breeds based on type and function between breeds within species (Djaout et al., 2018; Esquivelzeta et al., 201). The presence of these sheep in the region with unique phenotype, prompted to undertake the study and establish their phenotypic and morphometric characters and analyse the pattern of phenotypic diversity within the population.

Material and Methods

Demography and identification of purebred flocks

Primary characterization and documentation of *Gaddabolli* sheep was undertaken in farmer's flocks in ten mandals (sub division of revenue blocks) of Andhra Pradesh state across Prakasam, Bapatla, Guntur and Palnadu districts, where this genetic group are abundantly distributed and presumed to be their breeding tract. The bordering villages showing decline in number of breedable females and proportionate increase of other sheep genetic groups such as Nellore and Macherla Brown sheep were marked as the limits of breeding tract, thus the habitat and distribution were ascertained.

Collection of data for phenotypic characterization

All the four districts having this genetic group were considered for the study. The mandals with this genetic group and their adjoining mandals were identified and the sample villages were selected using Simple Random Sampling without Replacement (SRSWOR) method with each mandal as single stratum. The first stage units were census villages. From each stratum (mandal) about 10% of villages were selected. The second stage units were farmers / shepherds and ultimate third stage units are animals belonging to the particular breed. Data was recorded on 3675 animals which are maintained by local farmers in the 27 sampled flocks from 15 villages (Table1). Personal interviews were conducted with shepherds and information was collected on a pre-defined questionnaire for every purebred flock sampled in the area.

Physical features and appearance

The breed characters of sheep were studied in compliance with the descriptors and guidelines of FAO (2012) and ICAR-NGABR (2016). Discrete or categorical variables such as colour of hair coat, coat colour pattern, shape and orientation of horns, horn colour, orientation of ears; head profile, tail type and shape were recorded on each animal sampled in the flock.

Biometrical Measurements

The measurements (FAO, 2012) were recorded after making the animal stand squarely on an even ground and assume natural posture for accurate readings. Body weights for various age groups were taken with a circular spring balance in the morning before the animals were let out for grazing. In the case of adult ewes only non-pregnant animals were considered. Body measurements were taken with a standard measuring tape to the nearest unit centimeter (cm). From the measurements recorded the zootechnical indices were calculated according to Salako (2006), Chacon et al. (2011), and Costa et al. (2014).

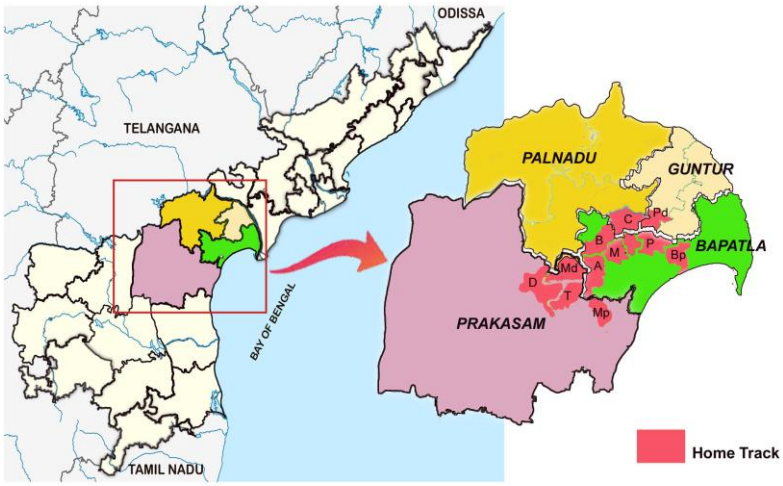


Fig 1. Demographic distribution of Gaddabolli sheep in Andhra Pradesh

D: Darsi, T: Talluru, Md: Mundlamuru, Mp: Maddipadu, A: Addanki, B: Ballikaruva, M: Marturu, P: Paruchuru, Bp: Bapatla, C: Chilakaluripeta, Pd: Pedanandipadu

Table 1. Details of the location and number of animals surveyed

District	Mandal	Village	Sampled Population				
			Number of flocks	Rams	Ewes	Lambs	Total
Prakasam	Darsi	East Veerayapalem	2	10	135	60	205
		Ramchandrapuram*	1	5	21	75	101
		Ganeshwarapuram	2	10	136	60	206
		Botlapalem	1	2	62	22	86
	Thalluru	Doskayalapadu	2	10	234	56	300
	Mundalmuru	Bhimavaram	1	8	115	45	168
		Purimetla	2	3	128	25	156
Bapatla	Ballikaruva	Guntupalle	2	11	287	73	371
	Addanki	Dharmavaram	2	9	206	39	254
	Paruchuru	Ramanayapalem	1	7	204	62	273
	Marturu	Jonnathalli	1	10	202	60	272
		Nagarajupalle	1	12	273	57	342
	Bapatla	Cheruvu	3	12	213	45	270
Palanadu	Chilakaluripeta	Pasumaaru	3	12	328	80	420
Guntur	Pedanandipadu	Varagani	2	12	215	24	251
	Grand Total		**27**	**133**	**2759**	**783**	**3675**

*Ram lamb unit

Classification and standardization of data

The data collected were collated and scrutinized for the outliners. The descriptive statistics were computed. Data were adjusted for the effect of sex of the animal and were studied on all the morphometric traits at different age groups. The data was analyzed using General Linear Model of SPSS statistics base 17 (2008).

Results and Discussion

Most of the sheep breeds in India are recognized by ethnic and geographic nomenclatures (Iyue, 2011) and are distinguishable by differences in appearance, conformation and dimension. The present genetic group of sheep under study is popularly known as *Gaddabolli* in vernacular language due to its patchy coat colour (Gadda= dry & hilly are, bolli = vitiligo patches). During the survey, it was recorded from the elderly local farmers that these sheep thrived in the area from very long past, known for attractive appearance and frequent twinning in the flocks.

Demographic distribution and description of the breeding tract

The breeding tract of this sheep is confined to bordering mandals of Prakasam, Bapatla, Guntur and Palnadu districts extended across the two Agroclimatic zones in Peninsular India- the Southern Plateau and Hills Region and, the East Coast Plains and Hills Region. The climate in this region is semi-arid and classified as tropical savanna climate. Red loamy, black cotton and sandy loams are the predominant soils apart from red sandy, gravelly red, lateritic soils. The region has hot and dry summers, mild and dry winters, receiving rainfall from South West (388.3 mm) as well as North-East (393.7 mm) monsoon. The mainly grown crops include groundnut, cotton, paddy,

sugarcane, millets, maize, pigeon pea, black gram and sunflower. The soils are well drained with low Nitrogen content.

The study revealed that the distribution of *Gaddabolli* sheep (Fig.1) are predominantly distributed in Darsi, Thalluru, Mundlamuru and Maddipadu mandals in Prakasam district; Chilakaluripeta mandal in Palnadu; Pedanandipadu mandal in Guntur district; Ballikaruva, Addanki, Marturu, Paruchuru, Bapatla mandals in Bapatla district of Andhra Pradesh. Though similar genetic group of animals are found in Kurichedu, Nagulapadu of Prakasam, and Chirala of Bapatla district, the number of true to type flocks dwindled in number and mixed flocks were observed.The survey revealed that *Gaddabolli* sheep population is approximately 76.3 per cent of the total sheep population in the breeding tract and Darsi mandal recorded maximum number of such sheep.

Out of 27 flocks enumerated in the breeding tract, 85.2 per cent were maintained as pure flocks (Fig.2) and the rest were mixed flocks containing other breeds or nondescripts in varying proportions. Out of the 3675 *Gaddabolli* sheep that were enumerated, 14.66 per cent were lambs, 17.14 per cent yearling and 68.19 per cent were adults.

Breed characteristics

Morphology: Morphology and appearance of *Gaddabolli* were studied from 539 lambs, 630 yearlings, 124 adult rams and 2382 ewes. The animals were medium to large in size. The ram and ewe of *Gaddabolli* are depicted in Fig. 3. In this genetic group two different coat colour patterns; predominantly patchy (75.4 %) and other plain white (24.6 %) were observed (Fig 4). The body hair coat colour was white, with mostly brown patches around the orbital region of eye, neck and shoulder region, back, knee, hock and pastern region and very few sheep were with black patches. Body skin colour was without any pigment (white) and in the surveyed flocks majority of the observed animals were with hairy coat type (97.2%) and rest were coarse (2.8%). The tail type was thin, but two sheep in the observed flocks were with thick at base. The shape of the tail was cylindrical and straight. The back of these sheep was straight and rump was slopy. The hooves were brown coloured.

Fig 2. Flocks of true to type Gaddabolli sheep

Fig 3. Adult Gaddabolli ram and ewe

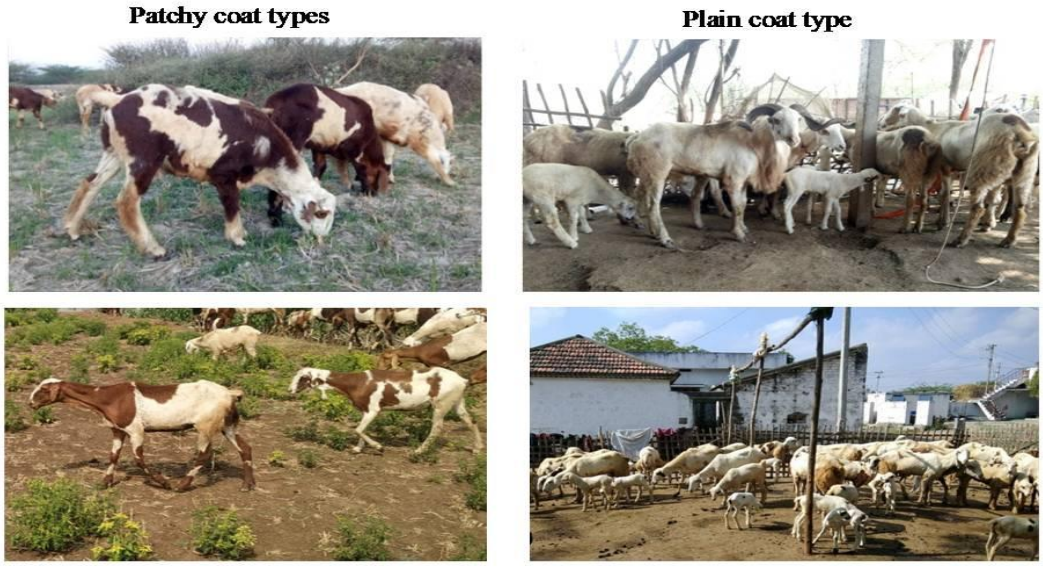
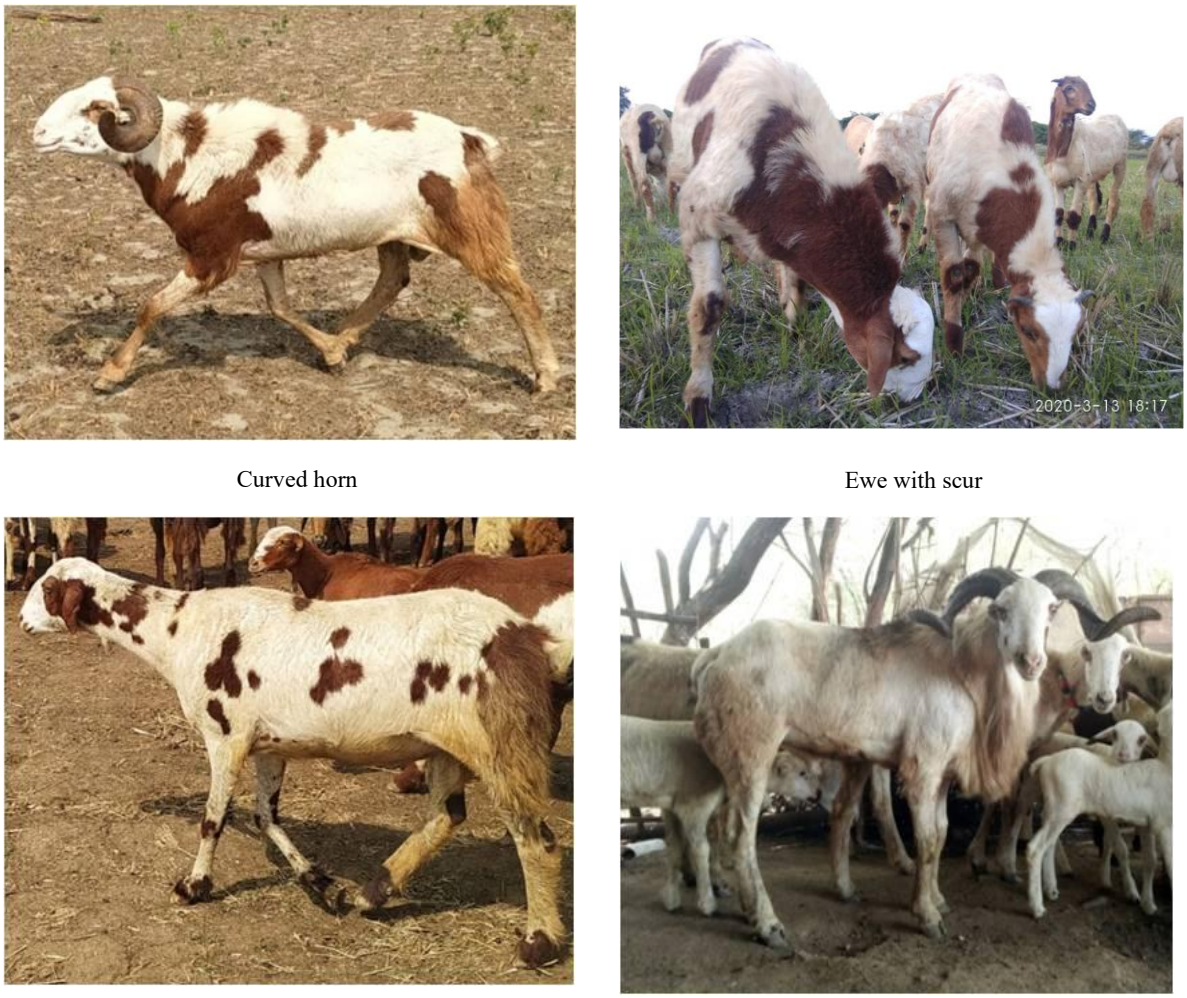


Fig 4. Coat Colour variants of Gaddabolli sheep



Curved horn

Ewe with scur

Polled ewe

Spiral horns

Fig 5. Horn shapes in Gaddabolli sheep

Fig 6. Ear orientation in Gaddabolli sheep

Table 2(a). Least-squares mean (±SE) of body measurements (cm) of lambs

Character/Age	Birth	3 months	6 months	9 months	12 months
n	M = 15, F=162	M = 40, F=167	M = 17, F=138	M = 60, F=149	M = 46, F=375
Height at withers (cm)					
Overall	42.5±0.4	59.3±0.2	63.8±0.3	72.0±0.1	73.6±0.1
Male	43.3±0.8	59.2±0.4	64.0±0.5	72.1±0.2	73.7±0.3
Female	41.7±0.3	59.4±0.2	63.4±0.1	72.1±0.1	73.4±0.1
Body length (cm)					
Overall	48.4±0.5	72.7±0.2	73.6±0.1	75.3±0.1	78.4±0.1
Male	49.5±1.0	72.5±0.4	73.8±0.3	75.3±0.2	78.3±0.1
Female	48.2±0.3	72.8±0.2	73.5±0.1	75.2±0.1	77.3±0.1
Chest girth (cm)					
Overall	30.6±0.3	55.1±0.23 (207)	66.7±0.5	77.1±0.4	77.3±0.2
Male	31.0±0.7	55.4±0.4	66.4±0.9	77.2±0.7	77.3±0.3
Female	30.2±0.2	54.8±0.2	67.01±0.3	76.9±0.4	77.2±0.1
Paunch girth (cm)					
Overall	38.3±0.6	50.2±0.5	54.3±0.6	73.6±0.3	73.9±0.4
Male	39.7±1.1**	51.6±0.8**	56.4±1.2**	77.5±0.5**	77.7±0.8**
Female	36.8±0.3	48.8±0.4	52.1±0.4	69.5±0.3	70.2±0.3
Face width (cm)					
Overall	6.5±0.1	7.9±0.1	8.6±0.1	10.4±0.1	10.2±0.1
Male	6.8±0.2*	7.9±0.2	8.6±0.2	10.3±0.1	10.2±0.2
Female	6.1±0.1	8.0±0.1	8.6±0.1	10.5±0.1	10.1±0.1
Tail length (cm)					
Overall	8.1±0.2	9.0±0.1	9.3±0.1	10.0±0.18	12.1±0.12
Male	8.3±0.4	9.1±0.2	9.5±0.3	10.3±0.31*	12.5±0.23*
Female	7.9±0.1	8.9±0.1	9.0±0.1	9.6±0.20	11.7±0.08
Ear length (cm)					
n#	M = 4, F=68	M = 18, F=77	M = 3, F=66	M = 7, F=66	M = 16, F= 182
Overall	11.1±0.7	11.7±0.4	11.7±0.9	11.8±0.56	12.0±0.33
Male	9.8±1.5	11.2±0.7	11.0±1.7	11.8±1.07	12.3±0.65
Female	12.5±0.3	12.3±0.3	12.4±0.4	11.8±0.85	11.8±0.19

*Significant (P<0.05) **Highly Significant (P<0.01); M=Male, F=Female; # The number of observations differed due to presence of rudimentary ears

The colour and other morphological characters of *Gaddabolli* sheep were clearly distinct from other sheep breeds of Andhra Pradesh (Nellore and Macherla Sheep) that were described by Acharya (1982), Prasanna (2019) and Reddy et al. (2021). Though Palla variety of Nellore breed is also white plain in coat colour with pendulous ears, the plain coat colour type in *Gaddabolli* sheep differs in having cream or brown patches around the eyes (orbital region), and light patches sparingly distributed over the body and with tubular type of the ears.

All the rams were horned that were mostly brown coloured (73%) and the rest were black. Characteristic curved shaped horns were observed in most of the rams (54.7 %) followed by cork screw (23.8 %) and spiral shaped (9.5 %) horns. Rudimentary horns were not uncommon and 11.9 % per cent of the adult rams were this type (Fig 5). The orientation of the horns was lateral. Out of all the ewes, 54.8% were horned and of those horned ewes, the vast majority (92.1%) had rudimentary horns, while the rest had scurs. Cylindrical and straight tails is characteristic of *Gaddabolli* sheep, in contrary to curved tails in Macherla (Reddy et al., 2021) and Vizianagaram sheep (Prasanna, 2019). The nose line was straight in all the sheep. Tubular (44.85%) and rudimentary (44.85%) type ears are predominant and equally frequented in this genetic group and few (10.3%) were having pendulous ears (Fig 6) contrary to the observations in other native sheep breeds of Andhra Pradesh. Though *Gaddabolli* sheep were also with convex heads the convexity was not prominent. Muzzle was brownish white coloured in most of the sheep with a rarity of white colored. Wattles were present in majority of these sheep (93.2 %) and were observed in both the sexes. Though the coat colour pattern of Vembur sheep with its native tract in Tamil Nadu seems to be similar to Gaddabolli, these sheep are taller, differ having small patches scattered on back, hairy coat with pale brownish white muzzle and convex head profile. Selvakumar et al. (2016) reported Vembur sheep as medium sized animals, with

head profile as straight and absence of wattles in both the sexes contrary to *Gaddabolli*. The perusal of literature and reports belonging to various breeds from neighbouring states in Southern India unveils the phenotypic distinctness of *Gaddabolli* sheep.

***Biometric Traits**:* The least-squares means of body measurements of *Gaddabolli* lambs and adults are presented in Table 2a and 2b. The pooled means for height at withers at full mouth of age was 82.6 ± 0.1 cm. The overall least-squares mean pooled over adults was 81.0 ± 0.1, rams measured 81.4 ± 0.2 and ewes 80.6. ± 0.1. Sex had no significant effect (P>0.05) on height at any stage of growth except at full mouth age group. The least-squares mean for body length at full mouth of age pooled over sex of the animals was 86.0 ± 0.1 cm, for chest girth was 87.5 ± 0.1 cm and the paunch girth was 83.1 ± 1.2 cm. Rams measured significantly (P<0.05) higher than ewes or all the three traits.

Table 2(b). Least-squares mean (±SE) of body measurements (cm) of adults

Character /Age	Two-tooth	Four-tooth	Six-tooth	Eight-tooth (Full mouth)	Broken mouth (>84 months)	Overall Adults
n	M = 9, F=492	M = 24, F=526	M = 22, F=583	M = 69, F=762	M = 0, F=19	M = 124, F=2382
Height at withers (cm)						
Overall	76.9±0.1	79.4±0.1	82.0±0.1	82.6±0.1	83.0±0.1	81.0±0.1
Male	76.9±0.1	79.3±0.1	82.0±0.1	82.4±0.1	-	81.4±0.2**
Female	76.8±0.1	79.4±0.0	82.0±0.1	82.7±0.0**	83.0±0.1	80.6±0.1
Body length (cm)						
Overall	79.8±0.1	81.4±0.1	84.2±0.1	86.0±0.1	87.8±0.1	85.5±0.1
Male	79.8±0.1	80.3±0.1	83.6±0.1	85.6±0.2	-	84.9±0.3**
Female	79.8±0.0	80.4±0.0	83.4±0.1	84.4±0.1**	87.8±0.1	84.1±0.1
Chest girth (cm)						
Overall	73.2±0.7	84.2±0.1	86.3±0.1	87.5±0.1	88.4±0.1	84.5±0.3
Male	73.4±1.4	84.0±0.1	86.2±0.1	87.3±0.1	-	85.4±0.5**
Female	72.9±0.1	84.4±0.0*	86.3±0.1*	87.8±0.1	88.4±0.1	83.6±0.1
Paunch girth (cm)						
Overall	71.4±0.9	78.5±0.7	82.3±0.8	83.1±1.2	47.3±0.6	76.7±0.5
Male	76.4±1.7**	82.9±1.4**	85.8±1.5**	88.6±2.3**	-	80.2±1.0**
Female	66.4±0.5	74.1±0.3	78.8±0.3	77.5±0.3	47.3±0.6	73.3±0.2
Face length (cm)						
Overall	26.4±1.0	25.6±0.7	25.2±0.4	23.4±0.4	25.52±0.9	24±0.3
Male	24.3±2.1	25.3±1.3	24.9±0.8	24.0±0.8	-	24.6±0.6
Female	24.4±0.3	25.8±0.2	25.5±0.1	22.8±0.2	25.5±0.9	24.6±0.1
Face width (cm)						
Overall	11.3±0.3	10.3±0.2	10.0±0.1	9.6±0.1	7.1±0.5	10.1±0.1
Male	11.4±0.7	10.5±0.4	10.7±0.2**	10.1±0.2**	-	10.4±0.2**
Female	11.1±0.1	10.1±0.1	9.4±0.1	9.1±0.1	7.1±0.5	9.8±0.1
Tail length (cm)						
Overall	10.4±0.3	10.9±0.2	11.8±0.3	11.6±0.2	13.5±0.4	11.1±0.1
Male	11.0±0.5*	10.9±0.3	11.8±0.5	11.2±0.3	-	11.0±0.2
Female	9.9±0.1	10.9±0.1	11.8±0.1	12.1±0.1**	13.5±0.4	11.1±0.1
Ear length (cm)						
n#	M = 4, F=257	M = 15, F=287	M = 10, F=314	M = 30, F=423	M = 0, F=1	M = 59, F=1282
Overall	11.4±1.7	12.1±0.8	13.0±0.4	12.3±0.3	16.0±0.0	12.3±0.3
Male	10.5±3.3	11.8±1.6	13.6±0.8	12.1±0.6	-	12.2±0.6
Female	12.2±0.4	12.5±0.4	12.4±0.1	12.4±0.1	16.0±0.0	12.4±0.1
Horn length (cm)						
n#	M = 5, F=54	M = 10, F=10	M = 17, F=11	M = 13, F=33	M = 0, F=7	M = 45, F=108
Overall	32.9±2.1	26.0±1.1	34.9±1.0	37.4±2.9	14.6±0.7	36.0±1.2
Male	39.0±4.0**	38.5±1.6**	54.8±1.3**	54.8±4.2**	-	45.7±2.0**
Female	11.9±1.2	13.6±1.6	14.8±1.6	14.9±3.0	14.6±0.7	16.3±1.2

*Significant (P<0.05) **Highly Significant (P<0.01); M=Male, F=Female; # number of observations differed due to presence of rudimentary ears/horns

Table 3(a). Least-squares mean (±SE) of body weights (Kg) of lambs from birth to 12 months

Effects	Birth	3 months	6 months	9 months	12 months
n	M=15, F=162	M=40, F=167	M=17, F=138	M=60, F=149	M=46, F=375
Overall	2.8±0.1	14.2±0.1	18.1±0.1	22.2±0.1	25.0±0.1
Male	2.8±0.1	14.1±0.2	18.2±0.2	22.2±0.1	25.0±0.1
Female	2.9±0.0	14.2±0.1	17.9±0.1	22.3±0.1	25.0±0.0

** Significant (P<0.01). M=Male, F=Female

Table 3(b). Least-squares mean (±SE) of body weights (Kg) of adults

Effects	2-tooth	4-tooth	6-tooth	8-tooth	Broken mouth	Overall adults
n	M=9, F=492	M=24, F=526	M=22, F=583	M=69, F=762	M=0, F=19	M=124, F=2382
Overall	35.8±0.1	38.4±0.1	40.5±0.1	43.0±0.1	44.8±0.1	40.5±0.1
Male	35.8±0.1	38.3±0.10	40.4±0.1	42.6±0.1	-	40.9±0.3**
Female	35.8±0.1	38.4±0.1	40.6±0.0	43.5±0.1**	44.8±0.1	40.1±0.1

*Significant (P<0.05) **Significant (P<0.01). M=Male, F=Female

Table 4. Zootechnical indices (Mean ± SD) of Gadda bolli sheep at different ages

Trait	Formula	3 months (n= 207)	6 months (n= 155)	12 months (n= 421)	2 teeth (n= 501)	4 teeth (n= 550)	6 teeth (n= 605)	8 teeth (n= 484)
Length Index (LI)	BL/HW	1.1±0.01^{f}	1.1±0.01^{e}	1.0±0.01^{d}	1.0±0.01^{d}	1.0± 0.01^{c}	0. 9±0.001^{a}	0.9±0.001^{b}
Cephalic index (ChI)	(FW/FL)x100	45.3±0.7^{d}	46.6±0.4^{e}	41.7±0.3^{c}	42.3±0.2^{c}	39.9 ± 0.3^{b}	37.5±0.2^{a}	41.5±0.2^{c}
Baron & Crevat / Conformation Index (CI)	CG^2 / HW	74.9±0.05^{a}	79.9±0.04^{b}	82.6±0.02^{c}	86.4±0.1^{d}	89.7±0.02^{e}	90.8±0.02^{f}	92.2±0.02^{g}
Proportionality Index (PrI)	(HW/BL)x100	91.4±0.04^{a}	93.4±0.07^{b}	96.2±0.04^{c}	96.2±0.1^{d}	98.7±0.04^{e}	101.0±0.01^{f}	100.8±0.02^{g}
Thoracic Development (TD)	CG/HW	1.1±0.01^{a}	1.1±0.01^{b}	1.1±0.01^{c}	1.1±0.01^{d}	1.1±0.01^{e}	1.1±0.01^{f}	1.1±0.01^{g}
Area Index	HWxBL	4793.6±4.1^{a}	5188.4±6.8^{b}	5745.7±4.5^{c}	6136.1±03.6^{d}	6395.1±4.0^{e}	6657.1±1.9^{f}	6754.1±1.6^{g}
Bodycapacity1	BWt/BL	0.2±0.01^{a}	0.2±0.01^{b}	0.3±0.01^{c}	0.4±0.01^{d}	0.5±0.01^{e}	0.5±0.01^{f}	0.5±0.01^{g}
Bodycapacity2	BWt/CG	0.2±0.01^{a}	0.2±0.01^{b}	0.3±0.01^{c}	0.4±0.01^{d}	0.5±0.01^{e}	0.5±0.01^{f}	0.5±0.01^{g}
Compact Index	BWt/HW	21.5±0.1^{a}	25.8±0.08^{b}	33.6±0.04^{c}	46.6±0.01^{d}	48.4±0.01^{e}	49.5±0.02^{f}	51.4±0.03^{g}
Body Index (BI)	(BL/CG)x100	102.8±0.03^{a}	99.9±0.07^{b}	98.68±0.04^{c}	98.1±0.1^{d}	95.4±0.04^{e}	94.1±0.03^{f}	93.9±0.02^{g}

Means with different superscript differ significantly (P<0.01) in a row; Figures in parenthesis are number of observations

The observation of head profile revealed that the face length and width were 23.4 ± 0.4 and 9.6 ± 0.1cm respectively at full mouth. Sex of the animals had highly significant (P<0.01) effect on face width. The overall means of ear lengths pooled over adult age groups were 12.3 ± 0.3 cm respectively and for tail length at full mouth was 11.6 ± 0.2 cm. Horn length measured 54.8±4.2cm, rams having significantly (P<0.01) longer horns than ewes (14.6±0.7 cm).

The sex wise and overall means for height at withers, body length and chest girth in *Gaddabolli* sheep at 12 months of age were higher than the reports on Vizianagaram sheep (Gangaraju, 2010; Prasanna, 2019). The adult *Gaddabolli* sheep measured more for height at withers, chest girth, body length compared to other sheep breeds of the region; Nellore (Acharya, 1982; Rani, 2012), and Macherla (Reddy et al., 2021). However, the Paunch girth was less than those reported in Nellore (Rani, 2012) and Macherla (Reddy et al., 2021) sheep. The sex wise and overall means for height at withers, body length and chest girth in the adult *Gaddabolli* sheep measured more compared to other south Indian sheep breeds, Nellore (Acharya, 1982; Rani, 2012), Vizianagaram sheep (Gangaraju, 2010; Prasanna, 2019), and Macherla (Reddy et al., 2021).

Traits such as ear length and height at withers are directly related to adaptive attributes of Animal Genetic Resource (AnGR), and are relevant to phenotypic characterization studies. The length of the ears of this genetic group indicate that they are well adapted in the region as the long ears are suggestive of adaptation to dry and hot climates (FAO, 2012). The pooled means for body weight at birth, three months, six months, nine months and 12 months of age were 2.8 ± 0.1, 14.2 ± 0.1, 18.1 ± 0.10, 22.2 ± 0.1 and 25.01 ± 0.1 kg respectively (Table 3a). No significant difference between the weights of rams and ewes below 12 months was observed (P>0.05). The pooled body weights at two-tooth, four-tooth, six-tooth and full mouth stages (Table 3b) were 35.8 ± 0.1, 38.4 ± 0.1, 40.5 ± 0.1 and 43.0 ± 0.1 kg respectively. The overall body weights of adults were 40.9±0.3kg for males and 40.1±0.1 kg for females. In the present study no significant difference between body weights of males and females could be observed at all stages of growth except at full mouth age (P<0.01).

In the present study no significant difference between body weights of males and females could be observed at all stages of growth except at full mouth age. The body weights of *Gaddabolli* sheep at adult pooled over sexes (40.9±0.3 kg for males, 40.1±0.1 kg for females) were more than that observed on Vizianagaram (Gangaraju, 2010; Prasanna, 2019) and comparable to the findings on Nellore (Rani, 2012) but less than Macherla (Reddy et al., 2021). The substantial amount of variation observed for morphometric and growth traits indicate existence of genetic variability giving scope for improving the trait performance by selection.

Zootechnical indices*:* Sheep and other livestock were characterized in terms of morpholohy (Cerqueira et al., 2011; Esquivelzeta et al., 2011; Handiwirawan et al., 2011), type and function utilizing the zootechnical indices (Solako, 2006; Costa et al., 2014; Djaout et al., 2018; Olaniyi et al., 2018; Nunes et al., 2020; El-Bouyahiaoui et al., 2021). In the present study the zootechnical indices were determined to ethologically classify *Gaddabolli* sheep. The means along with their standard deviations for the body indices at different stages of growth of *Gaddabolli* sheep were presented in Table 4. Among the indices calculated the length index is considered as functional and the rest are ethological. Ethological index could be used for breed description. The *Gaddabolli* sheep having lengthier face (24±0.3 cm) are dolichocephalic. Body length and height at withers are indicators of bone growth and chest girth for development of muscle, bone and fat (Pomeroy 1955). The cephalic index facilitates in identification of breed, origin and relationship between species (Jewel, 1963) and thus the analysis revealed that this genetic group to be dolichocephalic. The cephalic index (ChI) is not affected by managemental and environmental factors (Cerqueira et al., 2011). The decrease in value of the body index is evident as with increase in age in these sheep. The values being more than 90 these sheep can be considered as Longiline indicating a balance between the height and heart girth of the animals aiding in its ability to balance on the ground. The length index (>1.0) suggest that these sheep are with oblong body. The greater Baron & Crevat index (>1), TD index (nearing 1.2) categorizes them into a robust animal group having good thoracic development, The Conformation index also known as Anamorphosis index is indicative of the meat production aptitude (Sabbioni et al. 2016) revealing the better meat orientation aptitude of the breed. However, on perusal of the relevant literature the authors observed that the in most of the instances the indices

aimed to assess the type and functionality in other livestock species viz. cattle, horse, swine were directly adopted to categorize goat and sheep also. Though the derivation of the indices could be similar across the species, the applicability of them to predict the type and functionality should be used with caution and reviewed critically. The authors opine that the prediction of type and function using indices specific to sheep and goat should be developed.

Husbandry Practices: The flock size of pure Gaddabolli ranged from 55 to 196 sheep, and the flocks with mixed type were with upto 340. Gaddabolli sheep were reared under extensive system, housing mostly during nights in open system managemental practices similar to that adopted for Nellore sheep. These sheep farmers depend mostly on common grazing land for the feed and fodder requirement of the flocks.

Conclusion

Body measurements and growth pattern are useful for the description of a breed. On perusal of the observations on other south Indian sheep breeds having home tract adjoining the native tract of this genetic group, it could be comprehended that *Gaddabolli* sheep are taller and large sized sheep and, can be identified with distinct coat colour and differentiated phenotypically from other breeds existing in and around Andhra Pradesh. Based on the population size and phenotypic distinctiveness *Gaddabolli* may be considered for recognition as a descript breed of sheep of Andhra Pradesh and suitable breeding programmes advocated for sustainable production and growth.

Ethical Statement This study does not involve any animal testing and were not subjected to any experimentation. The weights and measurements were collected by a qualified veterinarian from live animals after the written informed consent from the rightful owners of the animals.

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Conflicts of interest The authors declare that they do not have any conflict of interest.

Data availability statement The data that support the findings of this study are not openly available as it is part of a ongoing study and being used in associated research project.

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