

Gynomicry in the Dwarf Gwembe breed from Zambia

Pere M Parés-Casanova¹ (peremiquelp at prodan dot udl dot cat) #, Andrew Kataba², Edwell S Mwaanga², Humphrey Simukoko²

¹ Department of Animal Production, University of Lleida, Catalunya, Spain. ² Department of Biomedical Sciences, University of Zambia, School of Veterinary Medicine, Lusaka, Zambia

: corresponding author

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Abstract

Sexual size dimorphism is a widespread phenomenon in different animal taxa, including the subfamily of goats and sheep. The purpose of this research was to study the sexual dimorphism of males and females of Gwembe Dwarf Goat based solely on cephalic indexes. Eleven indices were calculated for 30 dry skulls of adult Gwembe Dwarf Goat specimens aged 18 months and older. Sexes appeared no significantly different. This form of heterosexual mimicry must be viewed as simply as strongly human-selected for. The importance of controlled competition is capable of countering antagonist to peer competition, so no sexual competition appears. When the artificial nature of sexual competition is taken into account, Darwin's theory of sexual selection becomes not applicable to domestic goats -or at least to the Dwarf Gwembe breed-, which fail to develop the expected degree of sexual dimorphism. The breed can then described as a monomorphic and, more concretely, gynomic -imitation of female secondary sexual characters by males-.

Introduction

Local goat has great genetic resource potential that can be utilized as a source of superior breeding formulation adaptable to local conditions. FAO (2007) reported that breeds of local livestock are important and should be protected because of their ability to survive under low-quality feed, unfavourable local climatic conditions, and their high resistance to local diseases and parasites. These abilities are critical in cross-breeding ventures aimed at sustaining genetic pools that have evolved through centuries within the given locality.

Phenotypic and morphological characteristics are still commonly used by researchers and practitioners in characterization of animals breeds (Batubara et al., 2011). The morphologic and morphometric studies of the head region does not only reflect contributions of genetic and environmental components to individual development, but describe genetic and ecophenotypic variation (Monfared et al., 2013). Until now, there have been numerous comparative morphological studies of the skull anatomy in many of the mammalian species. In particular, in small ruminants the morphological structures and geometrical measurements of the skull bones have been examined to detect the distinguishing features of these species (Onuk et al., 2013) and breeds (Sarma, 2006; Shawulu et al., 2011; Monfared et al., 2013). To the best knowledge of the authors, there is no literature data on the morphometric parameters of the head region applied anatomy in the Zambian native goats. The thesis by Babagana Ahmadu (2001) does not contain detailed information on head conformation other than the head length and width for male and female goats of unknown breed. Parés et al. (2012a) provide an insight into the skull morphostructure of the breed, but with no distinction between sexes and basing their study only in linear measurements. The recent thesis by A. Kataba (2014, in press) is the most exhaustive study of the head conformation of this breed till the moment. All these morphometric studies will allow an applied anatomy of the head region and they will undoubtedly aid to better the description of the breed. Furthermore, the obtained results can provide important baseline data for further comparative studies on the skull of other African native goat breeds.

An index is a mathematical expression that represents the relationship between two numbers, showing the number of times one value contains or is contained within the other. Indexes can generally be divided into two categories. Descriptive indexes can reflect the skull conformation and, if they are chosen as the typically "zoethnological" ones, can be used not only for describe properly a breed, as for comparative studies, too.

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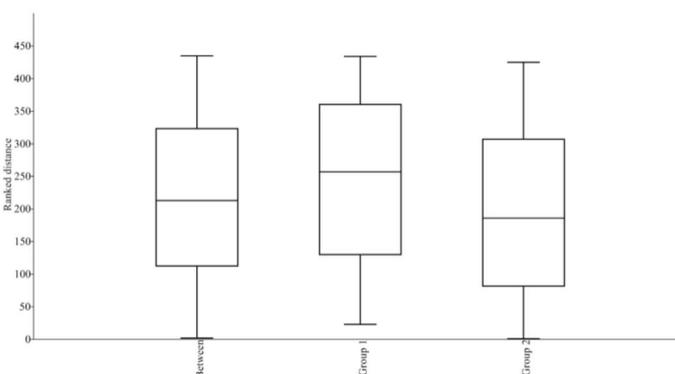


Figure 1. Box-plot of ANOSIM (ANalysis Of Similarities) test for comparing sexes, based on

The purpose of this research was to study the sexual dimorphism of males and females of Gwembe Dwarf Goat based solely on cephalic indexes. Mahalanobis distance measure. Sexes are no significantly different ($R=-0.02$, $p=0.740$). Group I: females; Group II: males.

The Gwembe Dwarf goat or locally known as "Mpongo" is a small breed with average weight of 35 kg for both males and females found in the Gwembe valley in Southern Province of Zambia. Well-adapted to hot and dry climatic conditions with low rainfall patterns, this breed is of multi colour coat variations ranging from completely black, brown, black and white, grey to white and brown- with horns of medium size and usually curved backwards (<http://dad.fao.org/>). Other goat breeds of Zambia include the Plateau Goat located on the plateau regions of Southern Province, the Sinazongwe district of the Southern and North part of the Gwembe Valley, and the imported Boer and Saanen (<http://dad.fao.org/>).

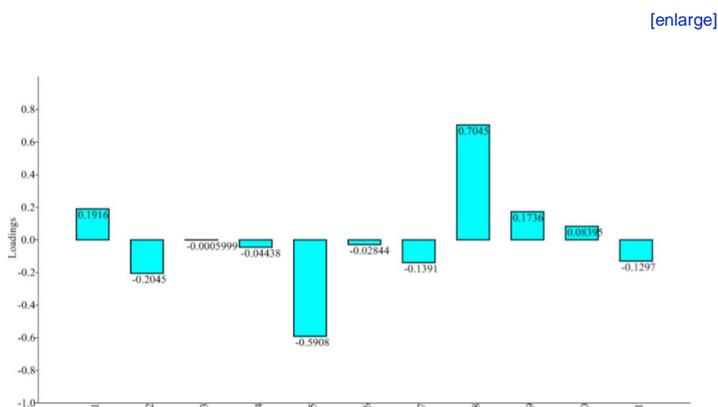


Figure 2. Component loadings for the eleven cephalic indices calculated. The figure shows to what degree the different original variables (given in the order along the x axis) enter into the Principal Component 1. Orbital index (5) and frontal index (8) appear as the most discriminative ones.

Materials and methods

Thirty dry skulls of adult Gwembe Dwarf Goat specimens aged 18 months and older were collected from five different local farms and studied. The age was determined on the basis of the growth of the third molar tooth (Dyce et al., 2002). All specimens used for this study showed no cranial deformities or scars. The total series included all specimens collected. For descriptive purposes, eleven indices were calculated according to Baranowski et al. (2009), Miller et al. (1964),

Miramontes et al. (2010), Parés et al. (2010) and Sarma (2006):

- 1) Skull/cephalic index: greatest frontal breadth / total length of the skull x 100.
- 2) Cranial index (neurocranium index): greatest neurocranium breadth / frontal length x 100.
- 3) Area of the foramen magnum: by using the formula $\frac{1}{2}pb$, where b=breadth and h=height of the foramen magnum.
- 4) Foramen magnum index: height of the foramen magnum / greatest breadth of the foramen magnum x 100.
- 5) Orbital index: orbital inner width / orbital inner height x 100.
- 6) Orbital area: $\frac{1}{2}ab$, where a and b are the halves of orbital inner width and height, respectively.
- 7) Facial index: facial width / facial length x 100.
- 8) Frontal index: least breadth between the orbits / frontal length x 100.
- 9) Nasal index: greatest breadth across the nasals/ greatest length of the nasals x 100.
- 10) Index 1: euryon-euryon / akrokranion-prosthion x 100.
- 11) Index 2: euryon-euryon / basion-prosthion x 100.

The method described by Von den Driesch (1976) was used for obtaining linear measurements.

Simple statistics were obtained for both sexes. To test the pattern of normality of distributions, the Shapiro-Wilk test was applied (Shapiro and Wilk, 1965). As some of the indexes presented no normal distribution ($p<0.05$), the non parametric ANOSIM (ANalysis Of Similarities) test for comparing sexes was selected, based on Mahalanobis distance measure. In a rough analogy with ANOVA, this test is based on comparing distances between groups with distances within groups (Clarke, 1993). Large positive R (up to 1) signifies dissimilarity between groups. The significance was computed by permutation of group membership, with 9,999 replicates, and Bonferroni-corrected p-value. Finally, a Principal components analysis (PCA) was used to find variables (components) accounting for as much as possible of the variance in your multivariate data (Davis 1986, Harper 1999), these new being linear combinations of the original variables. The component loadings were used to interpret the 'meaning' of the Principal Component 1. Statistical treatment was done with PAST v. 2.17c (Hammer et al., 2001).

Results

Table 1 shows simple statistics for both sexes. Sexes appeared no significantly different when considering all indexes ($R=-0.02$, $p=0.740$) (Figure 1). Component

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loadings are in Figure 2. Orbital index and frontal index appear as the most discriminative ones although they can't differentiate sexes, either (Figure 3). Principal component 1 explained a 60.6% of the variance and principal component 2 explained a 39.5%.

Discussion

While males and females obviously differ in their genitalia, sexual dimorphism - differences in male and female physiology, morphology or behaviour - often extends far beyond this. Sexual size dimorphism (SSD) is a widespread phenomenon in

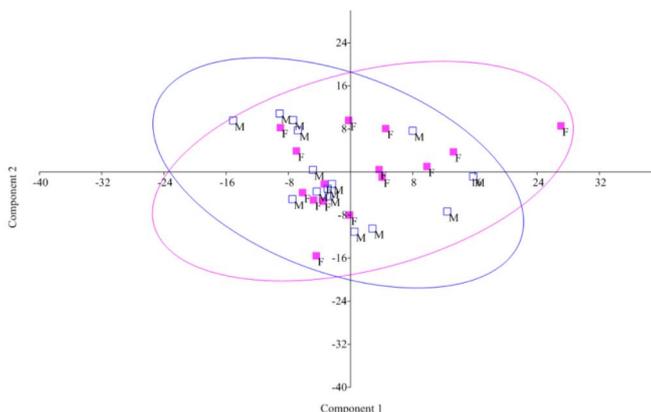


Figure 3. Principal Component Analysis for principal component 1 (60.6% of the explained variance) and principal component 2 (39.5% of the explained variance) using only orbital and frontal indexes. Sexes do not appear differentiated. 95% confidence ellipses.

	1	2	3	4	5	6	7	8	9	10	11
χ^2											
Min	49.1	57.3	2.0	76.1	87.0	27.8	51.5	96.4	38.0	34.6	40.6
Max	63.1	77.9	2.8	94.6	110.4	33.7	64.1	135.3	54.9	45.4	50.0
X	54.4	65.4	2.3	88.2	98.5	30.5	57.8	108.7	45.3	39.3	45.1
Std	3.97	6.41	0.22	5.80	6.15	1.92	2.99	10.11	4.57	3.16	3.05
CV	7.2	9.7	9.1	6.5	6.2	6.2	5.1	9.3	10.0	8.0	6.7
χ_i											
Min	49.7	57.1	1.8	81.0	87.0	27.9	54.3	97.8	36.8	36.2	39.7
Max	60.7	72.5	2.8	101.0	114.2	34.3	66.6	121.0	54.9	42.5	51.5
X	54.2	67.5	2.2	88.7	99.6	31.0	59.2	105.7	45.8	38.8	46.0
Std	2.77	4.23	0.29	5.61	8.90	2.20	3.83	6.77	6.43	1.84	3.10
CV	5.1	6.2	12.8	6.3	8.9	7.0	6.4	6.4	14.0	4.7	6.7
W	0.955	0.978	0.981	0.982	0.943	0.945	0.973	0.847	0.954	0.970	0.968
p	0.235	0.782	0.858	0.878	0.109	0.121	0.615	0.001	0.217	0.530	0.483

Table 1. Simple statistics for both sexes (n=15 for each). X: mean; Std: Standard deviation; CV: coefficient of variation (%); W: Shapiro-Wilk value for normality.

Domestication has affected certain characteristics, more in terms of their quantitative rather than qualitative expression (Mcpherson and Chenoweth, 2012). Also, on a global scale, environmental changes can have important phylogenetic implications for species which rely upon environmental cues for activities as migration, hibernation and breeding, especially when SD occurs in response to such cues (Mcpherson and Chenoweth, 2012).

Gwembe Dwarf Goat appeared with no sexual dimorphism. The answer to the question requires testing, but there are a number of plausible explanations. One would involve the viability costs of maintaining sexual difference. It is partially the Rensch's rule, the allometric law concerning the relationship between the extent of SSD and which sex is larger (i.e. larger species tend to exhibit higher ratios of male to female body size than do smaller species). In fact, Size Dimorphism Index [SDI, the ratio of mean size of one sex divided by mean size of the opposite sex (Lovich and Gibbons, 1992)] for the Gwembe Goat is 0.83 (male/female size) (data from Parés et al., 2012b), a rather low index typical of dwarf breeds. Other dwarf breeds are: Red Sokoto (Nigeria) which presents a SDI of 1.05, West African Dwarf a 1.1. Bergmann's rule is another empirical generalisation concerning body size in endothermic species. It states that within a species, body size varies such that individuals occupying colder environments tend to be larger than individuals who live in warmer environments. That could explain why in Europe, for instance, we can find larger (more eumetrical and hypermetrical breeds) than in Africa: Serrana, males averaging 70 cm withers height, presents a SDI of 1.25, White Rasquera Goat (70 cm) presenting a SDI of 1.3, as well is Saanen (85 cm), or Toggenburger (80 cm) presenting a 1.4, and so on. Examples would be numerous (data of average height and weight can be found in <http://dad.fao.org/>). An absolutely interesting review of this topic can be read in Polák and Frynta (2009).

But a mere explanation due to simple ecological reasons seems no to be absolutely sufficient and, as Parés-Casanova (2013) has demonstrated, ecological background not always can explain sexual dimorphism. Other explanations for the lack of sexual dimorphism could lie in the identical artificial selection of both sexes, with no sex fission. This selection would have the power to counteract selection for natural development of male secondary characters. The result in this case would be to reduce gender differences and aggression (equally sexual dimorphism

different animal taxa, including the subfamily of goats and sheep (Caprinae) (Polák and Frynta, 2009). Sexual dimorphisms (SDs) have evolved in mammals to assure greater reproductive success for individuals, usually males (Mcpherson and Chenoweth, 2012). Sexual selection and sexual dimorphism have remained intimately connected ever since, to the extent that sexual dimorphism has at times been used as a proxy of the strength of sexual selection in comparative studies.

may not mean sexual conflicts are resolved). If there is a common genetic architecture underlying sexually homologous traits, there is consequently a similar evolution of the sexes. The predation risk hypothesis can be ruled out by both the absence of important predators. The importance of controlled competition is capable of countering antagonist to peer competition, so no sexual competition appears. So this form of heterosexual mimicry must be viewed both as ecologically as human-selected for.

"From these various facts," Darwin (1871, p. 236) stated, "we may conclude that horns of all kinds, even when fully developed in both sexes, were primarily acquired by the males in order to conquer other males, and have been transferred more or less completely to the females, in relation to the force of the equal form of inheritance." Lande (1980) formulated this idea as a mathematical model of population genetics. In his words (p. 299) "...selection acting on one sex produces correlated responses in the characters of the opposite sex". Referring to the instances cited by Darwin, and including among his examples the tusks and horns of mammals, Lande (1980, p. 302) says, "Characters with subequal development in the two sexes, but which benefit only one sex, strongly suggest the involvement of correlated selective responses between the sexes, such that the second slow phase in the evolution of sexual dimorphism is still in progress". In other words, the presence of horns in females of some bovid species could occur simply because there was not strong selection either for or against their occurrence.

Monomorphism characterizes species in which a (presumed) absence of selection to develop distinctive secondary characters accounts for little or no sexual dimorphism. Into this term, andromimicry refers to the copying of male secondary characters by females. The imitation of female secondary sexual characters by males is called gynomimicry. Female mimicry of male secondary characters is only one form of intersexual mimicry, a phenomenon that is of widespread occurrence among vertebrates (Wickler, 1968). In many vertebrates, males can pass for females as long as they refrain from developing male secondary characters (Estes, 1991). Dwarf Gwembe breed from Zambia can then be described as a monomorphic and, more concretely, gynomimic breed.

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