Genetic Expression of Different Coat Colour Variants of Black Bengal Goat (BBG) in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAH performed the statistical analysis and wrote the first draft of the manuscript. Author AA conducted the study and collected data. Author AKFHB designed the study, wrote the protocol and checked final draft of the manuscript. Author MFA managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Aims: To investigate the genetic expression of different coat colour variants in Black Bengal Goat (BBG) of Bangladesh.
Study Design: CRD with non-orthogonal hierarchy.
Place and Duration of Study: This study was carried out at 3 rural village communities of Bhaluka Upazila in Mymensingh district of Bangladesh from 2009 to 2013.
Methodology: All goats in community breeding program under this study were ear-tagged and maintained under semi-intensive management system with three breeding strategies in progressive generations. Data were collected from a baseline survey for goat population study along with 3 progressive generations produced from the community foundation flocks. The colour distribution and the colours of kids from matings among different colour parents were observed and recorded accordingly. The recorded data were analyzed by "SPSS 20.0" statistical program.
Results: The highest colour populations of about 53% were solid black in colour and others being

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Bezoar (31%), black with Toggenbergpattern (9%), black with Dutch belt pattern (6%) and solid brown (only 0.5%). Sex and generation had no significant effect on coat colour expression, while, coat colour in different locations differed significantly. For the analysis of coat colour inheritance, two categories of offspring were considered in this study; one from known coat colour dams mated with unknown coat colour sire and another from known coat colour parents. In the earlier category, most of the offspring exposed their dam's coat colour when mated to unknown coat colour sires. For later category, there were varieties of coat colours offspring, produced from matings between two different or same colour parents.

Conclusion: Although the segregation of coat colours among offspring showed dominance of parents` colour, there were also offspring`s other than parents` coat colours. This might be due to polymorphism of coat colour gene in BBG.

1. INTRODUCTION

Bangladesh has only one goat breed of its own named popularly as "Black Bengal Goat (BBG)" which is estimated of about 90% of the total goat population and others being Jamnapari (popularly known as "Ram Chagol") and crosses between BBG and Jamnapari, Amin et al. [1]; Husain [2]. There are varieties of coat colour variants in the BBG. Husain [2] reported that about 80% of BBG is black in colour and others being solid white, solid brown, mixed grey or spotted. Chowdhury [3] also reported BBG to be mostly black in colour comprising 69% of the total goat population and rest being white stripe on black (13%), brown (5%), solid white (4%), black with white patches or brown with white or brown with black (9%).

People of different countries have special attention and choice on coat colour of goat. According to the observation of Hassen et al. [4], morphological differences have important socio-cultural and economic values to the Ethiopian communities; as a result, most farmers have specific consideration and choices for goat coat colours followed by body sizes. Banerjee et al. [5] who observed that colouration could be an adaptive trait or selected through farmers' preference for specific coat colour, Indetie et al. [6]; Manzi et al. [7]. In Ethiopia, goat coat colour has a direct effect on goat marketing value. Due to cultural taboo, for instance, goat with full black coat colour is not preferred for slaughtering for home meat consumption. Black coloured animals including goats, however, are believed to have superior adaptation to seasonal cold weather or cold nights as the dark pigment helps them to warm up earlier than goats with other coat colours, Robertshaw [8]. However, in Bangladesh goats having black coat colour are especially preferred over white or brown colour for meat consumption and demand for the skin.

Although, there are varieties of coat colours in BBG, very few studies have so far been conducted on the genetic basis of coat colour inheritance in Bangladesh. Genetic control of coat colour in goat is complicated which results from the interaction of several independence processes, Sponenburg [9]. In general consideration, two major types of pigments; eumelanin and pheomelanin are responsible for varying coat colour patterns in goat. Those pigments can be present or absent in varying combinations in goat. Some genes affect only one of the two; others affect both. The final colour of the goat is due to the interaction of eumelanin (black/brown) and pheomelanin (red-brown/cream/white) and white spotting (white). According to the studies of Nozawa et al. [10] and Alam [11], Black Bengal Goats are polymorphic in coat colour. At least four loci are responsible for the coat colour of goats, such as I, A, D and S. It was found that allele I is dominant over all the alleles at other loci and its presence with any alleles in the remaining loci makes the coat colour full white or cream. Considering the importance of coat colour variants, the present study was undertaken to know the genetic expression of coat colour in BBG.

2. MATERIALS AND METHODS

2.1 Location of the Study

This research work was carried out at community-based goat breeding flocks in three different villages named *Gangatia*, *Borachala* and *Pachpai* of Hobibari union under
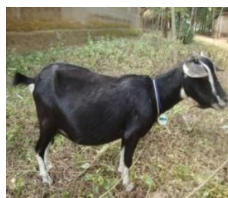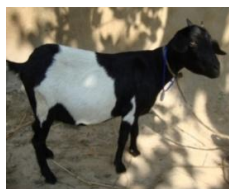
Fig. 1. Solid black   **Fig. 2. Toggenburg**   **Fig. 3. Dutch belt**   **Fig. 4. Brown bezoar**

Bhaluka Upazila in Mymensingh district of Bangladesh under a completed project named "UNEP-GEF-ILRI FAnGR Asia Project" conducted from 2009 to 2013.

2.2 Animals and Data

All animals under the study were ear tagged to maintain individual identity. The information on coat colour for each parent and progeny was observed and collected up to three progressive generations along with foundation flock from three different village flocks including their pedigree records. The study covered with information of a total number of 871 individuals including males and females, three different flocks and three progressive generations with foundation stock. The flocks were maintained under the existing semi-intensive management system.

2.3 Identification of Coat Colour Variants

In this study five typical coat colours' along with mixed colour goats were identified which are defined below:

Solid Black: Black coat around the body with no pattern (Fig. 1). The gene responsible for the black coat is A^a.

Dutch belt pattern ($S^d\_$): This varies from a nice ring around the barrel of the goat to a nearly white goat with coloured tail and head (Fig. 3). Also includes some with single side spots.

Toggenburg pattern (SS): Dark body, dark belly, pale legs, ears, facial stripes (Fig. 2). The Toggenburg pattern (A^{sm}), when eumelanin is brown.

Brown: Brown eumelanin varies from very dark (B^d) to very light brown (B^l).

Bezoar (wild type, A_D_ or A_dd): Wild colour (A^+), tan body, dark head with stripes, pale belly, striped legs and back, black shoulder stripe (Fig. 4). More dark in males than in females.

Others: Combination of different colours or mixed colour in the body.

2.4 Statistical Analysis

All information related to coat colour of goat including parents and progenies were recorded in excel spreadsheet. The statistical analysis for frequency distribution and *Chi-square* test were analyzed by SPSS 20.0.

3. RESULTS AND DISCUSSION

Table 1 illustrates the distribution of different coat colour patterns in BBG population observed in the studied areas. Irrespective of sex, flock and generation, most of the goat populations were solid black followed by Bezoar, black with Toggenberg pattern, black with Dutch belt pattern and solid brown. Coat colour did not differ significantly for sex and generation but differed significantly in different locations. The exact distribution of BBG goat population based on different coat colour varied among literature reviewed earlier, but no doubt that black colour goats are more visible than those of other colours in Bangladesh. Per cent of black coat colour as found in this study is lower than the earlier studies of Husain [2] and Chowdhury [3] who reported it to be 80% and 69%, respectively. Islam [12] in his study reported solid black, toggenberg, brown bezoar, silver bezoar and white to be 69, 19, 4, 6 and 2%, respectively in 4 upazilas of Mymensingh district which is not in accordance with this study. Choudhury et al. [13] collected morphometric data of 106 Black Bengal goats and found 16% solid black, 55% toggenberg pattern, 19% brown bezoar, 3% Dutch belt and 7% other combinations which do not agree with this findings. The variations of coat colour distribution among authors are very usual because every author worked on a very small sample population which does not represent the population as a whole. Despite this, people in different areas have different choice of colour. Further, the colour of breeding

Table 1. Coat colour distribution of BBG according to sex, flock and generation among black Bengal goats in Bangladesh

Factors	The frequency of type of goat[#] based on different coat colour observation					
	Solid black	Black with toggenberg	Solid brown	Brown bejoar	Black with dutch belt	Others
Sex	**NS**					
Male	169 (56.9)	25 (08.4)	1 (0.3)	90 (30.3)	11 (03.7)	1 (0.3)
Female	292 (50.9)	55 (09.6)	3 (0.5)	177 (30.8)	39 (06.8)	8 (01.4)
Flock	*******					
1 (*Gangatia*)	164 (48.1)	50 (14.7)	1 (0.3)	119 (34.9)	7 (02.1)	0 (0.0)
2 (*Borochala*)	65 (42.5)	8 (05.2)	3 (02.0)	48 (31.4)	28 (18.3)	1 (0.7)
3 (*Pachpai*)	232 (61.5)	22 (05.8)	0 (0.0)	100 (26.5)	15 (04.0)	8 (02.1)
Generation	**NS**					
Foundation (G_0)	150 (53.0)	17 (06.0)	0 (0.0)	91 (32.2)	18 (06.4)	7 (02.5)
Generation 1 (G_1)	238 (53.2)	45 (10.1)	4 (0.9)	134 (30.0)	24 (05.4)	2 (0.4)
Generation 2 (G_2)	51 (51.5)	14 (14.1)	0 (0.0)	27 (27.3)	7 (07.1)	0 (0.0)
Generation 3 (G_3)	22 (52.4)	4 (09.5)	0 (0.0)	15 (35.7)	1 (2.4)	0 (0.0)
Overall	461 (52.9)	80 (9.2)	4 (0.5)	267 (30.7)	50 (5.7)	9 (1.0)

Figures in the parenthesis indicate % values; [#]described in methodology; NS-not significant (p>0.05); ***-significant at 0.1% level (p<0.001)

Table 2. Colour progeny produced by various matings of does with unknown coat colour sires in black Bengal goat of Bangladesh

Colours mated		Colours of offspring produced					
Dam	*Sire	Solid black	Black with toggenburg	Brown	Bezoar	Black with dutch belt	Other
Solid Black	Unknown	249 (74.3)	24 (7.2)	0 (0.0)	56 (16.7)	6 (1.8)	0 (0.0)
Black with Toggenburg	Unknown	17 (27.9)	30 (49.2)	1 (1.6)	11 (18.0)	2 (3.3)	0 (0.0)
Bezoar	Unknown	85 (33.1)	14 (5.4)	1 (0.4)	147 (57.2)	7 (2.7)	3 (1.2)
Black with Dutch belt	Unknown	17 (32.7)	5 (9.6)	2 (3.8)	1 (1.9)	26 (50)	1 (1.9)

*Unknown sires were those mated with dam naturally

Table 3. Colour of offspring produced by various parent colour matings in black Bengal goat of Bangladesh

Colours mated	Kids produced				
	Black	Toggenburg	Brown	Bezoar	Dutch belt
Black × Black	160 (80.0)	8 (4.0)	-	29 (14.5)	3 (1.5)
Black × Bezoar	112 (51.9)	10 (4.6)	68 (31.5)	25 (11.6)	01 (0.5)
Black × Toggenburg	20 (42.6)	20 (42.6)	-	06 (12.8)	01 (2.1)
Black × Dutch belt	22 (61.1)	01 (2.8)	01 (2.8)	-	12 (33.3)
Bezoar × Bezoar	10 (16.7)	02 (3.3)	01 (1.7)	44 (73.3)	03 (5.0)
Bezoar × Toggenburg	11 (29.7)	13 (35.1)	01 (2.7)	10 (27.0)	2 (5.4)
Bezoar × Dutch belt	01 (5.3)	01 (5.3)	01 (5.3)	01 (5.3)	15 (78.9)
Dutch belt × Dutch belt	03 (100)	-	-	-	-
Dutch belt × Toggenburg	01 (20.0)	03 (60.0)	-	-	01 (20.0)
Toggenburg × Toggenburg	-	10 (83.3)	-	02 (16.7)	-

#Figures in the parenthesis are percentage values

buck is also an important factor for coat colour distribution among the offspring.

To study the coat colour inheritance of BBG, the distribution of progeny coat colour produced from various matings between the known colour dam and unknown sire are presented in Table 2 which shows that, offspring being produced from those matings dominantly exposed their dam's colour. Although, it may be difficult to explain coat colour inheritance without knowing coat colour of any of the parents, but the segregation of coat colour of offspring from mating known dam colour with unknown sire as obtained in this study, however, indicate that colour gene in female goat is dominant over colour gene in male goat. There is no evidence about the sex link nature of the genes responsible for coat colour in goat. More in-depth researches need to be conducted on this aspect.

There were five distinguished coat colours observed in the offspring from various matings among black, black with Toggenburg pattern, bezoar and black with Dutch belt pattern parents which are presented in Table 3. Black parents when mated to each other produced most of the black kids followed by bezoar, black with Toggenburg pattern and black with Dutch belt pattern, none of which were solid brown. When black parents mated to bezoar parents produced five colours kids in which most of the kids were black followed by brown, bezoar, black with Toggenberg and black with Dutch belt pattern. Black parents mated to black with Toggenburg pattern parents produced most of the kids with black and Toggenburg pattern followed by bezoar and black with Dutch belt pattern none of which were solid brown. Black parents mated to black with Dutch belt pattern parents produced two prominent colours kids, one of which was black kids and other being Dutch belt pattern none of which was a brown colour. Bezoar parents when mated to each other although produced five colour kids, but most of the kids were bezoar followed by black, Dutch belt, Toggenburg and brown. When bezoar parents mated to Toggenburg produced most of the kids of Toggenburg followed by black, bezoar, Dutch belt and brown. Bezoar parents mated to Dutch belt produced five colours kids but most of the kids were Dutch belt. Dutch belt parents, when mated to each other, produced all black kids. When black with Dutch belt pattern parents mated to black with Toggenburg pattern produced most of the kids with Toggenburg pattern followed by black and Dutch belt, none of

which were brown and bezoar. Black with Toggenburg pattern sire and dam mated together produced only two prominent colours kids in which most of the kids were Toggenburg pattern and other being bezoar.

The genetic expression of coat colour shows that parents of different colours combinations mated to each other produced kids possessing parents' colour dominantly with very few other colours. The segregation of coat colour of offspring from mating same colour parents is contradicted with the segregation data of Sponenberg and LaMarsh [14] who got all black kids when mated black goats to black goats and all brown kids when mated brown goats to brown goats. The colour of offspring other than black obtained from the mating of black parents in our study could be due to the fact that both parents may carry another recessive gene on the B or E locus. The segregation of coat colour of the offspring obtained from mating black parents with bezoar parents reveals that black is due to a gene A^a which is dominant to bezoar (wild type, A^+), and all black parents are heterozygous (A^aA^+) produced black offspring carries the A^a (black) agouti allele. The results further postulated that other colour offspring being produced from black and bezoar parents might be due to the presence of recessive alleles in another locus. This result agrees well with Waller [15]. He reported that any non-black animal bred to a black animal that produces black offspring carries the A^a (black) Agouti allele. He also suggested that the best way to determine if an animal carries but does not express a particular pattern is to breed that animal to a black (preferably solid black) animal. The segregation data on coat colour of offspring produced from a black parent with other colour/pattern parent further shows black to be dominant over other colours which are in agreement with Lauvergne and Howell [16] who postulated that both brown and light brown is recessive to black. On the other hand, Sponenberg and LaMarsh [14] in their study on American Pygmy goats found 40 kids from matings of black with dark brown parents in which 23 kids were black and 17 kids were dark brown. In other matings between black and medium brown parents, they obtained a total of 66 kids among which 62 kids were black and only 4 kids were medium brown. Finally, they concluded that dark brown (B^d) is dominant to black (*wild type, B^+*) and medium brown is recessive to black (*wild type, B^+*). Their findings partially agree with our study. Segregation data on coat colour of offspring from matings of

parents with other colour combination also reveals that all parents are carriers for the recessive gene responsible for different coat colours.

4. CONCLUSION

Results of the study suggest that black coat colour goats are prominently distributed among BBG population. This indicates that the gene responsible for black coat colour is dominant over genes responsible for other colours in BBG. The study further reveals that coat colour genes are polymorphic in nature and there are multiple loci for coat colour of goats.

CONSENT

As per international standard written participant consent from the goat owners has been collected and preserved by the authors.

ACKNOWLEDGEMENT

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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