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Productivity and Genetic Potential of Garole Sheep of India-A Review

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Abstract: Sheep are the only domestic animals which can utilize wastelands, stubbles of cultivated corps, tree topping, farm wastes or weeds from the field to convert them into meat, wool and skin. In India sheep contribute greatly to the agrarian economy, especially in the arid/semi-arid and mountainous areas where crop and/or dairy farming are not economical. Garole is a native and local sheep of Bengal in extended costal Sundarban area having distinct and separate phenotypic characters, productive performances of their own and is not thoroughly characterized and established as Breed. This sheep is the latest sensations in the world of domestic species by virtue of its prolificacy, lambing frequency, disease resistance and other extraordinary merits rarely or not even observed in other sheep breeds of the world. The sheep Garole is very popular for its bi-annual lambing, multiple birth, grazing on aquatic weeds and grass in knee-deep water and disease resistance characters. They are small in size; produce rough wool, good quality skin, manure and low fat mutton. Milk is having no importance as the quantity is too less to feed its kids. In this review an attempt has been made to present detail phenotypic and genetic characteristics of Garole in relation to other sheep breeds with emphasis on products characteristics, disease resistance, litter size and fecundity gene including conservation and development strategies for this remarkable sheep.

Key words: Garole sheep, fecundity, productivity, genetic potential, disease resistance

INTRODUCTION

Sheep are the very good economic converter of grass into meat, milk and wool. In fact, there is no substitute for sheep as a class of livestock for utilizing wastelands, stubbles of cultivated corps, tree topping, farm wastes or weeds from the field. No domestic animals are capable of existing on such a variety of food like weeds, grasses, shrubs, roots, cereals, leaves, barks (Sahana, 2001). Sheep utilize very sparse and low set vegetation for feed due to its extremely close grazing nature for bifid upper lip and therefore never compete with goat

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or cattle. With their small muzzles and split upper lips, they can nibble tiny blades of vegetation, which also cannot be eaten by bigger animals (Banerjee, 1989). In India sheep contribute greatly to the agrarian economy, especially in the arid/semi-arid and mountainous areas where crop and/or dairy farming are not economical. They play an important role in the livelihood of a percentage of small, marginal farmers and landless laborers engaged in sheep rearing. Moreover, throughout the world, when animal infertility is a common and acute threat, we are having a sheep with higher fertility. A number of rural based industries use wool and skin from sheep as raw material. Sheep manure is an important source of soil fertility especially in Southern states.

The FAO global inventory of Livestock Breeds (FAO, 1987) and World Watch List for Domestic Animal Diversity (DAD), (Loftus and Scherf, 1993) estimated the total number of breeds of sheep was 863 in the world. Of these 101 are listed, as at risk and the status of many more has not been adequately characterized. Mason (1980) and Banerjee (1989) also listed over 800 breeds of sheep in the world, whereas 59, breeds of indigenous sheep are identified so far in India (Das, 2000). Most of our textbook refer that 42 descript sheep breeds are listed in India (Singh, 2000). Many scientists defined the number of descript sheep breeds of India are 40 relating to region or utility (Acharya and Bhat, 1984; Acharya, 2000). Majority of Indian sheep population (75%) are nondescript (Singh, 2000).

Bengal Garole sheep has not been reported as a separate breed having distinguishable breed characteristics. Garole is a native and local sheep of Bengal in extended costal Sundarban area having distinct and separate phenotypic characters, productive performances of their own is not thoroughly characterized and established as Breed. This distinct but inadequately studied line of small sheep (locally named as Garole) is the dominant domestic species isolated so far pointed out at this extended coastal swampy Sundarban delta of West Bengal (Banerjee, 2008). This sheep is the latest sensations in the world of domestic species by virtue of its prolificacy, lambing frequency, disease resistance and other extraordinary merits rarely or not even observed in other sheep breeds of the world. Historical evidence favours the assumption that the acclaimed Fecundity gene (Booroola) in Australian Merino is derived from this Bengal line having high prolific trait (Turner, 1980, 1982; Piper and Bindon, 1996). Authentically not much is known about the origin of the Garole sheep. However, based on survey work and local farmer interrogation it is assumed that this domestic Garole sheep (*Ovis aries*) might have originated from the wild urial type (*O. vignei*) of Asia. The extremely hot, humid, saline climate with heavy rainfall and cyclone prone riverine deltas of Sundarban made naturally occurred beneficial mutation in fecundity gene of todays Bengal Garole, which is being well adapted for a long time in its native tract. Annual average rainfall, maximum and minimum temperature and relative humidity of this tract is 1622 mm, 36.5 and 12.0°C and 87.5 and 79% (Year wise data book, 1997-2006, Government of India (Pan *et al*., 2004). The native tract of this sheep is around 6210.867 sq. km extending coastal Sundarban area of West Bengal located between 21°32' to 22°40' North latitude and 88°05' to 89°00' is longitude having the boundary of river Hooghly on the West and the Bay of Bengal on the South.

The sheep Garole is very popular for its bi-annual lambing, multiple birth, grazing on aquatic weeds and grass in knee-deep water and disease resistance characters (Banerjee, 2008). They are small in size, produce rough wool, good quality skin, manure and low fat mutton. Milk is having no importance as the quantity is too less to feed its kids, although, it is very much costly and popular locally for feeding and treatment of infant babies in mouth ulceration. This small compact meat type animal predominantly white in color, are owned by landless and small farmers which provide principal source of income during

agriculturally lean period and govern socio-economic status of the sheep farmers of this region. The presence of the super-ovulatory gene and other important character in these Sheep has seldom been seriously studied in India (Bhattacharya, 1989).

Garole Sheep and its Farming

There is paucity of information on Garole sheep. Importance of high prolificacy of this breed was seldom appreciated widely. But it had been reported by Turner (1980, 1982), Piper and Bindon (1996) that the high incidence of multiple birth in Merino was due to a single gene (Booroola), which might have been migrated from the Bengal sheep in late 18th Century. Mason (1980), Acharya (1982), Bhattacharyya (1989) and Kar and Prasad (1992) pointed out distinct but inadequately studied unique type smaller lines of local sheep (commonly known as Garole) which were geographically restricted in costal Sundarban area of West Bengal. Mason (1988, 1996) in his book A World Dictionary of Livestock Breed Types and Varieties, mentioned that Garole, a dwarf prolific meat type sheep of Bengal where males were horned and females were polled. He also noted that the Garole could be compared with Bangladeshi. Actually, Hasnath (1980) described similar type of sheep with adult body weight of 16.8 kg, having the characteristics of high twinning rates and coarse wool production in adjacent areas of Bangladesh. Both the sheep were not similar in characteristics but could be comparable. According to survey results of Banerjee and Banerjee (2000) and Pan *et al.* (2004) in different locations of Sunderban area, it revealed that Garole was also called as bhera and mera to male and female or horned and polled by local people. There was no reference of this sheep as a breed but as variety by Mason (1988, 1996), whereas, Acharya (1982) and Acharya and Bhat (1984) referred Garole as little knowing breed. The United States National Research Council listed this sheep as microsheep based on measurements made on adult sheep. As per Board of Science and Technology for International Development (BOSTID) small sized sheep were discussed in chapter 3 of the book Microlivestock, but the breeds described were about twice the size of the Garole. According to Ghalsasi and Nimbkar (1993), Bose (1995, 1996), Das (2000), Sahana *et al.* (2001), Sahoo and Pan (2002), Pan and Sahoo (2003) and Pan *et al.* (2004), the sheep was very popular for its biannual lambing, multiple birth, grazing on aquatic weeds and grass in knee-deep water. Nimbkar *et al.* (2000), Bose (1995) and Ghalsasi *et al.* (1994) also reported its disease resistance characters. Livestock census report, Government of India in 1999, 1997 and 2004 illustrated that the population of sheep in this tract was 2 million, which was very much static from 1994 to 2004.

Ghalsasi and Nimbkar (1993) studied reproductive traits viz. number of lambs born per ewe, age of first lambing with lambing interval etc. and recorded impressive performance of Garole sheep. Bose (1995, 1996), Singh and Bohra (1996) and Sahoo and Pan (2002) mentioned the social and economic impact of Garole sheep. These sheep are owned by landless and small farmers and provide principal source of income during agriculturally lean period and thereby govern socio-economic status of this region.

Phenotypic Characteristics of Garole Sheep

Phenotype characters such as ear length, tail length, horns, head profile, wattles or beard, body size and conformation of Garole were reported by different scientists. It has been observed that they are small in size, produce rough wool and low fat mutton (Ghalsasi *et al.*, 1994; Banerjee and Banerjee, 2000; Singh and Bohra, 1996; Sahana *et al.*, 2001; Das, 2000). This small compact meat type animals predominantly black, white and fawn or brown in coat color with black patch at lower portion of the body (Ghalsasi *et al.*, 1994; Nimbkar *et al.*, 1998;

Bose *et al*., 1999, 2000; Bose and Maitra, 1999; Sharma *et al*., 1999). Bose *et al*. (1999), Sharma *et al*. (1999), Das (2000), Banerjee and Banerjee (2000) and Pan *et al*. (2004) illustrated different ranges of ear length (long or pendulous or >6 cm, medium or erect or 3-6 cm, rudimentary or <3 cm), tail length (>15, 5-15 or <5 cm) horns (in male), head profile (concave, straight or convex), wattles or beard (no wattles or beard), body size and conformation (weight of adult male 8-10 kg, adult female 10-14 kg, adult male and female chest girth 58-65 cm, adult male and female height at wither 42-49 cm adult male and female body length 42-53 cm).

Litter Size in Sheep Including Garole

A number of reports on the litter size of Garole sheep are available from different places. Ghalsasi and Nimbkar (1993) reported the average liter size of Garole as 2.27 with 7.3% single, 65.45 twins 21.8% triplet and 5.45% quadruplet, while Ghalsasi *et al*. (1994) found average litter size of 2.23 with 9% single, 65% twin, 21% triplet and 5% quadruplet. Sharma *et al*. (1999) noted average litter size of Garole as 1.68 with 40% single, 53.33% twins, 5% triplet and 1.67% quadruplet. However, Bose *et al*. (2000) recorded litter size in Garole as 1.74 with percentage of single, twin, triplet and quadruplet is 41.63, 43.35, 14.81 and 0.21, respectively. According to Pan *et al*. (2004) average lambing frequency was within 1.63-1.94 and with single 24% twin 66.4%, triplet 11.5% and quadruplet 0.2%. Singh and Bohra (1996) published average litter size at first lambing in Garole as 2 and in subsequent lambing it was 2-3 with single birth frequency of 25-30%, twins 55-60%, triplet 15-20% and quadruplet 1-2%. According to Nimbkar *et al*. (1998) average litter size was 2.3±0.9 with percentage of single 35%, twins 57%, triplet 7% and quadruplet 1% in deccan plateau of Maharashtra. In a recent survey in the native tract of Bengal Garole it was reported that Garole had liter size of 1.855 with 23.9% single birth, 67.22% twins, 8.31% triplet and 0.57% quadruplet was recorded (Banerjee, 2008). Fitch (1989) reported average lambing rate of 2.4 in Garole and observed that the sheep could breed throughout the year. Ghalsasi and Nimbkar (1993) reported average number of lambs born per ewe in Garole was 2.27 (prolificacy-227%) in its native tract, however, Ghalsasi *et al*. (1994) reported a lower value of 2.23 (223%). In present study, we have noticed during evaluation of phenotypic data, mean number of lambs born per ewe in Garole is 2.04 (prolificacy-204%) in its native tract and 1.93 (prolificacy-193%) as an average of native and out tract of Bengal (Banerjee *et al*., 2009a, b). It may be due to indiscriminate or unplanned cross breeding resulting dilution or adulteration and erosion of mutant *FecB* genotype from it's native tract. Although, these animals isolated geographically in different Islands surrounded by rivers and sagars in its native tract, we may lose this precise valuable outstanding genetic resources completely in near future.

Karyotype of Sheep Including Garole

From the chromosomal study of black karakul ewe, the diploid number of chromosome was recognized as 2n = 54, 52 being autosomes and 2 being sex chromosomes (Shirinskii *et al*., 1982). The autosomes were found to be metacentric (3 pairs) and acrocentric (23 pairs), the X chrosomes being acrocentric. De Oliveira Filho (1978) observed the diploid chromosome number of crossbred Polworth rams to be 54 with 6 large metacentric and 46 acrocentric or telocentric autosomes. Bunch and Foote (1976) observed that the diploid chromosome number of Iranian sheep breeds was 54 with 3 pairs metacentric and 23 pairs acrocentric autosomes. Babar *et al*. (1991) and Mukhamedgaliev *et al*. (1974) reported that sheep breeds *viz*., Lohi and other breeds of Kazakstan had 54 numbers of chromosomes with 6 submetacentric and 46 acrocentric chromosomes where X chromosome was the largest

acrocentric or metacentric and the Y chromosome was the smallest submetacentric. Similar report is available from McFee *et al.* (1965). Rakshit *et al.* (1999) found similar morphology in Sahabadi and Muzzarffarnagari sheep of India without clearly configured Y chromosome. Akhuli (1999) and Banerjee *et al.* (2008) studied the metaphase chromosome of Garole in its native tract and Muzaffarnagri sheep, where it was observed that chromosome of these breeds included 3 pairs submetacentric, 23 pairs acrocentric autosomes, acrocentric X chromosome and smallest dot like Y chromosome.

Montgomery *et al.* (1994) reported that fecundity gene was present in chromosome 6 of ovine species. However, there was no study regarding genome length, chromosome length, centromere index or investigation of chromosomal abnormality and its correlation of high fecundity of Garole sheep of Bengal. Bahri and Cribiu (1989) studied on Tunisian sheep and Chevelev (1986) studied on Soviet domestic sheep, Rcheulishvili and Dzhokhadze (1985) studied the Imeritian sheep, where all of them found no significant variation in genome length between breeds, sex and between different locations among breeds of sheep. Roy *et al.* (1991) pointed out that chromosome of local indigenous sheep of Orissa was 54 in diploid stage including 3 pairs submetacentric, 23 pairs acrocentric autosomes, acrocentric X chromosome and elongated dot like Y chromosome. Bhatia and Shanker (1989) reported the metaphase mitotic chromosomes in Nali sheep India which had karyotype consisted of 3 pairs of metacentric and 23 pairs of acrocentric chromosomes with largest acrocentric X chromosome and small biarmed metacentric Y chromosome. Mulsant *et al.* (2001) reported that a single nucleotide mutation in fecundity gene showed moderate to higher prolificacy and lambing frequency in Booroola Merino. Ansari *et al.* (1996, 1999) reported the variation of Idiogram assay between breed and sex of sheep.

Genetic Speciality of Garole Sheep

The phenotype in Booroola merino is reported to be due to the mutant fecundity gene, Bone Morphogenetic Protein Receptor IB (BMPR-IB) (Wilson *et al.*, 2001; Mulsant *et al.*, 2001; Montgomery *et al.*, 1995a, b, 2001). They also observed that BMPR-IB receptor of ovarian granulosa cell dimerized with BMPR-II and transmit signal through its natural ligant BMP 4, BMP 7 and GDF 5 for progesterone secretion. However, if BMPR-IB is mutant, it lost its responsiveness regarding progesterone secretion in ovarian tissue. As a result FSH stimulated estrogen production would be enhanced at oestrus (ovulatory peak) followed by FSH suppressed progesterone secretion would be increased if there was pregnancy. They also opined that Booroola-Merino sheep of Australia were characterized by high ovulation rate and litter size due to mutation in *FecB* gene present in Chromosome No. 6. The Booroola strain was developed through introgression of this *FecB* mutation from Indian Garole to Australian Egelabra Merinos (Turner, 1982). Davis *et al.* (2002) published evidence on origin of this Booroola (*FecB*) mutation present in Booroola-Merino was from Indian Garole sheep present in Costal Sundarbans area of West Bengal.

Fecundity Gene in Garole

Throughout the world, when infertility of sheep is a threat, historical evidence and different molecular tests demonstrated the presence of naturally occurred beneficial mutation in a major gene (*FecB*) in Indian Garole (the sheep of Bengal) related to higher prolificacy and lambing frequency in its native tract (Banerjee *et al.*, 2009a). According to Turner (1980, 1982 and 1983) highly prolific Booroola Merinos can be traced back to an early Australian flock known to include prolific Indian (Bengal) Garole sheep. Highly prolific Garole sheep of West Bengal, India have many of the fleece and body characteristics reported for the early Bengal

sheep in Australia (Piper and Bindon, 1996) and the two names possibly refer to the same sheep or very closely related breeds. Recent molecular tests demonstrated by different scientists (Davis *et al*., 2002; Montgomery *et al*., 2001; Wilson *et al*., 2001) established possible link regarding transmission of this beneficial mutation present in Bengal Garole to Australian Booroola Merino with high litter size and lambing frequency. Piper and Bindon (1996) defined the acclaimed genesis of Fecundity gene, *FecB* (Booroola) in Australian Merino as from the Bengal line having high prolific trait.

A preliminary study determined the segregation pattern of marker DNA fragment associated to the fecundity gene in Garole. National Bureau of Animal Genetic Resources (NBAGR), Karnal, India recorded a summary of micro-satellites exhibiting amplification in Garole sheep in their Annual Report in 1998-1999. Sodhi *et al*. (2003) studied the genetic characterization of Garole sheep using microsatellite markers and observed high level of genetic heterogeneity that was reflected in Garole sheep. Davis *et al*. (1982) and Piper and Bindon (1982a, b) observed that the Booroola fecundity gene (*FecB*) increased the ovulation rate and litter size in sheep and was inherited as a single autosomal locus. Montgomery *et al*. (1993, 1994) reported that *FecB* was located on sheep chromosome 6 between SPP-1 and EGF genes at chromosome $6q^{23-31}$ region which was syntenic group to human chromosome $4q^{21-25}$ region (Lanneluc *et al*., 1994, 1996). This *FecB* contained the BMPR-1B gene, considered as positional candidate to affect steroid synthesis of ovarian granulosa cells and oocytes (Hogan, 1996; Massague, 1998). Shimasaki *et al*.(1999) observed that BMPR-1B encoded a member of the transforming growth factor-, (TGF-,) receptor superfamily responsible for inhibitory effect on steroidogenesis of GDF-5 and BMP-4, natural ligands of BMPR-1B. Wilson *et al*. (2001) published novel findings regarding Booroola genotypes which had a nonconservative substitution (Q249R) in the BMPR-1B coding sequence. He found partial inactivation of BMPR-1B, leading to an advanced differentiation of granulosa cells and an advanced maturation of ovulatory follicles associated fully with the hyperprolificacy phenotype in Booroola ewes. Wilson *et al*. (2001) and Mulsant *et al*. (2001) revealed a point mutation in a major gene, fecundity booroola (*FecB*) in chromosome number 6 results higher prolificacy in Garole but not in other breeds of sheep or its wild variety. The nucleotide sequence obtained in mutant $FecB^B$ allele was identical to the wild type allele, except for AG (adenine to guanine) transition position 746, substituting the amino acid sequence, glutamine present in the wild type sequences as well as in human and mouse sequences to arginine (Mulsant *et al*., 2001).

According to the recent findings of Davis *et al*. (2002), *BMPR-1B* mutation was found in Indian Garole, Booroola and Javanese sheep. Frequency of homozygosity of mutant allele in Garole of India was higher than Booroola and Javanese sheep linked with higher prolificacy. Inheritance patterns suggested possible migration of major genes affecting prolificacy from Indian Garole to Australian Booroola-Merinos and in case of Javanese sheep it was directly from Garole or via Booroola-Merinos from Garole.

Fecundity Gene, its Mutation and Productivity

Pardeshi *et al*. (2005) studied to assess the *FecB* mutation in four Indian sheep breeds, *viz*., Garole, Deccani, Bannur and Madras Red and its introgression with relation to productivity and reported that only Garole possessed double copy *FecB* mutation with higher fecundity (Banerjee *et al*., 2009a) but Deccani, Bannur and Madras Red possessed one copy with medium fecundity in F_1 after crossing with Garole. Mulsant *et al*. (2001) reported mutation in bone morphogenetic protein receptor-IB (*BMPR1B*) was associated with increased ovulation rate in Booroola Merino ewes. Yi *et al*. (2001) observed the type I BMP

receptor *BMPRIB* was essential for female reproductive function on the actions of several hormones, signaling in early stages of folliculogenesis. Juengel and McNatty (2005) reported that proteins of the transforming growth factor beta (TGF-) superfamily, growth differentiation factor 9 (GDF9), bone morphogenetic protein 15 (BMP15) and BMP6 regulate intra-ovarian follicular development in female. Juengel *et al.* (2006) studied on bone morphogenetic proteins 2, 4, 6 and 7 and observed that these proteins would have an important intra-ovarian role in regulating follicular development in sheep and rat.

Montgomery *et al.* (2001) reviewed genes controlling ovulation rate in sheep. Galloway *et al.* (2000) observed mutations in an oocyte derived growth factor gene (BMP 15) caused increased ovulation rate and infertility in a dosage-sensitive manner in many breeds of sheep. Walling *et al.* (2000a, b) made characterization and mapping of the Booroola (*Fec B*) gene using regression analysis in sheep and consequences of carrying the booroola fecundity (*Fec B*) gene on live weight. Piper and Bindon (1982a, b) presented first evidence for segregation of a locas with a major effect on litter size in the Booroola strain of Merino sheep. Subsequently Davis *et al.* (1982) and Davis (1985) showed in New Zealand Booroola flocks to result from its additive effect on ovulation rate using imported genetic material. Thereafter many breeds of sheep with high fecundity or prolificacy had been evaluated by different scientists like Belle-Ile sheep of France by Mahler and Lechere (1998), Cambridge of Australia by Owen *et al.* (1990), Thoka, Icelandic sheep by Jonmundsson and Adalsteinsson (1985), Javanese sheep of Indonesia by Bradford *et al.* (1986), Lacaune sheep of France by Bodin *et al.* (1998), Beclare sheep by Hanrahan (1991), Olkuska sheep by Radomska *et al.* (1988) having autosomal inheritance. Davis *et al.* (2002) reported the presence of *FecB* mutation was in the Garole and Javanese sheep only but not in Cambridge, Thoka, Lacaune, Belclare and Olkuska sheep. Davis *et al.* (1995) discovered inverdale gene, which is X linked inheritance in Romney sheep of New Zealand with high prolificacy. Davis *et al.* (2001) further evidenced that an imprinted gene on the X chromosome increases ovulation rate in woodlands sheep of New Zealand.

Reproductive Function of BMP Gene

Otsuka *et al.* (2001) provided the first insight into the biological function of BMP-6 in the ovary and demonstrated its unique mechanism of regulating FSH action resulting marked decrease in Follicle-Stimulating Hormone (FSH)-induced progesterone production but not estradiol through selective modulation of FSH action in steroidogenesis. According to Shimasaki *et al.* (2004) role of the Bone Morphogenetic Protein (BMP) family of growth factors in the reproductive system using molecular, cellular and genetic approaches, had led to significant breakthroughs in our understanding of mammalian reproduction and fertility and reviewed thoroughly the evidence underpinning the importance of the BMP system in mammalian reproduction. Campbell *et al.* (2006) worked on enhanced response of granulosa and theca cells in sheep having carriers of the mutant *FecB*. *In vitro* study on gonadotropins and bone morphogenic protein 2, 4 and 6 made evidence to support the hypothesis that, *FecB* mutation increases the BMP response of somatic cells when stimulated to differentiate by gonadotropins. Faure *et al.* (2005) observed bone morphogenetic protein (BMP-4) inhibits follicle-stimulating hormone secretion in ewe pituitary. It revealed the presence of a functional BMP system which operates in the sheep pituitary at least, *in vitro* to decrease FSH release and to modulate the effect of activin.

Pierre *et al.* (2004) studied on molecular basis of bone morphogenetic protein 4 inhibitory actions on progesterone synthesis by ovine granulosa cells, which was a new implication in understanding the role of BMP family members in the control of ovarian folliculogenesis.

Hanrahan *et al.* (2004) reported first lime that a mutation in the gene for GDF9 causes increased ovulation rate and infertility in a manner similar to inactivating mutations in BMP15 and showed that GDF9 is essential for normal folliculogenesis in Cambridge and Belclare sheep. Furthermore, it is shown, for the first time in any species, that individual with mutations in both GDF9 and BMP15 have a greater ovulation rate than sheep with either of the mutations separately. According to Nilsson and Skinner (2003), Bone Morphogenetic Protein 4 acted as an ovarian follicle survival factor and promoted primordial follicle development in rat ovaries.

Xia *et al.* (2003) studied on the concentrations of progesterone, follistatin and Follicle-Stimulating Hormone (FSH) in peripheral plasma across the oestrous cycle and pregnancy in merino ewes that are homozygous or noncarriers of the booroola gene. The Booroola phenotype was due to a point mutation in the BMP1B. Progesterone concentrations began to rise earlier and were higher in the Booroola ewes than in the noncarriers in luteal phase but not during the follicular phase of the cycle. Follistatin concentrations remained unchanged across the oestrous cycle in both groups of ewes, with no differences between genotypes. FSH concentrations were higher in Booroola ewes than in noncarrier ewes on most days of the oestrous cycle, with a significantly higher and broader peak of FSH around the time of oestrus. Progesterone concentrations were significantly higher in early and mid gestation in Booroola ewes but were lower toward the end of gestation than those in noncarriers. These results suggested that progesterone and FSH not follistatin concentration was being regulated by the *FecB* gene during the estrous cycle and pregnancy. Pepin *et al.* (2003) published expression profiles and chromosomal localization of genes within BMP families and oocyte derived factors controlling meiosis and follicular development in the cyclic Ile-de-France sheep ova useful to identify potential candidate genes that might underlie these effects.

Meat, Skin and Wool Productivity of Sheep Including Garole

Meat

A wide variation in dressing percentage of Garole sheep has been reported by various authors. Bose (1995), Bose and Maitra (1999) recorded dressing% of Garole sheep as 48.26%, whereas, Banerjee and Banerjee (2000) and Das (2000) reported dressing% in Garole sheep as 52 and 66.54%, respectively. Singh (1998) observed dressing percentage of 53% in other Indian sheep breeds. Prasad (1997) noted variation in dressing percentage in male and female to the tune of 45-53% and 40-45%, respectively. Pal *et al.* (1997) reported dressing percentage of 44.61% and 48.49% in Muzaffarnagari lambs maintained under semi-intensive and intensive systems, respectively. According to Pan and Sahoo (2003) and Pan *et al.* (2004) carcass parameters like slaughter age of Garole sheep were 8-12 months in male and above 24 months in female; whereas slaughter weights were on an average 10-12 and 13 kg for male and female, respectively. Carcass weight of male and female animals were, however, 6.61-8.66 and 6.59 kg. Blazquez *et al.* (2001) observed significant differences in carcass and meat quality of sheep belonging to different body weight groups of 5 and 25 kg.

Crosby (2000) discussed on the need to improve marketing of lamb meat, mutton and mutton products through quality assurance, sheep traceability, tagging and the scrapie monitoring/testing programme. Ruiz de la Torre *et al.* (2001) recorded variation in pH, color, few kinase and dehydrogenase enzymes activity of sheep carcass as stress responses during transportation. In general, meat is composed of water (75%), fat (3%), protein (19%), non protein nitrogenous substances (1.5%), minerals (1%) and a small portion of carbohydrate (Lawrie and Ledward, 2006). Lipid is the most variable of these components, but is closely

and inversely related to the water content. Researchers reported sheep meat standards like moisture 73.0%±0.1, protein 18.9%±0.05, fat 6.0%±0.2, ash 1.5%±0.2, carbohydrate and vitamin etc 0.6%±0.002. They also noted that, moisture% is inversely related with fat%. Banerjee *et al.* (2009b) reported that dressing percentage of 55.87 in Garole sheep. The meat had pH, water holding capacity and refrigeration loss of 5.96, 43.33 and 0.86%, respectively. They further reported moisture, protein, fat, ash and carbohydrate content as 76.02, 18.20, 3.53, 1.65 and 0.60%, respectively.

Shackelford *et al.* (2005) made research regarding effects of breed on lamb meat quality. The experiment was conducted to compare the meat quality and carcass composition of a diverse sampling of sheep breeds. No single breed excelled to a great degree in carcass composition. Therefore, they are to improve lamb quality exploring breed effects using the most appropriate breeds in crossbreeding programs that produce market lambs. According to Watt and Merrill (1963) lowered pH and water holding never damage appearance (dark) and flavour as well as prevents bacterial growth and spoilage. Therefore, due to these qualities along with lowered refrigeration loss helps in long-term meat preservation also observed by Callow in 1948.

Zinc, cupper, iron, manganese, sodium, potassium and chloride are the major minerals in meat, which influence nutritive value of mutton (Rice, 1971). Meat is a good source of different minerals mainly dietary iron and phosphorus except calcium (Landmann, 1960). Magnesium, copper and zinc have been reported as highly essential in meat based baby foods (Vazir, 2003; Medappa, 2003; Mathur, 2004).

Skin

Daglioglu *et al.* (2001) carried out a comparative examination of the skin, leather properties and the histological structures of skin of different sheep genotypes. The thickness of total skin, epidermis, dermis, stratum superficiales and stratum profundum were measured. Density and the thickness of collagen and elastic fibres in dermis sublayer and density of wool follicles were established. The results were compared among three genotypes of sheep. Histometrical properties of Kivircik and crossbred lambskins were similar to each other but skin properties Merinos were different from other two genotypes. Prasad (1996,1997) examined all skin parameters and observed that sheep skin were valuable for leather industry producing leather coats, jackets, shoes, gloves, robes, rugs, slippers etc. According to Pan and Sahoo (2003) and Pan *et al.*(2004) skin parameters like skin length, skin width, skin area, skin weight and skin weight percentage of skin of adult Garole sheep was around 65.3-84.1, 59.7-63.2 cm, 4048.3-5474.1 sq. cm, 1.2-2.3 kg and 10.5-12.0%, respectively. Banerjee *et al.* (2009b) also reported almost similar values.

Wool

Horton and Rodriguez (1997) compared between hair (St. Croix) and wool (Targhee and Dorset) of lambs and the effect of heat stress on food and water intake, digestive function and nitrogen balance. They concluded that hair sheep were more heat-tolerant than wool sheep, as they consumed more feed, gained more body weight and improved digestibility when exposed to elevated temperatures. It is observed the significant effect of cortisol acetate on wool quality in sheep selected for divergent staple strength. Smuts *et al.* (2001) evaluated the role of sheep breed and mohair style and character in the OFDA curvature vs. staple crimp/wave frequency relationship. They summarized that the OFDA curvature can be used as a measure of wool staple crimp and mohair wave frequency without the need to take either sheep breed or mohair style and character into consideration. Wool Grading and

Marketing Rules mentioned to issue Conditioning Certificate which denotes clearance from quality control through different gradation testing procedures. Rodney in 1993 demonstrated different methods like American system, English or Spinning count system and the Micron system to evaluate certain qualities such as fineness, length, color and appearance that determine the end use and value of wool. He also discussed, fineness, the fiber diameter and its distribution, as the most important quality factors for grading. Fineness largely determines whether the wool is used in a suit, sweater and blanket or in a pair of socks. Singh (1997) elaborately discussed regarding all aspects of wool growth, structure, production, properties, grading and processing. Wool Research Association, Thane in their annual report of 2001-2002 defined different methods for quality testing and grading of wool for production of good quality wool and followed by upgradation of Indian wool Industry. Benavides and Maher (2003) worked on wool color and skin traits to assess phenotypic and genetic correlations between wool color and skin traits. They found that skin traits had high genetic correlation with clean wool and color of wool which might be useful for indirect selection of these traits.

Bose (1996) and Bose *et al.* (1999) studied on wool characters of Garole sheep. They showed that wool of Garole was extremely coarse, hairy and not very dense. Bose and Maitra (1999) defined annual average greasy fleece yield from each Garole sheep was 152 g. According to Ghalsasi and Nimbkar (1993) Garole wool was quite coarse. Sharma *et al.* (1999) observed average annual adult wool yield from each Garole sheep procured from Sundarban area was 179 g which was for rough carpet use. Singh and Bohra (1996) studied on wool parameters of Garole sheep and reported that average wool yield was 150 g per shearing from each sheep, which was of rough carpet type. Prasad (1996, 1997) also reported average annual production of wool per sheep was around 300 g. They studied fibre parameters like average fibre diameter, medullation, staple length and crimp/cm of Garole sheep which were reported to be 67.82 μ, 75.17%, 5.09 cm and 2.08, respectively. On the other hand Pan and Sahoo (2003) and Pan *et al.* (2004) recorded fibre diameter, medullation and fibre length as 53.02 μ, 78.7% and 4.99 cm, respectively in Garole sheep. They observed that shearing was not at all common practice, although each Garole was capable to yield approximately 400 g greasy fleece annually.

Disease Resistance in Sheep Including Garole

Internal parasitism and a few bacterial or viral diseases create a great threat to sheep industry. Indian sheep in general have low prolificacy and high worm infestation, which greatly affect productivity around most agro climatic regions of the country. The main impact of these infections is decreased appetite and disturbances on energy, protein and mineral metabolisms leading to reduced productivity. Further, some blood protozoa or blood sucking parasites causes anaemia and sometimes leads to death in severe infection. Apart from these, some bacterial diseases such as foot rot or infectious pododermatitis, Gid (*Multiceps multiceps*) and viral diseases as PPR, FMD, sheep pox and malignant ovine spongiform encephalopathy damage the sheep husbandry. Different anthelmentics, antibiotics and vaccines may be advocated against these infections. However, recently anthelmentic or drug resistance is posing a problem which necessitate the development of sustainable Integrated Pest Management (IPM) principles for worm control and/or genetic resistance of host against some bacteria or virus. Selection of host for individual genetic resistance towards parasite, bacteria or virus followed by their crossing to increase their frequency in the population is highly expected for the future generations. Gradually disease

resistant strains against selective diseases are developed e.g., in East African Red Maasai, Florida Native and St. Croix which are relatively worm resistant sheep breeds (Garran and White, 1985).

Interestingly Indian Garole have naturally developed resistance against natural and induced parasitic infections, foot rot, FMD, reproductive disorders etc. Garole sheep are considerably more resistant to dreaded round worm *Haemonchus contortus* as well as to the tropical liver fluke (Nimbkar, 2002). During authors survey hardly even single foot rot or FMD infection was found in its native tract (Banerjee, 2008). Garole sheep was identified mainly due to its high prolificacy but it was also hoped that it might have some useful genes for resistance to internal parasites, liver flukes and different bacterial or viral diseases. There is evidence that major autosomal genes affect host resistance to nematode parasites in Coopworth sheep that strongly support Garole phenomenon (McEwan and Kerr, 1998). Background of disease resistant feature in Garole is not well known clearly, however, it might be due to differential .-globulin expression than other breeds because of its power of adoption against natural stressful extreme costal climate in its native tract as .-globulin is one of the most defined immunomodulator, concentration of which determines individual resistance to diseases. Significant gamma immunoglobulin expression assay was done to understand the outstanding disease resistant characters of Garole (Banerjee, 2008).

Pan *et al.* (2004) recorded no trematode infection in Garole sheep and incidence of gastrointestinal tract infection was around 54.6% followed by abortion, repeat breeding, placenta retention and post-gestational mortality, was 7.82, 9.35, 2.62 and 14.08%, respectively and miscellaneous infection was also seen around 20.6%. Kooyman *et al.* (1997) found differential elevated immunoglobulin (IgE) level in sheep at normal infection with *Haemonchus contortus* resulted in significant increased level in serum as measured by sandwich ELISA and Western blots. Engwerda *et al.* (1992) reported resistance of one breed greatly varied on source of immunoglobulin, the amino acid sequence of variable or constant region. White *et al.* (2001) exhibited significantly different expression in sheep gamma/immunoglobulin assay, challenged with gastrointestinal nematode *Haemonchus contortus* by reverse transcriptase-polymerase chain reaction (RT-PCR) from Abomasal Lymph Node (ALN) B cells due to gamma/immunoglobulin (Ig) heavy-chain and lambda light-chain variable region nucleotide coding sequence present in sheep genome. Murray and Smith (1994) observed that level of host immunoglobulin greatly varies due to ingestion of it by *Haemonchus contortus*, *Ostertagia ostertagi*, *O.circumcincta* [*Teladorsagia circumcincta*] and *Dictyocaulus viviparus*, after staining of sections of the worms with fluorescent anti-sheep immunoglobulin technique even by the non-blood-feeding species, therefore, might be susceptible to vaccination by the gut antigen approach. Hailat and Lafi (1998) identified a deficiency in the Slow Moving Immunoglobulin in Awassi Sheep.

Seaton *et al.* (1992) detected different specific serum antibody responses of sheep in *L. cuprina* infection by ELISA and immunoblotting which were due to breed or individual variation in percent concentration of immunoglobulin mainly IgG and IgM. Diez-Tascon (2005) performed microarray analysis of selection lines from outbreed populations to identify genes involved with nematode parasite resistance in sheep. Miresan (2003) evaluated significant breed differences of main blood indices including gamma globulin using electrophoresis technique in Tsigai fattening sheep, Merino of Cluj and Corriedale breeds. Nimbkar *et al.* (2000) performed an analysis regarding comparison of the growth performance and worm resistance of lambs produced by diallel crossing of three Indian sheep breeds like Deccani (D), Bannur (B) and Garole (G) and he proved that lambs sired by G and B rams were more resistant to naturally acquired worm infections and to artificial challenge with *Haemonchus contortus* than those sired by D rams. However, lambs sired by D and B rams had higher birthweights and growth to 6 months than those sired by G rams.

Zhang *et al.* (1998) observed genetic enhancement of resistance to gastrointestinal worm infection predominantly *Trichostrongylus* sp. when selection was done in genotypes used for meat type sheep production in Australia. Waelchli *et al.* (1994) studied on immunoglobulin concentrations in colostrum and serum of lambs of dairy sheep breeds, which revealed lower colostral immunoglobulin concentrations, have no negative impact on the serum immunoglobulin concentrations, provided that good management practices are followed. McEwan and Kerr (1998) evidenced that major autosomal genes affect host resistance to nematode parasites in Coopworth sheep. Woolaston and Gray (1991) recommended for improving genetic resistance of sheep diseases. They discussed the h2 of faecal egg count, fleece rot and foot rot, their genetic correlations with other traits and the mechanisms of resistance to these diseases focus a great impact on disease resistant traits present in specific sheep breeds might be beneficial for global ovine industry.

Conservation and Development Efforts for Garole

Nimbkar *et al.* (1998) established prolific Garole sheep from Bengal in the semi-arid deccan plateau of Maharashtra through selection and breeding. Its crossing with other local breeds by Nimbkar Agricultural Research Institute (NARI), Phaltan, Maharashtra made it one of the most economic and feasible animal husbandry programme of this state. Outstanding reproductive performance of Garole had also been reported by Bose and Maitra (1999) and suggested the scientific breeding of this local sheep for improvement of economic conditions of the farmers. Singh (2000) narrated that significant opportunity for active conservation of sheep genetic resources remain. According to Fahmy (1996) and Fahmy and Davis (1996) major genes for prolificacy and body composition exist in this sheep. Because of these outstanding merits scientists from other countries had been attracted several times to genetically evaluate this particular breed.

The presence of the superovulatory gene and other important characters in these sheep had seldom been seriously studied in India, which is highly necessary to conserve and explore possible development of Garole. Das (2000) demonstrated that need of *in situ* conservation of Garole sheep was urgent in Bengal. He also stated that in the Xth Plan document of Planning commission of Government of India a major thrush was given on it. Dasgupta and Das (2005) strongly recommended *in-situ* conservation and development of Garole sheep through strategic breeding policy in West Bengal. It is demonstrated that Garole sheep had suffered enough degredation leading to diluted genetic quality. He also stated that population size of true to the breed was reducing fast, needed to be planned for conservation. In addition, he indicated that the best way to conserve the resources was within their native environment (*in situ*) with the direct involvement of stake holders and farmers. Pan *et al.* (2004) reported that Garole sheep was facing a constant threat from gradual shrinkage of grazing land and other feed resources. Therefore *in situ* conservation of the genetic material with available feed resources was the crying need of the time. Ahlawat *et al.* (2002) emphasized that there was a strong need for genetic improvement programme in Garole sheep at the farmers flock in order to make sheep rearing more profitable.

CONCLUSION

Due to static trend in population and negative trend in litter size, there may be immediate threat in sheep vis-à-vis Garole sheep of West Benga. In the same way, indiscriminate cross breeding during last few years has endangered a few important indigenous breeds of India

(Jammu and Kashmir). Therefore, conservation programme in terms of *in situ* or *ex situ* may be of immediate need along with strong need for genetic improvement programme of Garole sheep at the farmers flock in order to make sheep rearing more profitable. Considering the importance of Garole sheep of Bengal, tenth plan document of planning commission, Govt. of India, mentioned it at risk and proposed for specific project for its conservation and development. For growing realization of the improvement of indigenous genetic resources because of their adoption to specific agro-ecological condition and for conservation of biodiversity, it is not only the production but the efficiency of production in relation to physical environment, feed resources availability, management practices and disease factors which ought to be considered in deciding the future plans and strategies. In order to give holistic approach to productivity performance of a group of animals, their performance should be tested in native system of production to evaluate their relative efficiency as well as cost benefit ratios.

There is no definite breeding strategy of sheep in West Bengal. However a state level symposium cum round table on Breeding policy for conservation of small ruminants of West Bengal organized by West Bengal University of Animal and Fishery Sciences, Kolkata in collaboration with Department of Animal Husbandry, Dairying and Fisheries, Government of India and Animal Resources Development Department, Government of West Bengal on 02.09.2005 recommended selective breeding for improvement of Garole sheep. It was also recommended to follow open nucleus breeding for the production of improved rams for fecundity and lambing frequency parameters. It was also decided to take action regarding ram mother farm production and exchange of rams to the farmers may be carried out at the earliest. Simultaneously, development of marketing facilities for skin, meat and meat products is to be done through promotion of self help groups and cooperative marketing structure. The West Bengal Government has of late, shown keen interest in this breed and desired to conserve and explore possible development of the breed by adopting a definite breeding strategy. It is expected to augment the economy of poor farmers maintaining these Sheep in the coastal region of West Bengal. This great gift of the nature must be preserved and propagated through scientific breeding and management in its native tract and all possible measures must be undertaken to fulfill this goal.

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