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The *FecB* (*Booroola*) gene and implications for the Turkish sheep industry

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Abstract: Most traits of economic importance in livestock are quantitative traits. This means that they are influenced by a large number of genes, each contributing a small effect, scattered across the genome. Selection for these genes requires specialized methods such as progeny testing or genomic selection. The *FecB* or *Booroola* gene is an exception. Presence of this single gene increases ovulation and lambing rates dramatically with ewes producing 2, 3, or even more lambs per parturition. The *FecB* gene was first observed indirectly in Australian Merino sheep by Dr Helen Newton Turner. It was later determined that this allele was a single amino acid mutation in the bone morphogenetic protein receptor type 1B (BMPR1B) gene on chromosome 6 and it was designated *FecB*, where *Fec* stands for the fecundity locus and *B* for the *Booroola* gene. *FecB* probably originated in India and has now spread to 48 breeds and composites in 19 countries. Sheep production in Turkey has been declining over the past 20 years for many reasons, but the demand for sheep products remains high. Increased lambing rates could increase sheep production in Turkey, but changes in traditional practices of extensive, low input, and low output sheep production would probably be required.

Key words: *FecB* gene, *Booroola* gene, sheep production

1. Introduction

A large portion of the increased performance and productivity of modern livestock can be attributed to genetic improvement through selective breeding. In the early 19th century, animal geneticists and breeders began to understand how to improve traits that were influenced by large numbers of genes. Genetic evaluation programs were established to untangle the influences of environment that concealed breeding values of individual animals, and significant genetic improvement in many species and many different regions of the world has been the result. Recently advances in laboratory techniques and technology have made it possible to identify quantitative trait loci and even single genes that have major effects on performance. A case in point is the discovery of the *Booroola* gene in sheep. This gene can improve fecundity or fertility in sheep dramatically through introgression into current breeds that suffer from low reproduction rates. This promise of rapid and easy improvement in reproduction rates of sheep offers great promise, and research to determine how it might best be used to improve sheep production in Turkey should be a priority.

2. History of the *Booroola* gene

The discovery and evolution of our current understanding of the *Booroola* gene is a fascinating combination of animal husbandry, scientific inquiry, curiosity, and luck that has been well documented (1). In the mid-1900s, brothers Jack and Dick Sears identified a line of highly prolific Merino sheep that descended from a single ewe that had triplets. The main flock of sheep that the line was separated from was on their property, located at Cooma in New South Wales Australia, called Booroola. The brothers donated a ram to the Commonwealth Scientific and Industrial Research Organization (CSIRO) in 1958 and that same year Dr Helen Newton Turner selected 12 ewes born as triplets or quadruplets for purchase by CSIRO (2). A research project to study genetic determination of the Booroola Merino (BM) breeds' prolificacy was started by CSIRO and from 1977 to 1979 the average litter size of the BM sheep was 2.29 compared with 1.22 for the control (3).

With this strong scientific evidence that BM sheep were genetically prolific, research and speculation continued. Dr Turner studied the breeding records available in the Australian Merino Stud Registry to trace the origin of the high prolificacy of BM. She concluded that it came from either the Bengal or Cape sheep brought into Australia in the late 18th century from India (4). Other scientists observed that all rams did not pass on the prolificacy and some speculated that it might be the result of a single gene or a closely linked set of minor genes (3). Further study provided strong evidence for a major gene segregating in the BM sheep and the suspected gene was initially named

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the *fecundity* or *F* gene. It soon became apparent that more than one allele was affecting lambing rates in sheep, and so the gene was renamed *Fec* and the BM allele was named *Booroola*, designated *FecB* (5).

The gene was identified molecularly in 2001 (6–8). This allowed determination of individual sheep genotypes and the testing of Dr Turner's theory that the gene had originated in the Bengal or Cape sheep of India. Testing (9) revealed that *FecB* was homozygous in some lines of the Garole and mixed heterozygous/homozygous in Javanese Thin Tail sheep. *FecB* has also been found in Hu and Small Tail Han sheep of China (10). Recent mitochondrial DNA studies revealed 2 major haplotypes (A and B) and a minor haplotype (C) in sheep. Haplotype C is present in China and Turkey and has been found in the Chinese Hu breed, which is homozygous *FecB* (11), indicating that the *FecB* gene may be present in Turkish sheep.

3. Use of the *Booroola* gene

The potential that a single easily identifiable gene can increase lambing rate by several lambs per parturition offers great promise to sheep production. For this reason, discovery of this gene has generated great interest and numerous research and breeding programs throughout the world have resulted (12). By 1994 the *Booroola* Merino gene had been exported to France, Canada, Israel, South Africa, Uruguay, the United States, the United Kingdom, Germany, Hungary, Poland, the Czech Republic, Slovakia, and Spain (13,14). Major research and breeding programs are on-going in Australia, New Zealand, Israel, Indonesia, and India, and these countries have capitalized on its use in breeding programs (12). To date, the *Booroola* gene has spread to 48 breeds and synthetics in 19 different countries (1).

Introgression of the *Booroola* genes into native breeds has produced some unexpected results (15). In practice, it has often had unexpected and less than desired results (16–19). On the other hand, it has been successfully utilized in numerous countries and under a wide range of conditions to dramatically increase productivity and efficiency (12). Before use of this gene in breeding strategies can be recommended to local producers, it should be carefully evaluated and successful strategies worked out.

No *Booroola* genes have been positively identified in indigenous Turkish sheep to date. In a recent study (20), scientists randomly selected 6 breeds of sheep (Akkaraman, Morkaraman, Dağlıc, Awassi, Tuj, and Karakaş) and collected 111 DNA samples for identification of the *Booroola* gene using PCR-RFLP. They found no *Booroola* genes present in these samples. Sampled animals were not selected based upon mitochondrial haplotype or prolificacy. A targeted approach might yield different results. Research has indicated that a major gene may be segregating in a synthetic Karya-type population of sheep in Aydın Province, Turkey (21,22). Recently a small sample of animals selected from the population based on prolificacy did not reveal the presence of the *Booroola* or Inverdale genes (23).

4. Implications for Turkish sheep production

There is currently a meat shortage in Turkey, whereby the demand for meat exceeds the supply. Sheep provide a preferred source of meat for the Turkish consumer (24) and increasing the reproduction rate in sheep would benefit Turkey by increased meat production and improved selection efficiency. The *Booroola* gene increases reproduction rate in sheep rapidly due to an almost additive effect on number of lambs born combined with its ease of identification by molecular methods. Finding and proliferating the gene in locally adapted sheep by selection on genotype may be preferable to importing homozygous rams of nonadapted breeds due to the loss of adaptation in the F_1 offspring. Readaptation requires at least 3 back-crosses to recover the characteristics of the original native breed and the number of *Booroola* genes may decrease during this process.

In 2006, Gursoy (24) published an economic analysis of profitability of sheep and goat production in Turkey. In his report he documented that sheep and goat production had been declining rapidly in Turkey since the early 1980s. Reasons for the decline included low genetic potential of indigenous breeds, inappropriate breeding strategies, loss of grazing land, and resistance of producers to change in traditional practices. Sheep production was characterized as extensive with low inputs and low outputs. However, he also noted that in Turkey there is a general preference for meat and milk products from sheep and the decline in supply had resulted in a sharp increase in the prices of sheep milk products. He predicted that this would lead to a shift in sheep husbandry from extensive to more intensive production practices.

A more recent economic analysis of sheep breeding in Turkey (25) continues to show the need for increased sheep production. The authors stated that the total number of sheep, number of sheep slaughtered, and quantity of mutton produced per year decreased by 42.31%, 62.12%, and 55.27%, respectively from 1983 to 2007. While this decrease in production has been occurring, the domestic demand for mutton has been increasing at a rate of 6% to 7% per year. The problem continues. New and improved methods and technologies for sheep production are urgently needed to meet Turkey's future needs. The *Booroola* gene offers one way of improving productivity. Increased research activity in sheep genetics and production is needed, combined with a national initiative to provide education to producers in modern, more intensive, and profit-oriented production techniques.

5. Conclusions

Genetic technology that would result in a significant improvement in reproductive performance of sheep in Turkey would have a major impact. Sheep meat is a major source of protein in the Turkish diet and current national production does not meet the demand. The *Booroola* gene has obvious potential to make a quick and large improvement in reproductive rates, which could result in higher production. Research and genetic knowledge indicate that location of the *Booroola* gene in native animals might offer an advantage over importation of breeding animals from other areas. Obviously, when animals are brought into the native flocks to provide the *Booroola* gene, they bring the whole set of genes that have evolved and been selected for their native conditions. These genes may or may not be good for Turkish environmental and cultural conditions. If the *Booroola* gene were identified in sheep that are otherwise adapted to Turkish conditions, the frequency could be increased through a genotyping and breeding scheme and other undesirable characteristics of imported animals could be avoided.

Identification of the *Booroola* gene in native sheep would have great potential and should be investigated. Sheep production in Turkey could benefit from the use of modern breeding and management techniques, and research in these areas would stimulate adoption by local producers and consumers.

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