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A comprehensive review on genetic diversity and phylogenetic relationships among native Turkish cattle breeds based on microsatellite markers

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Abstract: Many local breeds belonging to different livestock species such as cattle are in danger of extinction, since farmers prefer high-yielding breeds as well as intensive selection pressure. This fact leads to conduct suitable breeding and conservation programs in worldwide. Revealing genetic diversity is the first step for applying breeding and conservation programs. In this respect, this is the first comprehensive study aimed to review current genetic diversity and phylogenetic relationships among native Turkish cattle breeds based on previous microsatellite marker studies. Compared to other local cattle breeds reared in different regions of the world, native Turkish cattle breeds hold a huge genetic diversity. On the other hand, the population size of native Turkish cattle breeds has been decreasing since 1991, and local breeds are crossed with exotic ones. It is thought that crossbreeding practices are leading to genetic erosion of native Turkish cattle breeds, while decreasing in population size will negatively affect genetic diversity in the future. Local cattle herds may be raised separately from exotic ones by smallholder farmers who are financially supported by the government. This kind of application may prevent genetic erosion and let the local herds to be raised in naturally adapted regions.

Key words: Anatolian cattle, genetic variability, simple-sequence repeat (SSR) markers

1. Introduction

Today in worldwide, detection and conserving genetic diversity in local livestock breeds is one of the main goals of the breeders for many reasons. For example, genetic diversity is needed to meet current and future demands for milk and meat deriving from different livestock species [1,2]. In this regard, native Turkish cattle breeds are of great importance, since large part of demands for both meat and milk is met by cattle breeding in Turkey [3]. Moreover, Turkey contributes to world's animal genetic resources with six different native cattle breeds. Native Turkish cattle breeds are one of the cultural values of Turkey and they are of unique characteristics [4]. These unique characteristics may be maintained by suitable breeding and conservation programs. It is known that both breeding and conservation programs are shaped by revealing genetic diversity in local breeds [4,5]. Today, microsatellite markers are commonly used to reveal genetic diversity in different livestock species. By evaluating the previous studies, this review aimed to reveal current genetic diversity and phylogenetic relationships among native Turkish cattle breeds. In addition, current genetic diversity of native Turkish cattle breeds was compared to other local cattle breeds raised in different countries of the world and some solid solutions for future challenges were proposed.

2. Cattle breeding in Turkey and native Turkish cattle breeds

As well as all over the world, cattle breeding is of great importance in Turkey due to supplying societies with milk and meat [6-8]. It is known that a balanced and healthy diet depends on consuming not only crop products but also livestock products obtained from different species such as cattle. In Turkey, cattle breeding is mainly centred on exotic breeds such as Holstein-Friesian (HF), Jersey (JR), Brown-Swiss (BS) and their crossbreds. According to official data, Turkey holds approximately 17.6 million cattle, of which the proportion of native Turkish cattle breeds is lower than 12% [3]. Since milk and meat yield of native Turkish cattle breeds are low, exotic breeds are preferred by farmers [9], which has caused dramatically decreasing in population size of native Turkish cattle breeds [3]. Moreover, several native cattle breeds namely Kultak, Halep, Çukurova, Dörtyol, Diyarbakır, Alacadağ etc. were extinct due to their low yield capacity [5].

Today, Turkey holds a total of six distinctive native cattle breeds namely South Anatolian Red (SAR), South

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Anatolian Yellow (SAY), Anatolian Black (AB), East Anatolian Red (EAR), Zavot (ZAV), and Turkish Grey Steppe (TGS) [10]. Although native Turkish cattle breeds cannot compete with exotic breeds in terms of milk and meat yields, they are of distinct characteristics such as resistance to temperature changes and local diseases in raised regions [4]. Moreover, native cattle breeds have been a part of cultural values of Turkey during history and contributed to the Animal Genetic Resources (AnGR). In published studies, the names of native Turkish breeds were translated to several alternative English names. This situation makes it difficult to distinguish the breeds and to compare the results of the published studies by authors who are not native to Turkey. In this review, also the translated names of native Turkish cattle breeds were evaluated, and a common translated name for each native Turkish cattle breed is proposed to be used in scientific papers from now on.

2.1. South Anatolian Red

Being called as "Güney Anadolu Kırmızısı" or "Kilis" in Turkey, South Anatolian Red (SAR) is raised for dual purpose (milk and meat) in the South Anatolian part of Turkey, especially in Mersin, Adana, Gaziantep, and Şanlıurfa provinces. Coat colour ranges from yellow to red (Figure). Compared to other native Turkish cattle breeds, unbalanced walking is one of the distinctive characteristics, since the back legs are thinner than the front legs in SAR [10]. So far, different English-translated names such as "Southern Anatolian Red" [11,12] and "South Anatolian Red" [13–18] were used to refer this cattle breed in previous studies. This situation leads to misunderstandings by the authors from different countries. Therefore, we recommend the authors to use the name of "South Anatolian Red" in order to prevent misunderstanding for further studies.

2.2. South Anatolian Yellow

South Anatolian Yellow (SAY) breed, also called as "Yerli Güney Sarısı" in Turkey, is raised in South Anatolian part of Turkey just as SAR breed. Compared to other native Turkish cattle breeds, climbing to mountainous areas is one of the distinctive characteristics of SAY. Highly adapted to mountainous areas, SAY breed is raised for both milk and meat production [10].

Different English-translated names such as "Southern Anatolian Yellow" [18], "Native Southern Yellow" [16,17], "Native South Yellow" [19] were used to refer this cattle breed. Here, we recommend using "South Anatolian Yellow", which is also accordant with "South Anatolian Red" for further studies to create a common name and to prevent misunderstandings.

2.3. Anatolian Black

Being the most distributed native cattle breed, Anatolian Black (AB) is called "Yerli Kara" in Turkey. Compared to other native Turkish cattle breeds, coat colour is one

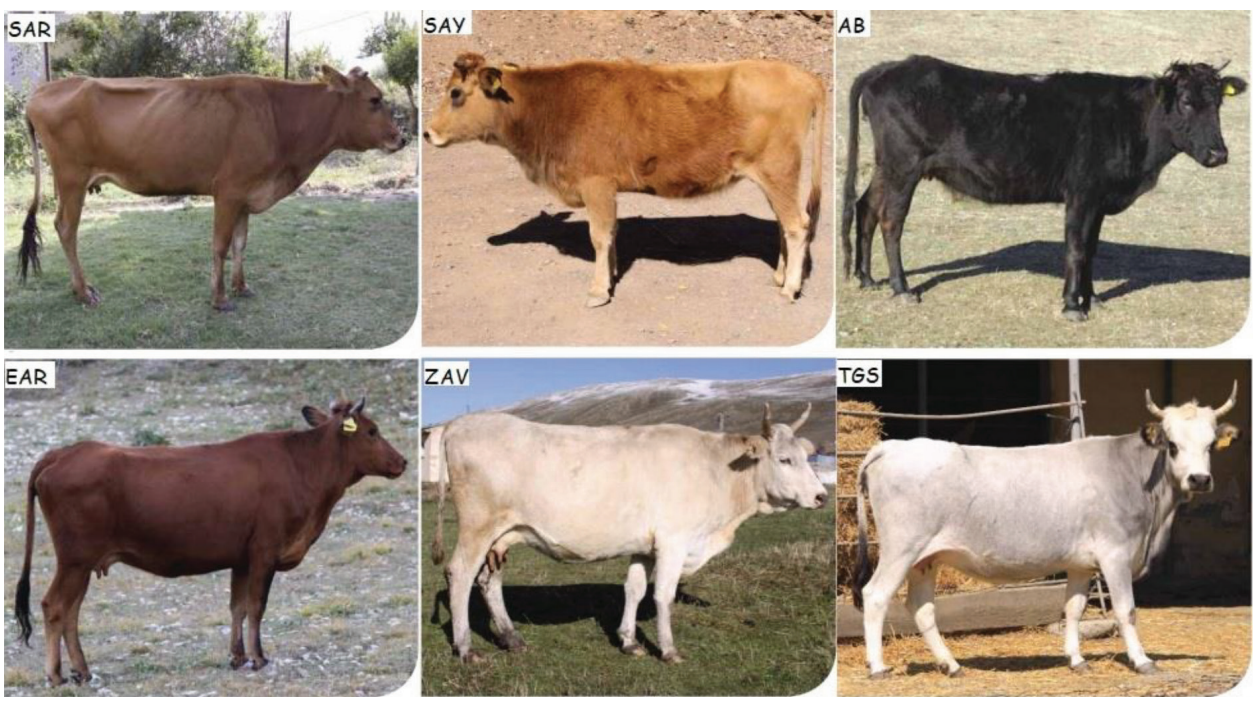

Figure. Six different native Turkish cattle breeds [10]. SAR: South Anatolian Red; SAY: South Anatolian Yellow; AB: Anatolian Black; EAR: East Anatolian Red; ZAV: Zavot; TGS: Turkish Grey Steppe.

of the distinctive characteristics of AB cattle breed, since the body is completely black (Figure). Mainly centred in Middle Anatolia, AB cattle breed is raised almost across all part of the country for both milk and meat production [10].

Although the term of "Native Black Cattle" was used by Akyüz et al. [20] and Öner et al. [17], "Anatolian Black" has been commonly used by many authors [4,12,13,18,21]. In this review, it is recommended using the name of "Anatolian Black" to refer this cattle breed in further studies in order to prevent misunderstandings.

2.4. East Anatolian Red

East Anatolian Red (EAR) cattle breed, also called as "Doğu Anadolu Kırmızısı" in Turkey, is raised in limited area of east part of Turkey including Erzurum, Kars, and Ardahan provinces. EAR cattle breed is raised by smallholder farmers for both milk and meat production [10]. Although coat colour is mainly red, ears and around eyes are black, which are the distinctive characteristics compared to other native Turkish cattle breeds (Figure).

There is a contradictoriness in terms of referring English-translated name of this cattle. For example, some authors used "Eastern Anatolian Red" [4,12], while "East Anatolian Red" was generally preferred by others [13,15,17,18,20]. In this review, we suggest the authors to choose the term of "East Anatolian Red" in order to make a common name and to prevent misunderstandings.

2.5. Zavot

Zavot cattle breed is raised in the limited region of the eastern part of Turkey including Kars and Ardahan provinces just as EAR breed. Compared to other native Turkish cattle breeds, white coat colour is one of the distinctive characteristics of ZAV breed (Figure). It is raised by smallholder farmers for milk and meat production [10].

2.6. Turkish Grey Steppe

Compared to other native Turkish cattle breeds, completely grey coat colour is one of the distinctive characteristics of TGS. It is raised by smallholder farmers for both milk and meat production in Thrace, Aegean, and Marmara regions [10].

There is a disagreement in terms of the naming of TGS cattle breed in both Turkish and English. It is called as "Boz Irk" "Step" and "Plevne" breed in Turkish, while it has been translated in English as "Gray Steppe" [20], "Grey Steppe" [13], "Anatolian Grey" [17,18], "Turkish Grey" [12,15], and "Turkish Grey Steppe" [4, 22-24]. It is of importance to highlight that all these terms refer the same native Turkish cattle breed. This situation in the literature causes misunderstandings to define the breed. We suggest the authors for further studies to use "Turkish Grey Steppe", since this name defines both coat colour and raised region of the breed.

3. Genetic diversity and its importance in farm animals

Genetic diversity is defined as presence of total alleles and genotypes which lead to different morphological, physiological, and behavioural traits among individuals of a species [1]. In other words, genetic diversity can be defined as total variability among subpopulations, varieties, and types of a certain livestock species. Maintenance of genetic diversity is of great importance for both humankind and livestock to face challenges in the future. Genetic diversity in local breeds is needed to respond to climate change, consumer demand, and production systems in the future [1,2]. Also, long-term food security depends on conserving genetic diversity in livestock species [25].

Today, worldwide, genetic diversity in local cattle breeds decreases due to selection process to increase several economically important yields, preferring highly productive exotic breeds rather than local breeds together with uncontrolled crossbreeding possibility [4,9]. Although there is a wide agreement that genetic diversity of AnGR should be conserved, the existence of a great number of livestock breeds (more than 7500) limits conservation programs, which require prioritization of some breeds [25]. Many factors such as productivity, adaptation, and breed demographics have been proposed for prioritization of breeds for conservation programs [25]. For example, total population size, trends in population size in the last 10 years, sociocultural importance of the breed, geographic distribution of breed across the country, crossbreeding possibility, farmer's organization, existence of conservation schemes, political stability of the country were proposed to prioritize conservation among African cattle breeds [26].

In general, the main aim of conservation programs is to preserve as much genetic diversity as possible [25]. Priority must be given the breeds represented with fewer individuals and at the risk of extinction in conservation programs. In this regard, genetic diversity among all native Turkish cattle breeds must be conserved, since they have unique characteristics and their population size decreases year by year [3]. In addition, molecular techniques such as microsatellite analysis are used not only to reveal genetic diversity but also to detect conservation priorities in livestock breeds [27].

4. Molecular techniques to detect genetic diversity

It is known that conducting both breeding and conservation programs depends on revealing genetic diversity among breeds [4,5]. The earlier studies made use of morphological markers and chromosomal karyotyping to detect genetic diversity among breeds [28]. Thanks to the invention of polymerase chain reaction (PCR), many different molecular techniques such as random amplified polymorphic DNA (RAPD), restriction fragment length

polymorphism (RFLP), amplified fragment length polymorphism (AFLP) and microsatellite DNA were discovered to reveal genetic diversity in farm animals. Although, all PCR-based molecular techniques are of some advantages and disadvantages, microsatellite DNA is one of the most preferred technique to reveal both genetic diversity and phylogenetic relationships in farm animals.

Also known as simple sequences repeats (SSRs) or short tandem repeats (STRs), microsatellites are generally less than 5 nucleotide length DNA fragments distributed both coding and noncoding regions across eukaryotic genome [29]. Although microsatellite motifs are conserved in livestock species, their repeat numbers vary from breed to breed as well as from individual to individual in the same breed. Microsatellites are commonly used to reveal genetic diversity because they are abundant, distributed through genome randomly, easy to access and apply, highly polymorphic, and showing codominant inheritance [30].

Characterization of AnGR by different molecular markers is the first strategic priority areas reported by the Food and Agriculture Organization (FAO) [31]. Moreover, FAO [31] recommended panels of 30 microsatellite markers to characterize nine major livestock species such as cattle, buffaloes, sheep, goat, horse, donkey, camelid, pig, and chicken.

Microsatellites have been used to detect genetic diversity of different local cattle breeds raised in different countries such as Turkey [4,17,18,21], Cuba [32], Indonesia [33], France [34], Brazil [35,36], Malawi [37], Taiwan [38], India [39–41], Ethiopia [42], Egypt [43], Cameroon [44], Pakistan [45,46], Philippines [47], Portuguese [48], Japan [49,50], Korea [51], and Poland [30]. Additionally, microsatellites have been applied to detect genetic diversity in other livestock species such as sheep [52–55], goat [56–59], chicken [60–62], pig [63], horse [64], donkey [65], duck [66], and rabbit [67].

5. Genetic diversity among native Turkish cattle

Both decrease in population sizes and increase in awareness of genetic conservation of local breeds have forced researchers to reveal genetic diversity among native cattle breeds in Turkey as well as in other countries in the world.

In Turkey, the first attempt to detect genetic diversity among both native Turkish cattle and exotic breeds via microsatellite markers was carried out by Altınalan [68]. A total of 1582 alleles were reported by revealing genetic structure of four native Turkish cattle breeds (SAR, AB, EAR, and TGS) and Holstein Friesian via 26 different microsatellite markers. Mean number of alleles was 11.65, 12.12, 12.77, and 13.27 for SAR, AB, EAR, and TGS breeds, respectively. Mean observed heterozygosity ranged from 0.433 (TGS) to 0.449 (EAR), while mean expected heterozygosity varied between 0.874 (AB) and 0.883 (TGS) in native Turkish cattle breeds. Although, the study conducted by Altınalan [68] is the first attempt to reveal genetic diversity among native Turkish cattle breeds, it cannot be compared to other studies, since allele bands were detected by polyacrylamide gel instead of fragment analyser [13,14,69].

Özkan [13] used a total of 7 different microsatellite markers to detect genetic structure of both native Turkish (SAR, AB, EAR, and TGS) and exotic cattle (Jersey, Brown-Swiss, and Holstein Friesian) breeds. The mean number of alleles ranged from 7.571 (Jersey) to 11.286 (SAR), while mean expected heterozygosity varied from 0.734 (Jersey) to 0.811 (AB). Author highlighted that higher mean number of alleles were detected in native Turkish cattle breeds than exotic breeds. A total of 102 different alleles and 11 private alleles with low frequencies were reported in studied breeds (Table). The allele frequencies of several microsatellite loci were decreased gradually from eastern Turkey to western Turkey due to geographic distance from cattle domestication centre. Besides, admixture of Zebu ranging from 8.11% (TGS) to 12.58 (EAR) was proposed as another reason for high number of alleles in native Turkish cattle breeds.

Özşensoy et al. [69] used a total of 20 FAO-recommended microsatellite markers to reveal population structure and phylogenetic relationships among six native Turkish cattle breeds. A total of 274 alleles ranging from 6 (ZAV) to 11 (SAR and AB) per breed were reported in studied populations. Inbreeding coefficient ranged from 0.013 (EAR) to 0.065 (SAY) with a mean of 0.042 ($P < 0.05$). It has been reported that lower genetic diversity was detected in EAR and ZAV breeds due to lower sample numbers. In addition, lower number of alleles was detected in TGS breed compared to SAR, SAY, and AB breed due to higher distance from domestication centre. Indeed, TGS are raised in Thrace region of Turkey, which is closer to Europe than Middle East. In addition, Özşensoy et al. [70] reported that 7 of 20 studied microsatellite markers (CSSM66, CSRM60, ETH03, INRA023, HEL9, ILSTS006, SPS115) were suitable for parentage testing.

Özşensoy [14] investigated genetic characterization and phylogenetic relationships of native Turkish cattle breeds (AB, TGS, SAR, SAY, EAR, and ZAV) using 20 microsatellite markers. A total of 266 different alleles, of which 39 alleles were private, were reported in studied cattle breeds. Mean number of alleles ranged from 6.9 (ZAV) to 10.65 (SAY) among studied breeds (Table). Mean observed heterozygosity ranged from 0.691 (TGS) to 763 (SAY), while mean expected heterozygosity varied from 0.740 (ZAV) to 0.804 (SAY). Significant inbreeding coefficients ($P < 0.05$) ranging from 0.018 (ZAV) to 0.110 (TGS) were reported in all native Turkish breed ZAV excluded.

Table. Genetic diversity parameters in native Turkish cattle breed.

Breed	MNa	PA	Ho	He	PIC	F_{IS}	References
SAR	11.286	1	0.677	0.784	-	0.137	Özkan [13]
	10.500	8	0.759	0.799	0.75	0.060	Özşensoy [14]
	9.860	8	0.75	0.77	-	0.056	Öner et al. [17]
SAY	10.650	11	0.763	0.804	0.74	0.061	Özşensoy [14]
	10.230	8	0.80	0.77	-	0.016	Öner et al. [17]
AB	10.286	2	0.735	0.811	-	0.096	Özkan [13]
	10.600	8	0.761	0.803	0.76	0.063	Özşensoy [14]
	8.450	-	0.68	0.78	0.73	0.128	Demir and Balcioğlu [4]
	9.770	3	0.74	0.75	-	0.064	Öner et al. [17]
EAR	10.143	-	0.665	0.780	-	0.149	Özkan [13]
	8.450	1	0.756	0.784	0.71	0.053	Özşensoy [14]
	7.150	-	0.59	0.74	0.69	0.202	Demir and Balcioğlu [4]
	120	38	0.90	0.86	-	-0.019	Öner et al. [17]
ZAV	6.900	3	0.754	0.740	0.75	0.018	Özşensoy [14]
TGS	10.286	3	0.682	0.775	-	0.120	Özkan [13]
	9.900	8	0.691	0.767	0.74	0.110	Özşensoy [14]
	7.950	-	0.61	0.78	0.73	0.216	Demir and Balcioğlu [4]
	12.050	42	0.88	0.85	-	-0.006	Öner et al. [17]

MNa: Mean number of alleles; PA: Mean number of private alleles; Ho: Mean observed heterozygosity; He: Mean expected heterozygosity; PIC: Polymorphic information content; F_{IS}: Inbreeding coefficient; SAR: South Anatolian Red; SAY: South Anatolian Yellow; AB: Anatolian Black; EAR: East Anatolian Red; ZAV: Zavot; TGS: Turkish Grey Steppe.

Demir and Balcioğlu [4] were assessed genetic diversity and population structure of 3 native Turkish cattle breeds (TGS, EAR, and AB) and Holstein Friesian by using 20 microsatellite markers. A total of 204 different alleles and 31 private alleles with low frequencies (<3%) were reported in studied breeds. Mean observed heterozygosity ranged from 0.59 (EAR) to 0.68 (AB), while mean expected heterozygosity varied from 0.74 (EAR) to 0.78 (TGS and AB). The authors highlighted that observed heterozygosity was lower than expected heterozygosity due to presence of more homozygous individuals than heterozygous ones in studied breeds. Among native Turkish cattle breeds, inbreeding coefficient ranged from 0.128 (AB) to 0.216 (TGS). The authors reported that compared to Holstein Friesian, native Turkish cattle breeds had higher inbreeding level due to lower effective population sizes. Indeed, population size of native Turkish cattle breeds has been decreasing year by year, while population size of exotic cattle breeds and their crossbreds is increasing since 1991. In addition, heterozygosity deficiency was reported in TGS breed based on bottleneck analysis.

Bottleneck analysis was also studied by Semen et al. [21] for AB breed by using 10 microsatellite markers. A total of 116 alleles were reported by genotyping 75 individuals from AB breed raised in International Centre for Livestock Research and Training. Mean number of alleles, observed and expected heterozygosity were reported as 11.60, 0.80, 0.78, respectively with low inbreeding coefficient (0.012). The authors declared no sign of bottleneck in the recent past in AB cattle breed based on the infinite allele model (IAM), two-phased mutation model (TPM), and stepwise mutation model (SSM).

The most comprehensive microsatellite study of native Turkish cattle breeds was carried out by Öner et al. [17] who evaluated genetic diversity and population structure of native Turkish cattle breeds (SAY, SAR, TGS, AB, and EAR) by means of 22 microsatellite markers. A total of 545 different alleles and 198 private alleles were reported by genotyping 199 animals. The frequency of 34 private alleles was higher than 5%. Mean number of alleles ranged from 9.77 (AB) to 12.05 (TGS) in native cattle breeds (Table). Mean observed heterozygosity varied from 0.74 (AB) to 0.90 (EAR), while mean expected heterozygosity ranged from 0.75 (AB) to 0.86 (EAR). Low inbreeding coefficient ranging from -0.006 (TGS) to 0.064 (AB) were detected in native Turkish cattle breeds. The study conducted by

Öner et al. [17] is of great importance in terms of higher number used microsatellite markers, higher number of individuals, and better sampling strategy compared to previous studies. It is obvious that it reflects current genetic diversity and population structure of native Turkish cattle breeds in which high genetic diversity and low inbreeding were reported.

The results of the previous studies showed that mean number of alleles, one of the genetic diversity parameters, detected in native Turkish cattle breeds [4,13,14,17,18] were higher than the values reported in many local cattle breeds raised in Europe, Asia, Africa, America, and India [36,39,41,43,46,48,51,71-79]. Basically, many factors such as sample size, number of microsatellite markers, and sampling strategy may affect genetic diversity parameters. Besides, there are another important reasons for higher genetic diversity in native Turkish cattle breeds.

Turkey, being near the Fertile Crescent, has a key role in domestication process due to its location connecting two continents such as Asia and Europe. It is also known that Turkey has been both trade and migratory route during history which might led cattle migration from Anatolia to Europe [80]. Moreover, Di Lorenzo et al. [81] hypothesized that migration of Middle Eastern cattle from Anatolia to Central Italy via different routes contributes the present gene pool of Podolian cattle breeds. As Turkey is the domestication centre of Taurine cattle, native Turkish cattle possess huge genetic diversity naturally [4,13,14,69,70]. Also, Özkan [13] indicated that selection intensity of native Turkish cattle breeds was lower than exotic cattle breeds originated from Europe. Additionally, native Turkish cattle breeds are subjected to conservation programs in which smallholder farmers rearing native cattle herds in their adapted areas are financially supported by government.

6. Phylogenetic relationships among Turkish native cattle

Microsatellite markers are not only useful tools to detect genetic diversity, but also to reveal phylogenetic relationships among different livestock breeds. They have been used to analyse phylogenetic relationships based on genetic distance, factorial correspondence analysis (FCA) and structure analysis among different breeds of cattle [4], chicken [62], goat [82], sheep [54]. In this section, phylogenetic relationships among native Turkish cattle breeds were reviewed based on previous studies making use of microsatellite markers.

Phylogenetic tree based on genetic distance values were constructed for native Turkish cattle breeds in several studies in which Özkan [13] showed that TGS and AB were closer, while Özşensoy et al. [69] reported that TGS and SAR were closer compared to other local cattle breeds. Recent studies revealed that SAY and SAR breeds were clustered into a single group in phylogenetic tree [17,18]. It is not surprising, since both SAY and SAR breeds are raised in South Anatolia, Turkey. On the other hand, native Turkish cattle breeds were clearly separated from exotic breeds such as Jersey, Brown Swiss, and Holstein in phylogenetic tree which is in accordance with the breed origins [4,13].

FCA, another analysis to reveal phylogenetic relationships among breeds, is used to locate breeds in three-dimensional space. FCA analysis conducted by several studies showed that although, native Turkish cattle breeds clustered separately, a high level of admixture were detected between them [4,13,18]. On the contrary, Demir and Balcioğlu [4] reported that native Turkish cattle breeds showed very clear separation from Holstein Friesian according to FCA analysis.

Structure analysis is commonly used to clustering breeds in microsatellite studies. SAY, SAR and AB cattle breeds were reported to clustered together, while TGS and EAR breeds were clustered separately in structure analysis [17]. Similarly, Özşensoy et al. [18] reported that results of structure analysis were similar to FCA analysis in which a high level of admixture were detected among native Turkish cattle breeds. On the contrary, Demir and Balcioğlu [4] showed that EAR, TGS and AB breeds were clustered separately according to structure analysis. Moreover, native Turkish cattle breeds were reported to be distinct from exotic cattle breeds which is accordant with the breeds origin [4,13].

7. Conclusion and future goals

In this study, genetic diversity and phylogenetic relationships among native Turkish cattle breeds based on microsatellite markers were reviewed by checking previous studies. It has been observed that native Turkish cattle breeds hold huge genetic diversity compared to other local cattle breeds raised in different regions of the world due to geographic location of Turkey. Still there are some challenges threating genetic diversity in native Turkish cattle breeds.

Today, native Turkish cattle breeds are replaced with high-yielding exotic breeds such as Holstein Friesian, Brown Swiss, and Jersey by farmers. Although, population size of native Turkish cattle breeds was 6.685.683 in 1991, today it is estimated at 1.573.659 heads [3]. Moreover, native Turkish cattle breeds are crossed with exotic breeds such as Holstein Friesian, Jersey, and Brown Swiss to increase milk production [16]. Indeed, Özkan [13] reported that contribution rate of alleles from Jersey to native Turkish cattle breeds ranged from 18.84 (AB) to 30.5% (TGS), whereas this value ranged varied from 7.52% (SAR) to 15.63% (TGS) for Holstein Friesian and

from 6.54% (EAR) to 24.82% (TGS) for Brown Swiss. These facts lead to genetic erosion in local breeds which possess unique characteristics needed sustainable use of local breeds in the future. In order to prevent the genetic erosion of native Turkish cattle breeds, smallholder farmers holding local cattle herds should be informed and breeding practices should be controlled. Also, genetic diversity and population structure of local cattle breeds should be revealed periodically to foreseen future challenges. Moreover, not only microsatellite markers but also new molecular techniques based on next generation sequencing (NGS) should be adopted by researchers in order to reveal detect genetic diversity corresponding to larger part of the genome.

8. Expected benefits of the review to the literature

It is clearly obvious that this review will contribute to scientific arena in terms of different points of view.

Firstly, different English-translated names of native Turkish cattle breeds were evaluated for the first time and appropriate names were proposed for each breed to be used for further studies which will make it easy to compare studies from different countries.

Secondly, this is the first comprehensive study aimed to review current genetic diversity and phylogenetic relationships among native Turkish cattle breeds. Gathering previous microsatellite studies on native Turkish cattle breeds will serve as a compiled guidebook for researchers in animal science, and it will facilitate planning stage of future microsatellite and/or other molecular studies.

Finally, management practises, which negatively affect the current genetic diversity of native Turkish cattle breeds were assessed and some solid solutions were proposed for the future challenges. These solutions may be helpful for other countries having the same management practices and future challenges.

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Conflict of interest

The authors declare no conflict of interest for the present study.

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