

The Use of Various SNPs in CAST and CAPN1 Genes to Determine the Meat Tenderness in Turkish Grey Cattle ^[1]

Süleyman KÖK ^{1,a}  Sertaç ATALAY ^{2,b}

^[1] This research was presented at the 12th Turkey National Food Congress, 05-07 October 2016, Edirne, Turkey

¹ Department of Genetics and Bioengineering, Faculty of Engineering, Trakya University, TR-22030 Edirne - TURKEY

² Trakya University, Institute of Science and Technology, Department of Biotechnology and Genetics, TR-22030 Edirne - TURKEY

^a ORCID: 0000-0002-9677-3571; ^b ORCID: 0000-0003-4942-7729

Article Code: KVFD-2017-17617 Received: 21.02.2017 Accepted: 28.09.2017 Published Online: 05.10.2017

Citation of This Article

Kök S, Atalay S: The use of various SNPs in CAST and CAPN1 genes to determine the meat tenderness in Turkish Grey Cattle. *Kafkas Univ Vet Fak Derg*, 24 (1): 1-8, 2018. DOI: 10.9775/kvfd.2017.17617

Abstract

The aim of this study is to investigate the relationship between some genotypic characteristics of purebred Turkish Grey Cattle (TGC) and beef tenderness characteristics. There is a linear relationship between meat tenderness and the increasing calcium activity after slaughtering. Calpastatin (CAST) is a neutral protease inhibitor of Calpain (CAPN1) in mammalian tissues. The three polymorphic places in the CAST and the CAPN1 genes in cattle (*UoG*-CAST, CAPN1 316 and 4751) are known as the markers of beef quality. The relationship between the tenderness traits of the *longissimus dorsi* (LD) and the 3 beef quality markers (3 SNPs) in pure TGC have been investigated and discussed. PCR-RFLP and ARMS-PCR methods were utilized to identify the genotypes. In order to determine the water holding capacity (WHC), cooking loss (CL) and the shear force (SF), samples extracted from LD were probed. The average and standard error SF of a two-year-old TGC bred in extensive conditions was 4.339 ± 0.217 kg/cm² for the heifers and 4.689 ± 0.569 kg/cm² for bulls. Both alleles of the *UoG*-CAST (C/G), the CAPN1 316 (C/G) and the CAPN1 4751 (C/T) polymorphisms in the samples were observed. The average SF of 3.943 ± 0.441 kg/cm², 4.537 ± 1.666 kg/cm², and 3.869 ± 0.721 kg/cm² were used for the CAST-CC, the CAPN1 4751-CC and the CAPN1 316-GC, respectively in order to cut the muscle fibers of the genotypes that have a positive effect on tenderness. No cattle of the CAPN1 316-CC genotype was identified among the samples. The average and standard error WHC, CL and SF values for the entire sample including heifers and bulls were found as $11.693 \pm 0.761\%$, $26.952 \pm 0.636\%$, and 4.483 ± 0.252 kg/cm², respectively. In conclusion, the presence of genetic variation in specific SNP markers of beef tenderness in purebred TGC can contribute to the process of raising TGC with more tender meat.

Keywords: Beef texture, Water Holding Capacity, Cooking Loss, CAST, CAPN1, PCR-RFLP, ARMS-PCR

Boz Irk Sığırın Et Gevrekliğini Belirlemede CAST ve CAPN1 Genlerindeki Kimi SNP'lerin Kullanımı

Özet

Bu çalışmanın amacı saf Boz ırk sığırın (TGC) kimi genotipik özellikleri ile et gevreklik özelliği arasındaki ilişkiyi araştırmaktır. Kesim sonrası sığır etlerinde artan kalsiyum aktivitesi ile et gevrekliği arasında doğrusal bir ilişki vardır. Kalpastatin (CAST), memeli dokularında bulunan kalpain'ın (CAPN1) nötr bir proteaz inhibitörüdür. Sığır CAST ve CAPN1 genlerinde üç polimorfik yer (*UoG*-CAST, CAPN1 316 ve 4751) et kalite markörü olarak bilinir. Saf TGC'nin *longissimus dorsi* (LD) kası gevreklik özellikleri ile 3 et kalite markörünün ilişkileri araştırılıp tartışılmıştır. Genotipleri tanımlamada PCR-RFLP ve ARMS-PCR metotları kullanılmıştır. Etin su tutma kapasitesi (WHC), pişme kaybı (CL) ve tekstürünü (SF) belirlemek için LD kası örnekleri üzerinde çalışılmıştır. Extansif koşullarda yetiştirilen iki yaşındaki TGC sığırın SF ortalama ve standart hataları düveler de 4.339 ± 0.217 kg/cm², erkekler de 4.689 ± 0.569 kg/cm² olduğu saptanmıştır. Çalışılan et örneklerinde *UoG*-CAST (C/G), CAPN1 316 (C/G) ve CAPN1 4751 (C/T) polimorfizmlerinin her iki alleli de gözlenmiştir. Et gevrekliği üzerine olumlu etkisi olan genotiplerin, kas liflerini kesmek için ortalama CAST-CC için 3.943 ± 0.441 kg/cm², CAPN1 4751-CC için 4.537 ± 1.666 kg/cm² ve CAPN1 316-GC için 3.869 ± 0.721 kg/cm² SF uygulanmıştır. Örneklerde CAPN1 316-CC genotipinde sığır belirlenmemiştir. Dişi ve erkek sığırlara ait tüm örneklerin dahil olduğu WHC, CL ve SF ortalama ve standart hata değerleri sırasıyla; $11.693 \pm 0.761\%$, $26.952 \pm 0.636\%$ ve 4.483 ± 0.252 kg/cm² olarak belirlenmiştir. Sonuç olarak, safkan TGC da et gevrekliğine özgü SNP markörlerin genetik çeşitliliğin olması, daha gevrek etli TGC sığır yetiştirme sürecine katkıda bulunabilir.

Anahtar sözcükler: Et tekstürü, Su Tutma Kapasitesi, Pişme Kaybı, CAST, CAPN1, PCR-RFLP, ARMS-PCR



İletişim (Correspondence)



+90 284 2261218/1301; Fax +90 284 2261225



koks@trakya.edu.tr

INTRODUCTION

Meat is obtained from warm-blooded and healthy cattle, ovine and poultry by butchery. The part that is left after all the blood is drawn and the parts that are not suitable for consumption are removed is the meat on the bone. The word "meat" usually refers to the skeletal muscles, which is also called striated muscles. After the rigor mortis stage ends, the meat which has become rigid softens with the ripening when it is not sliced and becomes tender. The meat should be kept in a cool and hygienic environment to ease the effects of rigor mortis. During the ripening pH ranges between 5.2 and 6.2 in butchery animals as a result of various enzymatic activities. The meat with pH 6.4 is suspected to have bacterial decomposition. The tenderness of meat which has a huge impact on customer satisfaction is one of the most important issues in beef cattle production [1]. CAPN proteolytic system is responsible for the tenderizing process after death. CAST prevents μ - and m -Calpain activity and regulates postmortem proteolysis. There is a linear correlation between the calcium activity after death and the meat tenderness [2]. Many studies show that CAPN-CAST system is important to the normal development of skeletal muscles. Smith *et al.* [3] reported that the specific SNPs in CAST and CAPN1 loci are related to some genetic effects that are important to meat tenderness. Also, most reports of the same subject point out the relationship between the CAST and CAPN1 genetic polymorphism and LD and the shearing resistance of the muscle [4-6]. Instead of choosing the best meat after determining the meat quality parameters (taste, juiciness or tenderness), it would be wiser to choose the animals with the genotypes which have more qualified meat. It is possible to choose the animals with more qualified meat by determining the polymorphisms in CAST and CAPN1 gene loci of the animals without using complicated selection procedures. In *Bos Taurus* beef, there is a relationship between the SF shearing resistance and UoG-CAST SNPs during the postmortem 7th, 14th and the 21st days. The cattle with UoG-CAST CC genotype are likely to have more tender beef compared to the cattle with GG genotype, and the cattle with CG genotype have to medium tenderness beef [5-7]. In addition, some researchers who worked on *Bos taurus* [3,8-10] and *Bos indicus* [4,11,12] beef found a correlation between the SF values and the CAPN1 316 SNPs and 4751 SNPs on the 7th and 14th days after the slaughter ($P < 0.05$). The SF applied to homozygous cattle meat with the CAPN1 316 CC genotype had 10% and 14.6% less resistance compared to the heterozygote CG genotypes and homozygous GG genotypes, respectively [13]. Beef from *Bos Taurus* cattle with the CAPN1 4751 CC genotypes are more likely to be tender compared to the cattle with other genotypes [8,14].

Some commercial genetic indicators have been developed to increase beef tenderness, such as the UoG-CAST and the CAPN1 316 markers [6,14]. National Cattlemen's Beef

Association in the USA has approved the efficiency of those genetic markers. The association recommends the cattlemen to increase the ratio of the CAPN1 316/4751 haplotype C/C frequency within the cattle population to have more tender beef [6].

The aim of this study is to obtain empirical data from the purebred TGC's beef (from the rib steaks) samples by comparing their WHC, CL, SF data to TGC with different genotypes which are formed by the UoG-CAST (CAST/Rsal), the CAPN1 316 and 4751 polymorphisms.

MATERIAL and METHODS

Animals

The samples that were extracted from 17 TGC (10 males and 7 females) from the rural cattle breeding barns in Enez District, Edirne in 2013 were used. The barns from which the samples were extracted utilized extensive breeding methods in grazing lands. In this study, female and male animals bred in Thrace and slaughtered at 24-months-old were used.

Separation and Evaluation Time of The LD

TGC brought from the rural grazing lands of Çandır village in Enez district were cut off in Keşan slaughterhouse. The LD samples of our research material were separated from TGC carcasses after 24 h of waiting in slaughterhouse.

The assessments of WHC (%), CL (%) and Warner-Bratzler SF (kg/cm²) on the LD were done on the 21st day after death at Istanbul University, Faculty of Veterinary Medicine, Zootechnics Department Laboratory.

Calculation of The WHC

In order to measure the WHC "Passive Drip Loss" method [15] was used. To do this, 100 g samples were extracted from the LD muscle and weighted (weight1). The samples were placed in a polyethylene bag without touching the surface of the bag and they were weighed again after they were stored at +4°C for 24 h (weight2). WHC was calculated with the following formula [15].

$$\text{WHC (\%)} = [(\text{weight1} - \text{weight2}) / \text{weight1}] * 100$$

Calculation of The CL

The meat frozen at -18°C was thawed at +4°C and 100 g meat samples were placed in polyethylene bags and vacuumed. The meat was cooked in water-bath for an hour until the internal temperature of the meat reached 80°C. The cooked meat was cooled down for 12 h at +4°C and the surface was dried before it was weighed. CL percentage was calculated with the following formula [15,16].

$$\text{CL (\%)} = [(\text{weight of raw steak after thawing} - \text{weight of cooked steak}) / \text{weight of raw steak after thawing}] \times 100.$$

Texture Analysis

After the calculation of CL, the cooked meat was sliced with a SF knife with a 50-kg cutting power at 20 cm/min speed to determine the shearing resistance of the muscle fibers for the texture analysis. The meat cooked at 70-72°C were cooled down 5-6°C and they were sliced as a section of 2.54 x 2.54 cm parallel to the muscle fibers. Six samples were extracted from each LD and they were sliced. *The highest force* (kg/cm²) and *force x time* graphics obtained during the application of the SF knife for each sample were saved on the computer. The peak SF value for a muscle of an animal was calculated by averaging the values obtained from the six samples extracted from that animal ^[11,15].

DNA Isolation

Genomic DNA of the tissue samples taken from TGC were isolated using Fujifilm QuickGene-mini-80 device and tissue kit (Quick Gene DNA Tissue kit, Fujifilm, UK) based on the instructions given by the manufacturer. A nanodrop (A^{260/280}) was used to determine the amount of the DNA and the samples were stored at -20°C in Trakya University Biotechnology and Genetics Laboratory.

Amplification of the Target DNA Samples and Identification of the Genotypes

The target DNA was amplified and The PCR-RFLP method with *RsaI* restriction enzyme was utilized to identify the genotypes of CAST gene SNP (AY008267.1:g.282C>G) according to the works of Schenkel *et al.*^[5] and Curi *et al.*^[11]. In order to determine the CAPN1 4751 SNP (AF 248054.2:g.6545C>T) and the CAPN1 316 SNP (AF252504.2:g.5709C>G) genotypes, the ARMS-PCR method was used based on the work of Rincón and Medrano ^[17]. The primers (Sentegen Biotech, Ankara/Turkey) used in this study

were given in *Table 1* and fragment sizes were amplified using the Bioneer My Genie 96 Thermal Block PCR device (Bioneer Corporation, South Korea). Amplification of DNA was run in the 2% horizontal gel electrophoresis and was used for the genotyping by "DNR Bioluminescence Systems Minibis Pro, Jerusalem, Israel".

Statistical Analysis

We genotyped TGC based on the polymorphic The *UoG-CAST* loci in CAST gene and the CAPN1 316 and 4751 loci in CAPN1 gene. After genotyping, the samples underwent phenotypic analysis to calculate WHC%, CL% and SF (kg/cm²). Averages (\bar{X}), standard error (s_x), the genotypic and phenotypic correlations (r) were calculated using SPSS statistics program. In addition, two-tailed t-test was used to compare the results. According to the Hardy-Weinberg (HW) equilibrium, the fit test of the distribution of Allele and genotype frequencies was calculated by the Chi-square (χ^2) test. The distribution of genotypic frequencies was evaluated based on the 5% significance level of the Chi-square table.

RESULTS

Cattle with one combination of the two different patterns one of which is matched with either homozygous or heterozygote genotypes in the *UoG-CAST*, the CAPN1 316 and 4751 loci were identified and the three unique band patterns of the cattle genotypes (except the CAPN1 316 CC genotype) were observed in the electrophoresis gel. The genotype and allele frequencies of the 3 different SNPs of the sample 17 purebred TGC were calculated in accordance with HW equilibrium, which are shown in *Table 2*.

Two genetic variances (C and G) were identified in The *UoG-CAST* polymorphism structure of TGC samples. According to the pattern images formed on the electrophoresis gel; homozygous CC genotype, homozygous GG genotype; and heterozygotes-GC were characterized and defined to have one band with 523 bp, two bands with 257 and 266 bp and three bands with 523, 257 and 266 bp, respectively. In all of the TGC samples the frequency of the *UoG-CAST* C allele, which is thought to have a positive effect on beef yield, is 0.559 and the distribution between C/G alleles is in HW equilibrium ($P>0.05$). The *UoG-CAST* genotypic frequencies of the male samples were significant ($P<0.05$) and in male samples were found to have a higher frequency of C allele (0.714). The genotypic frequencies of CC, CG and GG in TGC were observed as 0.312, 0.493 and 0.195, respectively (*Table 2*). TGC is in HW equilibrium for the *UoG-CAST* SNP ($P>0.05$).

In the TGC, the CAPN1 316 polymorphism genotypes were defined based on the patterns they form on the electrophoresis gel with the use of ARMS-PCR method. The ones forming 3 bands with 228, 269 and 446 bp were defined as Heterozygote CG genotype while the ones

Table 1. Primary Sequences used in PCR and the product size obtained

Marker	Primer Sequences (5' - 3')	bp
* <i>UoG</i> CAST	¹ Fop:CTCGACTGCGTACCAATTCGGAAGTAAAGCC AAAGGAACA	523
	² Rop: ATTTCTCTGATGGTGGCTGCTCACT	
**CAPN1 316	³ Fip: TTTCTGTCAGCTCCTCGGAGTGGAAAGGG	269
	⁴ Rip: GCTCCGCATGTAAGGGTCCAGGG	228
	¹ Fop: GCTGTGCCACCTACCAGCATC	446
	² Rop: CAGGTTGCAGATCTCCAGGCCG	
**CAPN1 4751	³ Fip: GCATCCTCCCTTGACTGGGGGAAACCC	158
	⁴ Rip: GTCACCTGACACAGCCCTGCGCCGCA	231
	¹ Fop: CCTGGAGTCCTGCCGAGCATGGTCAAC	334
	² Rop: AAGCTGCAGGAGCTGCCAAAGCCAGGC	

*RFLP method, ** ARMS method, ¹Fop: Forward outer primer, ²Rop: Reverse outer primer, ³Fip: Forward inner primer, ⁴Rip: Reverse inner primer, bp: Base pair

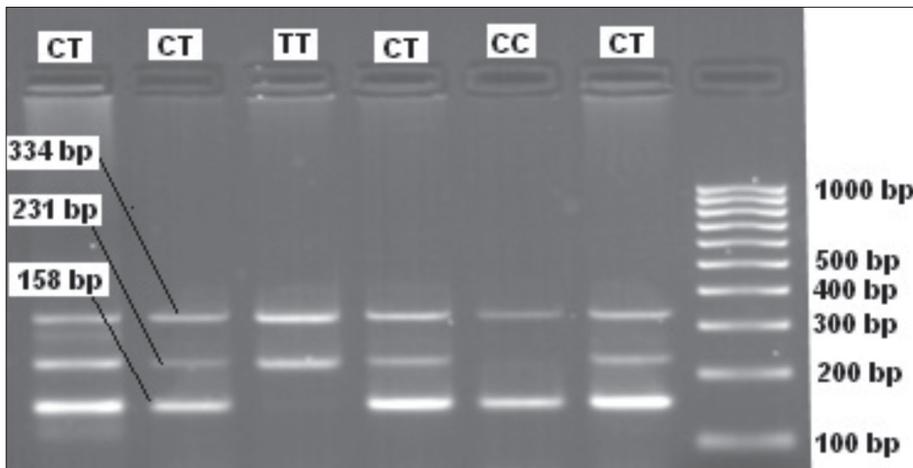
Table 2. The UoG-CAST (Calpastatin), the CAPN1 (μ -Calpain) 316 and 4751 allele and genotype frequencies of TGC samples

Cattle Race	Animal Number	UoG-CAST Allele Frequency		UoG-CAST Genotype Frequency (n)			Chi-square
		C	G	CC	CG	GG	
Turkish Grey Cattle	17	0.559	0.441	0.312 (5)	0.493 (9)	0.195 (3)	0.529
		CAPN1 316 Allele frequency*		CAPN1 316 Genotype frequency* (n)			
		0.059	0.941	0.003 (0)	0.111 (2)	0.886 (15)	36.41*
		CAPN1 4751 Allele frequency		CAPN1 4751 Genotype frequency (n)			
		0.412	0.588	0.171 (2)	0.485 (10)	0.346 (5)	1.582

* The population is not in HW equilibrium ($P < 0.05$)

Table 3. The comparison of the results related to WHC %, CL % and Meat Texture (SF kg/cm²) of the LD samples based on Gender, the UoG-CAST, the CAPN1 4751 and 316 genotypes in all TGC

Phenotypic Features	All Group	Sex Group		UoG-CAST Genotype		
		Female	Male	CC	GC	GG
SF(kg/cm ²) ($X \pm s_x$)	4.483 \pm 0.252	4.339 \pm 0.217	4.689 \pm 0.569	3.943 \pm 0.441	4.488 \pm 0.298	5.55 \pm 0.633
CL % ($X \pm s_x$)	26.952 \pm 0.636	27.505 \pm 0.929	26.161 \pm 0.866	26.688 \pm 1.108	27.584 \pm 1.015	25.793 \pm 1.560
WHC % ($X \pm s_x$)	11.693 \pm 0.761	12.687 \pm 1.082	10.272 \pm 0.947	10.188 \pm 0.969	11.667 \pm 1.293	14.772 \pm 0.740
Phenotypic Features	All Group	CAPN1 4751 Genotype			CAPN1 316 Genotype	
		CC	CT	TT	GG	GC
SF(kg/cm ²) ($X \pm s_x$)	4.483 \pm 0.252	4.221 \pm 0.873	4.537 \pm 1.666	4.986 \pm 1.303	4.565 \pm 1.102	3.869 \pm 0.721
CL % ($X \pm s_x$)	26.952 \pm 0.636	24.385 \pm 2.123	27.688 \pm 2.730	26.506 \pm 2.530	27.068 \pm 2.866	26.077 \pm 0.270
WHC % ($X \pm s_x$)	11.693 \pm 0.761	12.406 \pm 4.843	11.850 \pm 3.568	11.093 \pm 2.554	11.644 \pm 3.251	12.060 \pm 3.251

**Fig 1.** The agarose gel electrophoresis images of TGC with the CAPN1 4751 SNP genotypes using ARMS-PCR method

forming 2 bands with 269 and 446 bp long were defined as Homozygous GG genotype. However, there were no TGC carrying 2 bands with 228 and 446 bp that define the homozygous CC genotype in our sample. The CAPN1 316 C/G allele frequencies distribution of the samples is significant ($P < 0.05$). There were no cattle with CC genotype in our TGC sample group and the C allele frequency which has a positive effect on the tenderness of the beef was quite low (0.059). TGC is not in HW equilibrium for the CAPN1 316 SNP ($P < 0.05$) (Table 2).

In the TGC, the CAPN1 4751 SNP with Homozygous CC genotype, Heterozygote CT genotype and Homozygous TT genotype were observed to form two band patterns with 334 and 158 bp, three band patterns with 334, 231 and 158 bp and two band patterns 334 and 231 bp size, respectively in the electrophoresis gel with the use of ARMS-PCR method (Fig. 1). The distribution of the CAPN1 4751 C/T allele frequencies in TGC samples are in HW equilibrium. Similarly, the distribution of the CAPN1 4751 genotypic frequency was found to be in HW equilibrium ($P > 0.05$).

Table 4. The correlations derived for meat quality features and SNPs

Traits	UoG CAST	CAPN1 4751	CAPN1 316	WHC (%)	CL (%)	SF (kg/cm ²)
UoG-CAST						
CAPN1 4751	0.155					
CAPN1 316	-0.052	0.400				
WHC (%)	-0.126	0.135	0.043			
CL (%)	0.015	-0.106	-0.122	0.263		
SF (kg/cm ²)	-0.227	-0.221	-0.216	0.148	-0.199	
Gender	0.262	0.536*	0.306	0.379	0.252	-0.166

* In bold, significant values (except diagonal) at the level of significance $P < 0.05$ (two-tailed test)

The ratio of heterozygous TGC was observed in higher frequency than other genotypes with the CAPN1 4751 (Table 2).

WHC, CL and SF values for the LD samples of TGC genotypes with the UoG-CAST, the CAPN1 4751 and 316 are presented in Table 3. According to the results of the study, TGC with the UoG-CAST CC (3.943±0.4414 kg/cm²) genotype have more tender meat compared to TGC CG and GG genotypes. Also the statistical relationship was found that between the SF value after death and the UoG-CAST CC SNP genotype ($P < 0.05$) of the LD muscle. The SF values of TGC with the CAPN1 316 GC genotype were found 3.869±0.7214 kg/cm². TGC with the CAPN1 316 GC genotypes were determined to have more tender meat than the GG genotypes (4.565±1.1025 kg/cm²). The difference between each other measurement was found statistically insignificant ($P > 0.05$). According to the SF values of TGC with the CAPN1 4751 CC (4.221±0.8734 kg/cm²) in our sample, TGC with CC genotype were found to yield more tender meat compared to the cattle with CT and TT genotypes although the difference was not statistically significant ($P > 0.374$).

The marker combinations associated with meat tenderness in TGC samples were compared. TGC with the toughest meat in our sample was the male cattle with GG/TT/GG genotype where the UoG-CAST "GG", the CAPN1 4751 "TT" and the CAPN1 316 "GG" combinations merge with 6.557 kg/cm² SF value. On the other hand, the male cattle with CC/CT/GG genotype seemed to have the tenderest meat with 2.329 kg/cm² SF. The haplotype C/C/C frequency, which is positive for meat tenderness, in our TGC sample was found 0.014. The triple genotypic combinations affecting the meat tenderness in a positive way were not evaluated statistically in our sample due to their inadequate number in our sample. Except for the linear correlation between TGC with the CAPN1 4751 genotype and gender ($P < 0.05$), the analysis results for the meat quality and SNP correlations did not yield a significant difference between SF, CL, WHC, gender, the UoG-CAST, the CAPN1 316 and 4751 poly-morphisms (Table 4).

DISCUSSION

The frequency of C allele in the UoG-CAST locus is reported to be 0.74-0.79 in *Bos taurus* genetic groups [6], 0.69 [11], 0.72 [18] and 0.75 [19] in *Bos taurus* crossbreeds, 0.64 [20] in Aberdeen Angus cattle, 0.61 in Pirenaica cattle and 0.70 in Parda de Montana [21], 0.623 on average in Aberdeen Angus, Limousine, Charolais and Simmental breeds [5], 0.623 in Nellore-*Bos indicus* [11]. The C allele frequency in our sample which is made up of purebred TGC is 0.559, which is also lower than the frequencies reported by previous researchers [20,21]. For the UoG-CAST SNP genotypes Gill *et al.* [22] found the CC, CG and GG genotypic frequencies in Aberdeen Angus cattle as 0.41, 0.47 and 0.12, respectively. On the other hand, Schenkel *et al.* [5] found them as 0.430, 0.398 and 0.172, respectively for *Bos taurus* while Curi *et al.* [11] found 0.377, 0.491 and 0.132, respectively for purebred *Bos indicus* Nellores. In our study, the ratio of the purebred TGC with CC genotype which expected to beef with more tenderness is lower than previous researches [20,21], except Kök *et al.* [23]. The CAPN1 316 C allele is associated with meat tenderness. TGC with the CAPN1 316 C allele frequency in our study is close to *Bos taurus* x *Bos indicus* crossbreeds [11] and similar to that of Pirenaica and Parda de Montana breeds. The frequency ratio of the TGC with the CAPN1 316 CC genotype is quite low. Except for Aberdeen Angus [22] and Hanwoo cattle [24], *Bos taurus* with CC genotype have not been observed in previous studies [11,25,26]. The CAPN1 4751 C allele frequency (0.412) that is considered to have a favourable impact on the beef tenderness seems to be higher than the other breeds except for Aberdeen Angus (0.65) [22] and Hanwoo cattle (0.80) [24]. TGC with the CAPN1 4751 CC genotype frequency (0.171) were found to be higher compared to Nellore (0.00) and Canchim (0.07) [4], Simmental and their crossbreeds (0.05) [26]. The ratio of TGC with CC genotype, which is favourable for meat tenderness, is lower than Brahman crossbreeds (0.53) [26], Aberdeen Angus (0.41) [22] and Hanwoo cattle (0.64) [24] populations.

Lee *et al.* [27] who worked on Hanwoo cattle found the average SF as 5.803±0.275 kg cm², for the heifers as 6.598±0.265 kg/cm², for the bulls as 7.200±0.275 kg/cm² and 3.400±0.061 kg/cm² for calves. Soysal [28] who worked on the texture of beef stated that gender and muscle factor do not seem to be statistically significant ($P > 0.05$). When the result of the study is compared to Yüksel *et al.* [29] who worked on East Anatolian Red (EAR) breeds and found (6.84-9.46±0.49 kg/cm²) and to Özlütürk *et al.* [30] who found (5.76±0.58 kg/cm²), the meat obtained from TGC can be said to have higher levels of tenderness than EAR. Soysal's [28] applied more force to the meat of the gender groups, (4.74±0.461 kg/cm²) and female (4.94±0.393 kg/cm²), compared to the ones in our study; however he applied less force compared to the cattle with GG genotype. The difference between the Soysal's [28] TGC sample and ours may be the genotypic differences or the nutrition of the animals. The SF values (9.95-9.97±0.23 kg/cm²) that Preziuso *et al.* [31] obtained from

Limousine cattle and Limousine crossbreeds were two times higher than the values Soysal's [28] (4.85 ± 0.294 kg/cm²) and the authors (4.483 ± 0.252 kg/cm²) of this study obtained from TGC beef samples. So, our and Soysal's [28] TGC samples of meat can be said to have higher tenderness compared to EAR and Limousine beef according to the results of this study. Also, according to Pirenaica and Panda de Montana breeds (bulls 5.1 ± 1.23 and 6.5 ± 1.80 kg/cm², respectively) LD muscle SF values, TGC breeds are estimated to have more tender meat than Pirenaica and Parda de Montana bulls although they have tougher meat. When the average SF of TGC samples (4.483 ± 0.252 kg/cm²) in our study is compared to that of 15 European cattle breeds (5.49 ± 1.25 kg/cm²) [32] and EAR, TGC seem to have more tender meat. The shearing force applied to the LD muscle of Hanwoo cattle is [27] (-1.32 kg/cm²) less than the average SF value for TGC.

Previous researchers reported that less force was applied to the LD muscle of the cattle with the UoG-CAST CC genotype than the cattle with CG and GG genotypes and those cattle with CC genotype have more tender meat [5,6,11,22]. SF was applied to LD of Aberdeen Angus, Limousine, Charolais, Simmental and their crossbreeds on the 21st day after death as average 4.53 ± 0.12 kg/cm² for with the UoG-CAST CC and 4.91 ± 0.15 kg/cm² for with GG genotype, and the difference was statistically significant ($P < 0.05$) [5]. The SF average values of *Bos indicus* (Nellore) and *Bos taurus* x *Bos indicus* crossbreeds with the UoG-CAST CC and CG genotypes were 3.47 ± 0.007 kg/cm² and 3.63 ± 0.07 kg/cm², respectively, and the difference was significant ($P < 0.05$) [11]. Compared to the average SF of TGC (3.943 ± 0.441 kg/cm²) with the UoG-CAST CC genotype, the Aberdeen Angus, Limousine, Charolais, Simmental and the other crossbreeds with the same genotype that Schenkel *et al.* [5] worked on have less tender meat than TGC; however TGC with the UoG-CAST GG genotype are estimated to yield tougher meat than the other cattle with the same genotype. Also, Nellore breeds with the UoG-CAST CC and CG genotypes [11] are estimated to have more tender meat than TGC with the UoG-CAST GG genotype.

The SF average of Piedmontese, Simmental, Angus, Hereford, Irish, Charolais and their crossbreeds with the CAPN1 316 CC genotype found lower than the other two genotypes (GC and GG) [8,9,13,33]. Brahman breeds have a similar structure also [3,22]. Chung *et al.* [24] found the SF averages with the CAPN1 316 genotypes as CC 4.868 ± 0.44 kg/cm², CG 5.180 ± 0.22 kg/cm² and GG 5.437 ± 0.27 kg/cm² in Hanwoo cattle, which suggests no relationship between the results and the genotypes ($P = 0.530$). TGC breeds also have a similar structure. TGC with the CAPN1 316 GC genotype were found to have more tender meat than TGC with GG genotype but the difference (-0.696) was not statistically significant ($P > 0.05$). We can assume that TGC with the

CAPN1 316 GC genotype (3.869 ± 0.721 kg/cm²) are more likely to have tougher meat than the Piedmontese, Angus and Brahman breeds.

Bos taurus and *Bos taurus* x *Bos indicus* crossbreeds with the CAPN1 4751 CC genotype seem to have more tender meat compared to the other genotypes, and the difference is significant ($P < 0.005$) [4,7,14,16]. Hanwoo cattle with the CAPN1 4751 CC, CT and TT genotypes seem to have the highest (4.946 ± 0.19 kg/cm²), medium (5.700 ± 0.28 kg/cm²) and the lowest (5.974 ± 0.72 kg/cm²) level of meat tenderness, respectively [24]. We can say that TGC with the CAPN1 4751 CT genotype (4.537 ± 1.666 kg/cm²) are more likely to have less tender meat than the Nellore breeds and *Bos taurus* crossbreeds [4], Brahman calves with the CAPN1 4751 CT [3], and also Piedmontese and Aberdeen Angus with the CAPN1 316 GG [9]. On the other hand, Gill *et al.* [20] claim these the CAPN1 4751 and the UoG-CAST SNPs do not seem to affect meat tenderness in Aberdeen Angus cattle.

Ciobanu *et al.* [34] who worked on pigs and Reardon *et al.* [19] who worked on cattle could not find a correlation between the polymorphisms in CAST gene and WHC. Li *et al.* [10] who worked on the meat of Angus, Charolais, Hereford, Limousine, and Simmental calves in Sweden also could not find a meaningful relationship between the WHC properties; and some of the SNPs genotypes of CAST, CAPN1, LEP, DGAT1 and SCD1 gene. Similarly, we could not find a significant relationship between the genotypic properties of the CAPN1 or CAST SNPs and WHC or CL values of TGC.

In our research was found that the male cattle with CC/CT/GG genotype seemed to have the most tenderness meat with 2.329 kg/cm² SF. The previous research carry outed on Hereford, Brahman, Brangus, Red Angus cattle and Charolais X Angus crossbreeds showed that the cattle with GG/TT/GG genotype among the UoG-CAST, the CAPN1 4751 and 316 triple SNPs combination had the toughest meat while the cattle with CC/CC/CC genotype tend to have the most tenderness meat [6,18]. Our findings show that TGC with GG/TT/GG genotypes have the toughest meat and this finding supports the previous studies. TGC carry SNPs that are related to meat tenderness in their CAPN1 and CAST genes, which are polymorphic. Except for the CAPN1 316 CC genotype, all CAST and CAPN1 SNP genotypes, which are associated with meat tenderness, were observed in TGC samples. Based on the SF averages which measure the resistance of the red muscle fibers, we can conclude that TGC yield more tender meat compared to East Anatolian Red, Jersey, Limousine, Pirenaica and Parda de Montana breeds. The presence of genetic variation in specific markers in TGC contributes to the process to yield more tender beef. The purebred TGC with the haplotype which includes heterozygous or double homozygous positive genes in CAST and CAPN1 genes should be kept for breeding. The effects of monadic

genes of TGC which are independent of the potential interactions with the environment on the meat tenderness, which has of economic importance and the productivity, can be designated through crossbreeding. TGC with (C/C/C) haplotype or (CC/CC/CC) genotype carrying the positive genes can be kept for breeding with the use of DNA tests to evaluate the cattle based on the UoG-CAST, the CAPN1 316 and 4751 markers. In order to make TGC breeding a sustainable business, it is necessary to have cattle with more tender beef and to increase the consumption of it. Thus, there is a need to cattle which yield beef of good quality and whose genetic potential is defined. By focusing on more genes and the specific genetic indicators in these genes that are related to the quality of meat, it is possible to improve the precision in selection processes.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENT

We thank Prof. Alper Yılmaz who from Veterinary Faculty in Istanbul University.

REFERENCES

1. Miller M, Huffman K, Gilbert S, Hamman L, Ramsey C: Retail consumer acceptance of beef tenderized with calcium chloride. *J Anim Sci*, 73 (8): 2308-2314, 1995. DOI: 10.2527/1995.7382308x
2. Koohmaraie M, Whipple G, Kretchmar D, Crouse J, Mersmann H: Postmortem proteolysis in longissimus muscle from beef, lamb and pork carcasses. *J Anim Sci*, 69 (2): 617-624, 1991. DOI: 10.2527/1991.692617x
3. Smith T, Thomas M, Bidner T, Paschal J, Franke D: Single nucleotide polymorphisms in Brahman steers and their association with carcass and tenderness traits. *Genet Mol Res*, 8 (1): 39-46, 2009. DOI: 10.4238/vol8-1gmr537
4. Curi RA, Chardulo LAL, Mason M, Arrigoni M, Silveira AC, De Oliveira H: Effect of single nucleotide polymorphisms of CAPN1 and CAST genes on meat traits in Nelore beef cattle (*Bos indicus*) and in their crosses with *Bos taurus*. *Anim Genet*, 40 (4): 456-462, 2009. DOI: 10.1111/j.1365-2052.2009.01859.x
5. Schenkel F, Miller S, Jiang Z, Mandell I, Ye X, Li H, Wilton J: Association of a single nucleotide polymorphism in the calpastatin gene with carcass and meat quality traits of beef cattle. *J Anim Sci*, 84 (2): 291-299, 2006. DOI: 10.2527/2006.842291x
6. Van Eenennaam A, Li J, Thallman R, Quaas R, Dikeman M, Gill C, Franke D, Thomas M: Validation of commercial DNA tests for quantitative beef quality traits. *J Anim Sci*, 85 (4): 891-900, 2007. DOI: 10.2527/jas.2006-512
7. Casas E, White S, Wheeler T, Shackelford S, Koohmaraie M, Riley D, Chase C, Johnson D, Smith T: Effects of and μ -markers in beef cattle on tenderness traits. *J Anim Sci*, 84 (3): 520-525, 2006. DOI: 10.2527/2005.83113x
8. Allais S, Journaux L, Levéziel H, Payet-Duprat N, Raynaud P, Hocquette J-F, Lepetit J, Rousset S, Denoyelle C, Bernard-Capel C: Effects of polymorphisms in the calpastatin and μ -calpain genes on meat tenderness in 3 French beef breeds. *J Anim Sci*, 89 (1): 1-11, 2011. DOI: 10.2527/jas.2010-3063
9. Page B, Casas E, Quaas R, Thallman R, Wheeler T, Shackelford S, Koohmaraie M, White S, Bennett G, Keele J: Association of markers in the bovine gene with meat tenderness in large crossbred populations that sample influential industry sires. *J Anim Sci*, 82 (12): 3474-3481, 2004. DOI: 10.2527/2004.82123474x
10. Li X, Ekerljung M, Lundström K, Lundén A: Association of polymorphisms at DGAT1, leptin, SCD1, CAPN1 and CAST genes with color, marbling and water holding capacity in meat from beef cattle populations in Sweden. *Meat Sci*, 94 (2): 153-158, 2013. DOI: 10.1016/j.meatsci.2013.01.010
11. Curi RA, Chardulo LAL, Giusti J, Silveira AC, Martins CL, de Oliveira HN: Assessment of GH1, CAPN1 and CAST polymorphisms as markers of carcass and meat traits in *Bos indicus* and *Bos taurus* X *Bos indicus* cross beef cattle. *Meat Sci*, 86 (4): 915-920, 2010. DOI: 10.1016/j.meatsci.2010.07.016
12. Casas E, White S, Riley D, Smith T, Brenneman R, Olson T, Johnson D, Coleman S, Bennett G, Chase C: Assessment of single nucleotide polymorphisms in genes residing on chromosomes 14 and 29 for association with carcass composition traits in cattle. *J Anim Sci*, 83 (1): 13-19, 2005. DOI: 10.2527/2006.843520x
13. Corva P, Soria L, Schor A, Villarreal E, Cenci MP, Motter M, Mezzadra C, Melucci L, Miquel C, Paván E: Association of CAPN1 and CAST gene polymorphisms with meat tenderness in *Bos taurus* beef cattle from Argentina. *Genet Mol Biol*, 30 (4): 1064-1069, 2007. DOI: 10.1590/S1415-47572007000600006
14. White S, Casas E, Wheeler T, Shackelford S, Koohmaraie M, Riley D, Chase C, Johnson D, Keele J, Smith T: A new single nucleotide polymorphism in extends the current tenderness marker test to include cattle of and crossbred descent. *J Anim Sci*, 83 (9): 2001-2008, 2005. DOI: 10.2527/2005.8392001x
15. Honikel KO: Reference methods for the assessment of physical characteristics of meat. *Meat Sci*, 49 (4): 447-457, 1998. DOI: 10.1016/S0309-1740(98)00034-5
16. Karakaya M, Saricoban C, Yilmaz M: The effect of mutton, goat, beef and rabbit-meat species and state of rigor on some technological parameters. *J Muscle Foods*, 17 (1): 56-64, 2006. DOI: 10.1111/j.1745-4573.2006.00035.x
17. Rincon G, Medrano J: Assays for genotyping single nucleotide polymorphisms in the bovine CAPN1 gene. *Anim Genet*, 37 (3): 294-295, 2006. DOI: 10.1111/j.1365-2052.2006.01430.x
18. Quaas R, Li J, Thallman R, Van Eenennaam A, Fernando R, Gill C: Validation of commercial DNA tests for quantitative beef traits. 8th World Congress on Genetics Applied to Livestock Production, August 13-18, 2006, Belo Horizonte, Brasil
19. Reardon W, Mullen A, Sweeney T, Hamill R: Association of polymorphisms in candidate genes with colour, water-holding capacity, and composition traits in bovine *M. longissimus* and *M. semimembranosus*. *Meat Sci*, 86 (2): 270-275, 2010. DOI: 10.1016/j.meatsci.2010.04.013
20. Ağaoğlu ÖK, Akyüz B, Kul BC, Bilgen N, Ertuğrul O: Genetic polymorphism of five genes associated with meat production traits in five cattle breeds in Turkey. *Kafkas Univ Vet Fak Derg*, 21, 489-497, 2015. DOI: 10.9775/kvfd.2014.12722
21. Kök S, Atalay S, Eken HS, Savaşçı M: The genetic characterization of Turkish Grey Cattle with regard to UoG-CAST, CAPN1 316 and CAPN1 4751 markers. *Pakistan J. Zool*, 49 (1): 281-287, 2017. DOI: 10.17582/journal.pjz/2017.49.1.281.287
22. Gill JL, Bishop SC, McCorquodale C, Williams JL, Wiener P: Association of selected SNP with carcass and taste panel assessed meat quality traits in a commercial population of Aberdeen Angus-sired beef cattle. *Genet Sel Evol*, 41 (1): 36, 2009. DOI: 10.1186/1297-9686-41-36
23. Kök S, Atalay S, Savaşçı M, Eken HS: Characterization of calpastatin gene in purebred and crossbred Turkish Grey Steppe cattle. *Kafkas Univ Vet Fak Derg*, 19 (2): 203-206, 2013. DOI: 10.9775/kvfd.2012.7470
24. Chung H, Shin S, Chung E: Effects of genetic variants for the bovine calpain gene on meat tenderness. *Mol Biol Rep*, 41 (5): 2963-2970, 2014. DOI: 10.1007/s11033-014-3152-3
25. Calvo J, Iguácel L, Kirinus J, Serrano M, Ripoll G, Casasús I, Joy M, Pérez-Velasco L, Sarto P, Albertí P: A new single nucleotide polymorphism in the calpastatin (CAST) gene associated with beef tenderness. *Meat Sci*, 96 (2): 775-782, 2014. DOI: 10.1016/j.meatsci.2013.10.003

- 26. Frylinck L, Van Wyk G, Smith T, Strydom P, van Marle-Köster E, Webb E, Koohmaraie M, Smith M:** Evaluation of biochemical parameters and genetic markers for association with meat tenderness in South African feedlot cattle. *Meat Sci*, 83 (4): 657-665, 2009. DOI: 10.1016/j.meatsci.2009.07.016
- 27. Lee SH, Kim SC, Chai HH, Cho SH, Kim HC, Lim D, Choi BH, Dang CG, Sharma A, Gondro C:** Mutations in calpastatin and μ -calpain are associated with meat tenderness, flavor and juiciness in Hanwoo (Korean cattle): Molecular modeling of the effects of substitutions in the calpastatin/ μ -calpain complex. *Meat Sci*, 96 (4): 1501-1508, 2014. DOI: 10.1016/j.meatsci.2013.11.026
- 28. Soysal D:** Determination of fattening performance, carcass characteristics and meat quality in Turkish Grey Cattle. *PhD Thesis*, Namik Kemal University, Institute of Science, 2012 (in Turkish).
- 29. Yüksel S, Yanar M, Aksu MI, Kopuzlu S, Kaban G, Sezgin E, Oz F:** Effects of different finishing systems on carcass traits, fatty acid composition, and beef quality characteristics of young Eastern Anatolian Red bulls. *Trop Anim Health Prod*, 44 (7): 1521-1528, 2012. DOI: 10.1007/s11250-012-0098-0
- 30. Özlütürk A, Esenbuğa N, Yanar M, Uenlue N, Macit M, Kopuzlu S:** The effect of duration of finishing period on the performance, slaughter, carcass, and beef quality characteristics of Eastern Anatolian Red bulls. *Turk J Vet Anim Sci*, 32 (6): 441-448, 2008.
- 31. Preziuso G, Russo C, D'Agata M:** Quality of carcass and meat in bullock of different genotypes raised under organic system. *Annali Della Facoltà di Medicina Veterinaria*, 57, 265-274, 2004.
- 32. Christensen M, Ertbjerg P, Failla S, Sañudo C, Richardson RI, Nute GR, Olleta JL, Panea B, Alberti P, Juárez M:** Relationship between collagen characteristics, lipid content and raw and cooked texture of meat from young bulls of fifteen European breeds. *Meat Sci*, 87 (1): 61-65, 2011. DOI: 10.1016/j.meatsci.2010.09.003
- 33. Costello S, O'Doherty E, Troy D, Ernst C, Kim K-S, Stapleton P, Sweeney T, Mullen A:** Association of polymorphisms in the calpain I, calpain II and growth hormone genes with tenderness in bovine *M. longissimus dorsi*. *Meat Sci*, 75 (4): 551-557, 2007. DOI: 10.1016/j.meatsci.2006.06.021
- 34. Ciobanu DC, Bastiaansen JW, Lonergan SM, Thomsen H, Dekkers JC, Plastow GS, Rothschild MF:** New alleles in calpastatin gene are associated with meat quality traits in pigs. *J Anim Sci*, 82 (10): 2829-2839, 2004. DOI: 10.2527/2004.82102829x