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Differences among four meat goat breeds for doe fitness indicator traits in the southeastern United States[1]

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ABSTRACT: Sustainable meat goat production begins with the identification and use of maternal breeds that demonstrate relatively enhanced levels of fitness under less-than-optimal conditions. The Myotonic goat is a heritage breed that is lacking in comparative assessment for female fitness. In this study, Boer (n = 73), Kiko (n = 115), Myotonic (n = 80), and Spanish (n = 114) meat goat does were compared for traits associated with health and reproduction. The herd was semi-intensively managed on humid subtropical pasture for 6 yr. The study included 838 doe–year matings and over 2,000 records for BW, fecal egg count (FEC), and packed cell volume (PCV). Body weights of Boer and Kiko does were heavier ($P < 0.05$) than for Spanish does, which, in turn, were heavier ($P < 0.05$) than for Myotonic does. In production does, FEC were lower ($P < 0.05$) for Myotonic does than for Boer does, whereas Kiko and Spanish does had intermediate FEC that differed ($P < 0.05$) from Myotonic and Boer does. Kiko, Myotonic, and Spanish does had greater ($P < 0.05$) PCV than Boer does. Doe age and physiological status also affected ($P < 0.05$) BW, FEC, and PCV. Annual kidding rates, weaning rates, doe retention rates, and kid crop weaned were greater ($P < 0.05$) for Kiko and Spanish does than for Boer does, whereas Myotonic does were intermediate and differed ($P < 0.05$) from the other 3 breeds. The results suggest that Kiko and Spanish does should be preferred over Boer and Myotonic does for sustainable meat goat doe performance under limited-input management conditions. Myotonic does maintained the lowest FEC among all doe breeds and warrant further evaluation as a genetic resource for controlling gastrointestinal parasitism.

Key words: Boer, breed, health, Kiko, Myotonic, reproduction

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INTRODUCTION

Boer, Kiko, and Spanish are the primary breeds of meat goats in the United States (Browning et al., 2011, 2012). Boer and Kiko goats were imported in the mid 1990s from South Africa and New Zealand, respectively (Batten, 1987; Casey and Van Niekerk, 1988). The Spanish is a landrace goat resident in southern North America since the Spanish conquests of the 1500s (Glimp, 1995). Boer does had reduced fitness levels compared with Kiko and Spanish does in previous work (Browning et al., 2011; Nguluma et al., 2013). A fourth meat goat breed in the United States is the Myotonic. The Myotonic goat is a landrace type like the Spanish. Myotonic goats are small in stature and noted for myotonia congenita, an inherited trait causing delayed muscle relaxation and subsequent muscle stiffening after an animal is excited or attempts strong voluntary skeletal muscle activity (Bryant, 1979). Myotonia is caused by a mutation in the muscle chloride channel gene *CLCN-1* (Lossin and George, 2008). Myotonic goats were first noted as a farm oddity in south central Tennessee during the late 1800s (Lush, 1930; Clark et al., 1939). Excited Myotonic goats either fall over unable to stand up or learn to widen their

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stance to avoid tipping over. Stiffening episodes last a few seconds before normal muscle tone returns.

The biomedical community has used Myotonic goats as a model for characterizing myotonia congenita (Bryant et al., 1968; Beck et al., 1996; Lossin and George, 2008). The breed has not been characterized for livestock production traits. Myotonic goats may be a valuable genetic resource for enhanced herd productivity because of their landrace type and unique muscularity. One effect of myotonia evident in Myotonic goats is muscle hypertrophy. It was hypothesized that the landrace Myotonic goat would be a preferred maternal breed, similar to the landrace Spanish goat. The objective of this study was to characterize Myotonic does alongside Boer, Kiko, and Spanish does for female fitness traits.

MATERIALS AND METHODS

Study Animals

Herd management protocols were approved by the Tennessee State University Animal Care and Use Committee. Herd management was consistent with the American Dairy Science Association – American Society of Animal Science – Poultry Science Association *Guide for the Care and Use of Agricultural Animals in Research and Teaching* (FASS, 2010).

Boer (n = 73), Kiko (n = 115), Myotonic (n = 80), and Spanish (n = 114) straightbred does were managed for once-a-year kid production over 6 production years. A production year ran from September to August. The general management plan was fall mating by natural service for 35 d, spring kidding on pasture, and summer weaning after a 90-d preweaning period. References to the calendar year correspond to the year of kidding. Does were exposed to bucks in single-sire breeding groups. Boer, Kiko, Myotonic, Savanna, and Spanish herd sires were used. Does across breeds were exposed similarly to the various sire breeds to produce straightbred and crossbred kids. The one exception was that most Myotonic does were bred to produce straightbred kids to avoid dystocia. Prior work at this station did not find significant effects of service sire breed on exposed doe performance (Browning et al., 2011). Kids were tagged with unique identification numbers within 24 h of birth and recorded with the dam identification number.

The herd consisted of does produced on the Tennessee State University (**TSU**) research station (Nashville, TN) and does purchased from various herds (Table 1). Myotonic does were purchased in 2009 and 2010 to start the project. A regional flood in 2010 necessitated a herd rebuilding effort before starting the 2011 production year (Table 2). The rebuilding permitted the sampling of additional Boer, Kiko, and Spanish source herds to broaden the genetic pool beyond the earlier evaluation of Browning et al. (2011). Unlike the original TSU herd building effort in 2002 (Browning et al., 2004, 2011), age restrictions were relaxed for the post-flood herd repopulation because of time constraints. Does in Table 1 were between 2 and 11 yr of age. Mean doe ages at herd entry were 3.7 yr for Boer, 3.5 yr for Kiko, 3.1 yr for Myotonics, and 3.3 yr for Spanish. Entries in 2011 included 21 does from the pre-flood herd of Browning et al. (2011): 1 Boer, 3 Kiko, and 3 Spanish purchased does and 8 Kiko and 6 Spanish TSU-born does. Except for the 2011 entries, TSU-born does entered the project as 2 yr olds. No TSU doelings were retained from the 2010 flood year; therefore, there were no herd entries in 2012. Boer does were from 21 source herds, Kiko does were from 21 source herds, Myotonic does were from 15 source herds, and Spanish does were from 4 source herds. Only 5 Boer, 6 Kiko, and 2 Spanish source herds were common to this evaluation and that of Browning et al. (2011). Mean (SD) doe ages across the complete doe–year study inventory (Table 2) were 3.9 yr (1.4) for Boer, 4.0 yr (1.8) for Kiko, 3.7 yr (1.6) for Myotonic, and 4.2 yr (1.8) for Spanish.

Table 1. Number of does entering the study herd by year, breed, and source

		Production year of doe entry					
Breed	Source[1]	2009	2010	2011	2012	2013	2014
Boer	TSU	9	2	0	0	2	0
	New	0	0	56	0	0	0
Kiko	TSU	18	13	15	0	19	5
	New	0	0	45	0	0	0
Myotonic	TSU	0	2	2	0	10	2
	New	19	19	26	0	0	0
Spanish	TSU	17	13	12	0	15	9
	New	0	0	48	0	0	0

[1]TSU = Tennessee State University (does born at the research station; Nashville, TN); New designates purchased does.

Herd Management

The herd was managed semi-intensively on the TSU research station along the Cumberland River (36°10′ N, 86°49′ W; Nashville, TN). The research station is in the humid subtropics at 183 m above sea level with annual precipitation of 1,222 mm evenly distributed throughout the year. The herd continuously grazed cool-season pastures of predominantly tall fescue (*Festuca arundinacea*) and warm-season pastures of primarily bermudagrass (*Cynodon dactylon*) at a stocking rate of about 9 does/ha. Numerous other species of grasses, clovers, broadleaf weeds, and woody browse species were available in grazing areas. The herd had free access to orchardgrass hay (*Dactylis*

Table 2. Doe inventory at the start of each production year by breed

	Production year of study					
Breed	2009	2010	2011	2012	2013	2014
Boer	9	2	58	25	9	3
Kiko	18	13	70	62	65	52
Myotonic	19	21	46	31	21	16
Spanish	17	13	76	66	68	58

glomerata) on winter pasture. Water and minerals were provided for ad libitum consumption.

Nutritional supplementation varied by year. In 2009 and 2010, does were supplemented with 262 g/d of a commercial pellet (16% CP and 69% TDN, as-fed basis) during the 5-wk breeding season and from kidding to weaning. During gestation, the does ate from molasses self-feeder tubs (16% CP and 57% TDN, as-fed basis). Forage was not supplemented in 2011. The molasses tubs were reintroduced from breeding to weaning in 2012 and 2013. In 2014, the doe herd was fed the commercial pellet (454 g/d) during the breeding season and whole cottonseed (*Gossypium hirsutum*; 22% CP and 85% TDN, as-fed basis; 262 g/d) during gestation and the first 30 d of the lactation period. Nutritional management varied by year but was consistent across the doe breeds being tested.

Does were vaccinated once a year against *Clostridium perfringens* Types C and D, tetanus, and pneumonia (*Mannheimia haemolytica* and *Pasteurella multocida*) during the fourth month of pregnancy. Does were dewormed as a group once a year with moxidectin or levamisole via oral drench at kidding. Individual does and kids were dewormed throughout the year when clinical signs of gastrointestinal parasitism were presented. The herd was routinely checked every day for wellness. Does exited the herd primarily because of death or culling after the second failure to wean a kid.

Data Collection

Doe weight, packed cell volume (**PCV**), and parasite fecal egg count (**FEC**) were recorded at breeding, kidding, weaning, and after weaning. Doe data were collected within 72 h after parturition, most within 24 h. There were some periods over the 6 yr in which a particular measurement was not taken. The recording of PCV was introduced during the 2011 weaning period. During the breeding and kidding periods of 2011, FEC was not recorded because of flood-related resource limitations. Similarly, doe weight was also not recorded during the 2011 breeding season because of flood-related resource limitations. Recording postweaning data (30 to 60 d after weaning) and data collection on dry does (females not rearing kids) began in 2011.

Table 3. Number of records used for each doe trait analysis

Trait	Production does	Dry does
BW	1,439	982
FEC[1]	1,265	1,100
PCV[2]	1,077	1,022
Kidding rate[3]	838	–
Weaning rate[3]	838	–
Retention rate[3]	838	–
Litter size born	478	–
Litter size weaned	390	–
Kid crop weaned[3]	838	–

[1]FEC = fecal egg count.

[2]PCV = packed cell volume.

[3]Trait included all does in the herd at the start of a production year.

Blood samples drawn from the jugular vein were stored in EDTA-coated blood tubes until processing for PCV determination. Samples were processed for PCV recording by spinning capillary tubes of blood in duplicate for 10 min at 17,000 × *g* and at ambient temperature. Fecal samples were collected from does to determine FEC using the McMaster technique (Cringoli et al., 2004) with a detection limit of 50 eggs/g.

Statistical Analysis

The data set was split for data analysis (Table 3). One data set was for productive doe records, including data from all does during the breeding season, does with kids at parturition, and does with kids at weaning. The second data set was of records from dry does, which included does without kids at parturition, does without kids at weaning, and data from all does after weaning. During a given year, a doe may have been in the productive group at kidding but moved to the dry population by weaning if she failed to wean her kids.

The MIXED model procedure for repeated measures of SAS (SAS Inst. Inc., Cary, NC) was used for FEC, PCV, and doe weight. The FEC values were transformed by $\log_{10}$(FEC + 1) for statistical analysis and back-transformed to geometric means for presentation. Sources of variation in the statistical models were doe breed, doe age, and time as fixed effects and production year and doe nested in doe breed as random effects. Time of sampling for the productive doe records was breeding, kidding, and weaning. For the dry doe records, time of sampling was kidding, weaning, and after weaning. Does 7 yr of age and older were merged into one senior age group to improve balance across the age classifications.

Additional whole-herd response variables tested in the fall breeding population included the proportion of

Table 4. Effects of breed and nongenetic factors on weight and indicators of gastrointestinal parasitism in productive meat goat does

Class	BW, kg	FEC,[1] eggs/g	PCV,[2] %
Doe breed	**	**	**
Boer	33.4 (2.8)^{a}	1,777^{c}	17.1 (0.8)^{b}
Kiko	33.6 (2.8)^{a}	911^{b}	21.2 (0.4)^{a}
Myotonic	23.9 (2.8)^{c}	489^{a}	21.1 (0.6)^{a}
Spanish	29.8 (2.8)^{b}	831^{b}	22.3 (0.4)^{a}
Doe age, yr	**		**
2	23.1 (2.7)^{e}	723	22.5 (0.5)^{a}
3	26.7 (2.8)^{d}	890	21.9 (0.5)^{a}
4	30.4 (2.8)^{c}	850	20.5 (0.5)^{b}
5	32.2 (2.8)^{b}	999	20.0 (0.5)^{b}
6	33.7 (2.8)^{a}	976	19.5 (0.5)^{bc}
7+	35.0 (2.8)^{a}	1,070	18.1 (0.6)^{c}
Time	**	**	**
Breeding	30.5 (2.7)^{a}	397^{c}	22.3 (0.4)^{a}
Kidding	29.8 (2.8)^{b}	1,548^{b}	21.1 (0.5)^{b}
Weaning	30.2 (2.7)^{b}	1,229^{b}	17.9 (0.4)^{c}

[a–e]Least squares means (SE) within a class and trait with different superscripts differ ($P < 0.05$).

[1]FEC = fecal egg count.

[2]PCV = packed cell volume.

**Significant source of variation ($P < 0.01$).

Table 5. Effects of breed and age on weight and indicators of gastrointestinal parasitism in dry meat goat does

Class	BW, kg	FEC,[1] eggs/g	PCV,[2] %
Doe breed	**	**	**
Boer	39.2 (1.3)^{a}	500^{b}	18.2 (1.0)^{b}
Kiko	38.2 (1.1)^{a}	323^{ab}	21.6 (0.8)^{a}
Myotonic	25.4 (1.3)^{c}	223^{a}	22.1 (0.9)^{a}
Spanish	33.2 (1.1)^{b}	281^{a}	22.7 (0.8)^{a}
Doe age, yr	**	*	**
2	28.6 (1.2)^{d}	239^{a}	23.4 (0.9)^{a}
3	31.7 (1.1)^{c}	262^{a}	22.6 (0.8)^{a}
4	33.3 (1.1)^{b}	308^{ab}	21.2 (0.9)^{b}
5	36.0 (1.1)^{a}	331^{ab}	20.7 (0.9)^{bc}
6	36.6 (1.2)^{a}	331^{ab}	20.2 (0.9)^{bc}
7+	37.6 (1.2)^{a}	457^{b}	18.8 (0.9)^{c}

[a–d]Least squares means (SE) within a class and trait with different superscripts differ ($P < 0.05$).

[1]FEC = fecal egg count.

[2]PCV = packed cell volume.

*Significant source of variation ($P < 0.05$).

**Significant source of variation ($P < 0.01$).

does kidding (kidding rate) and weaning kids (weaning rate), kids weaned per doe (kid crop weaned), and proportion of does avoiding death or culling and remaining in the herd at the end of the production year (retention rate). The GLIMMIX model procedure of SAS with the binomial distribution option was used for rates of kidding, weaning, and retention. Litter size was an additional trait tested on parturition records and weaning records for does with kids at the respective time marks. The GLIMMIX model procedure of SAS with the Poisson distribution option was used for kid crop weaned and litter size.

Breed of doe was tested using doe nested within breed as the error term. The Tukey–Kramer means separation test was used to compare least squares means ($\alpha = 0.05$). Probability levels less than 0.05 for the F-statistic were regarded as indicating a significant difference.

RESULTS AND DISCUSSION

Doe breed, doe age, and time of measurement affected ($P < 0.01$) BW of does in the production herd (Table 4) and dry doe population (Table 5). Production doe weight continuously increased ($P < 0.05$) from 2 to 7 yr of age (Table 4). Body weight in dry does increased ($P < 0.05$) from 2 to 5 yr of age (Table 5). Doe weights in this study were lower than in the previous study at this location (Browning et al., 2011). Reduced nutritional supplementation in this study compared with that in the study of Browning et al. (2011) was partly responsible for the lower weights. Increased doe weight with advancing age agreed with Browning et al. (2011) and Rhone et al. (2013). Does were heavier ($P < 0.05$) at kidding and weaning than at breeding (Table 4).

Boer and Kiko does were heavier ($P < 0.05$) than Spanish does, which, in turn, were heavier ($P < 0.05$) than Myotonic does (Tables 4 and 5). Relative BW comparisons for Boer, Kiko, and Spanish does agreed with Browning et al. (2011). The light Myotonic doe BW corresponds with their small body frame. Relative BW of Myotonic does have not been previously reported in the scientific literature. Additional work is needed to determine how low BW of Myotonic does affects kid performance. Individual progeny performance by dam breed could not be adequately assessed because Myotonic does were not mated to various sire breeds as were the other doe breeds.

Gastrointestinal parasite indicators were affected ($P < 0.05$) by doe breed, doe age, and stage of production. Mean PCV decreased ($P < 0.05$) as doe age increased in production and dry does (Tables 4 and 5). Mean FEC increased with age in dry does (Table 5) but were not affected by age in the production doe group (Table 4). In agreement, doe age did not previously affect FEC in lactating does (Browning et al., 2011). The FEC and PCV patterns were similar to the observations of Burke et al. (2009) in that FEC and FAMACHA© scores (Kaplan et al., 2004) increased with doe age. Increasing FAMACHA© score and decreasing PCV both indicate progressing anemia (Kaplan et al., 2004). Within the production doe group, FEC was lowest ($P <$

Table 6. Effect of doe breed and doe age on litter size at parturition and weaning in meat goats

	Litter size, no. of kids	
Class	Parturition	Weaning
Doe breed	*	
Boer	1.77 ± 0.15	1.29 ± 0.17
Kiko	1.67 ± 0.07	1.47 ± 0.07
Myotonic	1.48 ± 0.08	1.32 ± 0.09
Spanish	1.54 ± 0.06	1.47 ± 0.07
Doe age, yr		
2	1.58 ± 0.08	1.30 ± 0.08
3	1.54 ± 0.08	1.39 ± 0.10
4	1.59 ± 0.08	1.39 ± 0.09
5	1.67 ± 0.09	1.49 ± 0.09
6	1.58 ± 0.10	1.42 ± 0.10
7+	1.71 ± 0.10	1.36 ± 0.10

*Significant source of variation ($P = 0.04$). The Tukey–Kramer test did not identify differences among means.

0.05) and PCV was greatest ($P < 0.05$) at breeding compared with kidding or weaning. This was expected because gastrointestinal parasite burdens typically increase during the peripartum and spring postpartum periods when doe immune function is suppressed and pasture conditions favor parasite development.

In the production doe herd, FEC were greatest ($P < 0.05$) for Boer does and lowest for Myotonic does with Kiko and Spanish does being intermediate and differing ($P < 0.05$) from the 2 extremes (Table 4). Myotonic and Spanish does remained lower than Boer does for FEC when tested in the dry doe group (Table 5). Boer does had consistently lower ($P < 0.05$) PCV than Myotonic, Kiko, and Spanish does within both doe populations (Tables 4 and 5). Gastrointestinal parasitism is a primary threat to efficient goat productivity and could be reduced by using breeds identified as having reduced gastrointestinal parasite susceptibility (Bishop et al., 2002). Consistently lower PCV for Boer does supported the narrative of Boer goats being more parasite sensitive than other breeds. Boer does were also greater than Spanish does for postpartum FEC among lactating does in Browning et al. (2011). Low FEC for Myotonic does, particularly among productive does, suggests that Myotonic goats are less sensitive to gastrointestinal parasite exposure than other breeds. Wildeus and Zajac (2005) observed that Myotonic does had lower FEC than Spanish does whereas the 2 breeds had similar PCV means. Myotonic germplasm may enhance parasite-related hardiness in meat goat breeding programs.

Among reproductively successful does, breed was a significant source of variation for litter size at kidding (Table 6). However, the means separation test failed ($P > 0.10$) to identify any differences among breed means. Age of doe did not affect ($P = 0.56$) litter size at kidding. Litter size at weaning was not affected ($P > 0.25$) by breed or age of doe (Table 6). The current outcomes differed from those of Browning et al. (2011) and others (Hamed et al., 2009; Zhang et al., 2009; Rhone et al., 2013) that found that doe age affected litter size at kidding and weaning. The lack of an age effect on litter size at birth and weaning agreed with Marai et al. (2002). The insignificant breed influence on litter size among reproductively successful does concurred with Browning et al. (2011) at kidding but disagreed at weaning. In the study by Browning et al. (2011), Spanish does had larger litters at weaning than Boer and Kiko does. Myotonic does in the current evaluation did not show a different level of prolificacy relative to the other breeds.

All whole-herd fitness traits were affected ($P < 0.01$) by doe breed. Annual kidding rate, weaning rate, kid crop weaned, and retention rate were lowest for Boer does, intermediate for Myotonic does, and greatest for Kiko and Spanish does (Table 7). Age of doe was also a significant source of variation for all of the whole-herd traits. Does in the oldest age group had lower ($P < 0.05$) whole-herd performance rates than the other age groups. Two-year-old does also had lower ($P < 0.05$) kidding rates and smaller kid crops weaned than the middle age groups. Whole-herd fitness values were lower in the current study compared the earlier study (Browning et al., 2011), probably because of the scaled-back nutritional supplementation program. The whole-herd reproductive values were consistent with other doe evaluations under limited nutritional supplementation (Blackburn, 1995; Alexandre and Mandonnet, 2005; Nogueira et al., 2012). The age of doe effect on whole-herd reproductive rates agreed with past studies (Erasmus et al., 1985; Wilson and Light, 1986; Browning et al., 2011) in that performance was generally lower for young 2-yr-old does and in aged does beyond 6 yr of age (Table 7). Doe retention rates in Table 7 (the relative inverse of exit rates) were generally consistent with the wide range of published goat herd adult exit values that vary from under 10 to over 40% (Malher et al., 2001; Otte and Chilonda, 2002; Ershaduzzaman et al., 2007; Salisi et al., 2012), with the possible exceptions of the Boer group and the oldest age group.

Boer does were inferior performers compared with the Kiko and Spanish does, with the latter 2 breeds not differing for whole-herd annual reproductive output and survival. This 6-yr outcome mirrored the breed effect of the previous 6-yr evaluation (Browning et al., 2011; Pellerin and Browning, 2012). Current Kiko and Spanish means at the lower nutritional level were similar to the Boer means of Browning et al. (2011) at a higher nutritional level.

Myotonic does were intermediate compared with the Boer does and the Kiko–Spanish pair for each of the whole-herd fitness traits. Earlier studies on the

Table 7. Effects of breed and age of doe on annual whole-herd fitness traits in meat goats[1]

Class	Kidding rate, %	Weaning rate, %	Retention rate, %	Kid crop weaned,[2] %
Doe breed	**	**	**	**
Boer	15.5 (4.5)[c]	7.9 (3.0)[c]	35.1 (5.5)[c]	10.8 (11.2)[c]
Kiko	71.4 (5.0)[a]	58.7 (5.2)[a]	82.8 (2.9)[a]	87.9 (9.5)[a]
Myotonic	45.1 (6.5)[b]	31.5 (5.4)[b]	64.0 (4.9)[b]	43.7 (10.3)[b]
Spanish	67.8 (5.3)[a]	59.9 (5.1)[a]	80.3 (3.0)[a]	89.6 (9.5)[a]
Doe age, yr	**	**	**	**
2	42.4 (5.9)[bc]	27.7 (4.6)[ab]	78.7 (3.6)[a]	41.1 (9.5)[bc]
3	52.8 (6.8)[ab]	37.2 (6.0)[ab]	78.9 (4.2)[a]	60.8 (10.4)[abc]
4	65.1 (6.7)[a]	43.2 (6.6)[a]	60.7 (5.6)[b]	68.6 (10.7)[a]
5	53.4 (6.9)[ab]	43.4 (6.4)[a]	70.5 (5.1)[ab]	73.7 (10.5)[a]
6	49.2 (7.7)[abc]	39.6 (7.0)[a]	70.4 (5.9)[ab]	67.9 (11.5)[ab]
7+	29.1 (6.1)[c]	21.2 (4.8)[b]	40.0 (5.7)[c]	35.7 (11.1)[c]

[a–c]Least squares means (SE) within a class and trait with different superscripts differ ($P < 0.05$).

[1]Based on population of does available for mating at the start of each production year.

[2]Kids weaned per doe available for mating (×100).

**Significant source of variation ($P < 0.01$).

fitness of Myotonic does compared with other breeds were not readily available in the scientific literature. The advantage in FEC for Myotonic does did not translate into advantages in general fitness levels compared with Kiko and Spanish does. The reason for diminished Myotonic doe fitness was not readily apparent. It could be associated with their unique musculature. Lower reproductive levels were reported for cows homozygous for the *myostatin* gene (Arthur et al., 1989) but not for ewes homozygous for the *callipyge* gene (Freking and Leymaster, 2006) compared with females homozygous for normal muscle structure. Because most Myotonic does were bred to Myotonic bucks, a separate analysis was done by removing the Myotonic does to determine if the Myotonic service sires may have contributed to the reduced Myotonic doe reproductive rates. When Myotonic does were excluded from the data set, doe breed and doe age remained important sources of variation ($P \leq 0.01$) but service sire breed was not important for doe rates of kidding ($P = 0.74$) or weaning ($P = 0.44$). Doe kidding and weaning rates among Boer (47 ± 7% and 33 ± 8%, respectively), Kiko (58 ± 7% and 48 ± 8%, respectively), Myotonic (51 ± 10% and 34 ± 9%, respectively), Savanna (52 ± 9% and 38 ± 9%, respectively), and Spanish (48 ± 8% and 37 ± 9%, respectively) service sires did not differ. Myotonic service sires were likely not a contributing factor to the reduced Myotonic doe reproductive rates.

Boer and Myotonic groups were represented by approximately 80% purchased animals whereas the Kiko and Spanish groups were represented by about 40% purchased animals (Table 1). The Myotonic and Boer groups may have been disadvantaged if purchased does had adaptation issues to overcome compared with does born and raised on site. To test this possibility, weaning rate, retention rate, and kid crop weaned were retested by removing all TSU-born animals. The 3 whole-herd values remained affected ($P < 0.01$) by breed and doe age. Weaning rate, retention rate, and kid crop weaned for Boer does (7.3 ± 3.5%, 29.3 ± 7.9%, and 11.0 ± 14.8%, respectively) were lower ($P < 0.05$) than for Myotonic does (29.8 ± 7.0%, 60.6 ± 7.8%, and 39.5 ± 13.6%, respectively). In turn, annual weaning rate, retention rate, and kid crop weaned for Myotonic does were lower ($P < 0.01$) than for Kiko (57.4 ± 8.4%, 79.7 ± 5.7%, and 83.8 ± 14.2%, respectively) and Spanish does (59.0 ± 8.3%, 84.2 ± 4.8%, and 88.5 ± 14.1%, respectively). Results from the purchased-only doe population showed that no bias was introduced because of unbalanced outsourced versus home-grown doe profiles among the breeds. The analysis of purchased does further emphasized the level of breed divergence for female fitness that exists in the U.S. meat goat industry.

Production conditions on pasture are rarely ideal or consistent. Conditions change by season, by year, and across geographic area. It is easier to manage around environmental challenges when starting with goats inherently fit and able to withstand adverse or stressful changes in production conditions. A sustainable meat goat commercial system requires maternal breed types that can perform favorably under dynamic and suboptimal conditions. It would benefit commercial goat producers to have breeds tested for relative fitness levels under adverse conditions (James, 2009). Kiko and Spanish does appear better than Boer does for managers seeking to implement low-input meat goat production systems. Blackburn (1995) foretold the limitations of Boer does under limited forage conditions in the United States when the breed was first being introduced. The current study validated the computer simulation of

Blackburn (1995) as well as the earlier evaluation of Browning et al. (2011) for relative doe fitness by breed using a new set of Boer, Kiko, and Spanish does.

Results using new sources of germplasm affirmed that Kiko and Spanish does were superior to Boer does for fitness within a challenging production environment. Limited resources and challenging environments generally characterize meat goat production systems. It is important to identify and use breeds that demonstrate enhanced relative fitness under low to moderate input levels to enhance commercial enterprise sustainability. In this regard, Boer does would not be a favorable option under conditions similar to those of this research setting. It was thought that the small stature and landrace type might translate to a fitness advantage for Myotonic goats. Moderate levels of Myotonic doe fitness were comparatively lower than expected. One positive attribute of Myotonic goats worth pursuing was their potential to enhance herd tolerance to gastrointestinal parasites. More work evaluating local and introduced meat goat breed options for female performance and fitness under low- to moderate-input production systems is warranted.

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