Productivity benchmarks for community-based genetic improvement of Abergelle, Central Highland and Woyto-Guji indigenous goat breeds in Ethiopia

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Abstract

Assessments of production parameters and flock productivity were made in three indigenous goat breeds of Ethiopia. The goat breeds included Abergelle (AB), Central Highland (CH) and Woyto-Guji (WG). Objectives of this work were to estimate production parameters including three month weight (3mw), kidding intervals (KI) and litter size (LSB) at birth for the breeds and to assess their productivity at flock level that could be used as benchmark for evaluation of genetic progress to be realized. As AB is used for milk production, adjustment was made to their 3mw. The overall mean of 3mw (kg) were 7.44, 10.96 and 9.38 for AB, CH and WG goat breeds, respectively. Generally, wet season, male sex and single birth resulted in higher 3mw for three breeds. The overall means of KI were 362, 268 and 309 days for the breeds in respective order. The overall means of the LSB for the goat breeds, in respective order, were 1.03, 1.40 and 1.09 per doe per parturition. The flock productivity ranged from 0.27 to 0.53. Higher LSB, survival to three months (S3M), 3mw and number of parturition per year (N) resulted in higher flock productivity. CH goat breed had the highest flock productivity. The parameters estimated in this paper could be used as benchmarks for the designed CBBP of goats in the studied localities.

Key words: *doe, growth, litter siz, kidding interval, milk*

Introduction

In increased human population, urbanization and changing climate, goat population in Ethiopia showed an increasing trend (FAO 2014; CSA 2017). Where the recent goat population of Ethiopia was reported to be 30.20 million (CSA 2017), it used to be considerably smaller than the sheep population of the country. However, since very recently, the ratio of goat to sheep showed an increasing trend; 0.93 (CSA 2012), 0.99 (CSA 2015) and 0.98 (CSA 2017). This might be an indication that goats are becoming equally important as sheep in Ethiopia.

In developing countries, including Ethiopia, indigenous goats make valuable contributions, especially to the poor in the rural areas. They are important sources of meat, milk, manure, fibers & skins, and satisfy various cultural and religious functions (Tesfaye 2004; Aziz 2010; Devendra 2012).

The importance of this valuable genetic resource is, however, underestimated and contribution to the livelihood of the poor is inadequately understood (Kosgey and Okeyo 2007; Aziz 2010). The productivity of these indigenous goats is also low as a result of many interrelated factors including lack of applicable and impactful breeding programs.

Genetic improvement through establishment of central nucleus small ruminant flocks in the research centres in Ethiopia was known to be ineffective due to various factors (Getachew et al 2018). As an alternative, community based breeding program (CBBP) of small ruminants has emerged. The CBBP is a design of breeding scheme that is deemed suitable for smallholder farming system (Gizaw et al 2014). This approach is preferred to the more common top down breeding programs that are mostly established on governmental stations in developing countries (Mueller et al 2015b) and particularly suitable for small ruminants. The CBBPs have been established in different parts of the world; for sheep and goats in Ethiopia (Duguma et al 2011; Haile et al 2011; Abegaz et al 2014), for goats in Mexico (Wurzinger et al 2013) and in Iran (Mueller et al 2015a). Many African countries are also establishing the CBBP for small ruminants.

Implementation of CBBP of three indigenous goats in Ethiopia was done by the leading role of Bioscience for eastern and central Africa and International livestock Research Institute (BecA-ILRI) in six villages (CBBP sites). The breeds included Abergelle kept in arid agro-pastoral, Central Highland inhabiting crop-livestock production system and Woyto-Guji from semi-arid agro-pastoral production systems (Tatek et al 2016). The implemented CBBP on these goat breeds are being monitored by the national research systems and being implemented with technical backup from International Center for Agricultural Research in Dry Areas (ICARDA).

Alternative breeding programs to the current ones had been simulated to improve the breeding objective traits of the three indigenous goat breeds in there reproducing habitat (Temesgen 2016). In order to evaluate the genetic progress to be realized, however, bench mark indicators were not well documented. The values presented for Woyto-Guji and Centeral Highland (Ambo site) by Zergaw et al (2016) and for Abergelle and Central Highland (Gonder site) by Alubel (2015) were based on small data size which question its representativeness. Flock productivity, was not considered in any of the former works. In addition, in Alubel (2016), early live weights of Abergelle goat breeds was not adjusted for the milk consumed by their producers that could have been converted to weight. Therefore, the present work was designed with the objective of setting benchmarks for community based breeding programs for Abergelle, Centeral Highland and Woyto-Guji indigenous goats in Ethiopia based on which realized genetic improvements could be compared later on. Lack of benchmarks against which genetic progresses could be compared was appreciated in some of the CBBP of sheep in Ethiopia.

Materials and methods

Description of the study sites

The study was conducted in six villages and on three indigenous goat breeds, two villages per breed, in Ethiopia. The goat breeds were Abergelle (AB), Centeral Highland (CH) and Woyto-Guji (WG). The villages for AB, CH and WG are located in Tigray and Amhara, Amhara and Oromia and in and SNNP's (Southern Nations, Nationalities, and People's) region, respectively. Specific villages were *Dingur* (Tigray region) *and Blaku* (Amahara region) for AB, *Waykaw* (Amahara region) *and Tatessa* (Oromia region) for CH and *Messale* and *Arkisha* (SNNP's) for WG. The location of these villages is detailed in Table 1. Study sites' identification was guided by the respective district agriculturalists.

Table 1. Latitude, longitude, altitude and rainfall of the study villages

Parameters	*Dingur*	*Blaku*	*Waykaw*	*Tatessa*	*Massale*	*Arkisha*
Latitude	13° 22'	12° 81'	12° 86'	9° 54'	5° 21'	5° 26'
Longitude	38° 89'	38° 76'	37° 35'	38° 23'	37° 26'	37° 34'
Altitude#	1731	1405	1192	2176	1383	1326
Rainfall (ml)*	711	547	1879	911	511	511

** average rainfall of 2013 and 2014 (national meteorology agency of Ethiopia) and meteorology stations for rainfall were*
Abi Adi, Sekota, Tikil Dingay, Ambo Agriculture, and Konso, from left to right, respectively; #=meters above sea level

Recording and analyses of traits

In order to set the benchmarks, three production parameters and a flock productivity index were analyzed and presented. The production parameters included weight (kg) at three months (3mw), litter size (LSB) at birth and kidding interval (day) (KI). *Ad hoc* enumerators were hired to collect data on production of growth and reproduction traits. The enumerators were recording weight of kids at birth (birth weight), live weight at three months, live weight at six month, and post-partum weight right after birth. In this paper, the three month weights and post partum weights were considered. The reproduction traits were kidding interval (KI) and litter size at birth (LSB). The types of births (whether kids were born single or twin) were captured at birth from which the type of births of kids was calculated whereas; the kidding intervals were derived from the already recorded data as the difference between consecutive parturitions for a doe. The data collection duration was from mid July 2013 to Mid April 2015 for all breeds.

On the other hand, a flock productivity index was computed based on various parameters generated from data specific to each breed (Table 6); these parameters included number of parturitions per year (N), LSB, survival rate to three months (S3M), 3mw, post partum weights. Overall mean values were taken while computing the flock productivity index. In addition, correction was made to 3mw of AB based on the information provided in Table 2.

In the analysis of all traits fixed effects of villages, year, season, type, sex, and parity of kids' birth were investigated. Parity of does was captured from owners at beginning of monitoring work of the base flock. Numbers of records were found to be unbalanced across year, type and parity of births. Records from triplets, parity ≥ seven and the year 2015 were small. Due to these reasons, merging of records in 2015 and 2014, from triplets and twins and from parity ≥ seven and parity six was made. In addition, post-partum weight of does was fitted as linear covariate for the analyses of 3mw where the rest were fitted as fixed effects.

Seasons were categorized into 'dry' and 'wet' based on 2013 and 2014 rain fall data purchased from the national meteorology agency of Ethiopia. Accordingly, 'wet' months were July, August and October in *Dingur*; July, August and September in *Blaku*; June, August, September, October and November in *Waykaw*; April – October in *Tatessa*; and January, March, June, August, September, October and November in *Massale* and *Arkisha*. The rest months in the respective villages were 'dry' season.

Productivity analysis

Using the estimated biological parameters generated from data specific to each breed, flock productivity analysis was made to investigate productivity at flock level. In analyzing the flock productivity Bosman et al (1997) used parameters including flock weight which was not captured or hardly possible to capture in our cases. Due to this fact, flock mean weight was replaced by post partum weight (ppw) in the present study thinking that it could give good indication of the flock productivity.

Flock productivity was assessed and compared across the three indigenous goat breeds using index given bellow:

where y=productivity in kg live weight per kg post-partum weight per year; N = number of parturitions per year; LSB=litter size at birth; S3M = survival rate to three months of age; 3mw= live weight at three months (adjusted for milk consumed by producers for AB based on information given in Table 6); PPWm=mean postpartum weight of does.

Overall mean values or mean values of 3mw, LSB, KI and PPW were used in the calculation of this productivity index. Number of parturition per year was calculated based on overall mean KI values. When KI is less than 365 days, number of parturition is definitely more than one times and when the KI is more than 365 number of parturition per year is less than one times.

Milk was economically important trait in AB where producers compete for milk with kids (Alubel 2015; Tatek et al 2016); from CH and WG breeds, however, farmers do not milk goats. If this circumstance is not taken into account, flock productivity of AB would be under estimated. Therefore, the amount of milk consumed by producers which would otherwise be used by kids for growth was converted in to growth based on information contained in Table 2.

Table 2. Metabolizable energy (ME) required per gram growth in kids (ME/ g growth), ME content of Abergelle goat
milk and percentage milk consumed by producers

Parameters*	**Values**	**Citations**
ME/g growth	6.7	Temesgen (2016)
ME of AB goat milk (range)	881.75 (567.70 – 1306.63)	Muhi (unpublished data)
% of milk consumed by producers	50% (about milk from one teat)	Peacock, 1996

** Average daily milk yield was 453.38 ml and 308.10 ml in Dingur and Blaku villages, respectively (Temesgen 2016)*

Based on information contained in Table 2, kids at *Dingur* and *Blaku* were losing about 226.690 g and 154.050 g daily and these were about 199.880 kcal and 135.830 kcal, respectively. When converted to growth that was 29.830 g and 20.270 g for the villages which was, in respective order, 2.680 kg and 1.820 kg at three months of age, for the villages, hence these values were added on actual 3mw of AB goat breed at the two sites in order to favor them while assessing the flock productivity.

Results

Least squares means of weights at three months (3mw) are given in Table 3 for AB, CH and WG goat breeds. The overall mean of 3mw (kg) were 7.4, 11.0 and 9.4 for AB, CH and WG goat breeds, respectively. Generally, wet season, male sex and single birth resulted in higher 3mw in the three breeds (Table 3). The 3mw showed an increment with a unit increment of the does' ppw in all the goat breeds (Table 3). The effect of parity of birth was not significant on 3mw of all the breeds. AB and WG kids born in 2013 had higher 3mw than those born in 2014. Contrary to AB, for CH kids, the vice versa was observed where kids born in 2014 had higher 3mw than those born in 2013.

Table 3. Least squares means (X ± standard errors (SE) of three month weight (3mw) (kg) by fixed factors in three indigenous Ethiopian goat breeds under farmers' production practices

Factors[₡]	**Abergelle**		**Central Highland**		**Woyto-Guji**	
	N	**X±SE**	**N**	**X ±SE**	**N**	**X±SE**
Overall	885	7.4±1.41	779	11.0±2.30	504	9.4±1.44
Village[¥]	p =0.021		p =0.167		p < 0.001	

1	351	7.6±0.16a	376	10.6±0.16	199	7.4±0.14b
2	534	7.3±0.18b	403	10.9±0.16	305	10.6±0.11a
Year		*p* < 0.001		*p* < 0.001		*p* < 0.001
2013	539	7.9±0.17a	198	10.2±0.19b	157	9.3±0.14a
2014	346	7.0±0.16b	581	11.4±0.11a	347	8.7±0.10b
Season		*p* =0.012		*p* =0.039		*p* =0.617
Dry	829	7.2±0.14b	250	10.6±0.17b	243	9.0±0.12
Wet	56	7.7±0.24a	529	11.0±0.11a	261	9.0±0.11
Sex		*p* =0.244		*p* =0.006		*p* =0.065
Male	447	7.5±0.17	394	11.0±0.13a	280	9.1±0.11
Female	438	7.4±0.17	385	10.6±0.14b	224	8.9±0.11
Birth type		*p* =0.276		*p* < 0.001		*p* =0.065
Single	837	7.6±0.12	315	11.6±0.17a	419	9.2±0.08
Twin	48	7.4±0.25	464	10.0±0.13b	85	8.8±0.17
PPW		0.1±0.01		0.1±0.02		0.1±0.02

n= number of observations; ₡= least squares means with different letter are significantly different; ¥=1=Dingur, Waykaw and Massale for AB, CH and WG breeds, respectively and 2=Blaku, Tatessa and Arkisha for AB, CH and WG, respectively; PPW=Post-partum weight

The least squares means and standard errors of kidding intervals (KI), in days, are given in Table 4 for AB, CH and WG goat breeds. The overall means of KI were 362, 268 and 309 days for the breeds in respective order. Does that had their previous parturition in 2014 had shorter KI in AB and CH does. AB does having their previous parturition in *Blaku* had longer KI than does that had their previous parturition in *Dingur*. The KI of does for CH did not significantly differed by villages of production.

Table 4. Least squares means (X ± standard errors (SE) of kidding intervals (days) in three indigenous Ethiopian goat breed under farmers' production practices

Factors₡	**Abergelle**		**Central Highland**		**Woyto-Guji**	
	N	**X±SE**	**N**	**X±SE**	**N**	**X±SE**
Overall	229	362±82	162	268.1±72.21	59	309.5±89.42
Village¥		*p* < 0.001		*p* =0.116		*p* =0.109
1	98	304.8±21.08b	72	252.1±11.06	-	-
2	131	348.4±20.34a	90	276.2±9.31	-	-
Year		*p* < 0.001		*p* < 0.001		*p* =0.132
2013	203	371.9±18.55a	101	294.0±9.94	36	312.6±28.94
2014	26	281.3±24.29b	61	234.2±10.48	23	268.8±34.12

n= number of observations; ₡= least squares means with different letter are significantly different; ¥=1=Dingur, Waykaw and Massale for AB, CH and WG breeds, respectively and 2=Blaku, Tatessa and Arkisha for AB, CH and WG, respectively

Least squares means of litter size at birth (LSB) are given in Table 5 for AB, CH, and WG goat breeds. The overall means of the LSB for the goat breeds, in respective order, were 1.00, 1.40 and 1.09 per doe per parturition. The CH does from *waykaw* were characteized with higher LSB than same breed does from Tatessa village. In similar fashion, CH does that had births during dry seasons had higher LSB than does that had births during wet seasons.

Table 5. Least squares means of litter size at birth (LSB) in Abergelle (AB), Central highland and Woyto-Guji (WG) breeds

Fixed factors[z]	AB		CH		WG	
	N	X±SE	N	X±SE	N	X±SE
Overall	1159	1.00±0.170	714	1.40±0.450	601	1.09±0.290
Village[¥]		*p* =0.523		*p* < 0.001		*p* =0.105
1	541	1.03±0.008	290	1.56±0.030a	245	1.10±0.020
2	618	1.02±0.009	424	1.34±0.030b	356	1.14±0.020
Season		*p* =0.453		*p* =0.038		*p* =0.470
Dry	1009	1.03±0.005	216	1.49±0.030a	284	1.11±0.020
Wet	150	1.02±0.014	498	1.41±0.020b	317	1.13±0.020
Parity		*p* =0.005		*p* < 0.001		*p* < 0.001
1	247	1.00±0.012b	135	1.17±0.040b	146	1.02±0.020b
2	157	1.00±0.014b	136	1.25±0.040b	137	1.02±0.030b
3	204	1.03±0.013ab	135	1.45±0.040a	107	1.08±0.030b
4	223	1.03±0.012ab	124	1.60±0.040a	97	1.18±0.030a
5	190	1.05±0.013a	81	1.62±0.050a	63	1.18±0.030a
≥6	138	1.05±0.015a	103	1.60±0.050a	51	1.21±0.040a

N=number of observations (observations in LS3M were equal to observations in LSB in respective breeds and factors); z=least square means with different letters are significantly different. ¥=1=Dingur, Waykaw and Massale for AB, CH and WG breeds, respectively and 2=Blaku, Tatessa and Arkisha for AB, CH and WG, respectively

Table 6. Summary of productivity parameters used in calculation of productivity indices in the three goat breeds**

Parameters*	Abergelle		Central Highland		Woyto-Guji	
	Dingur	***Blaku***	***Waykaw***	***Tatesa***	***Massale***	***Arkisha***
LSB	1.029	1.023	1.56	1.34	1.10	1.14

3mw(kg)	10.26	9.16	10.63	10.94	7.39	10.64
PPWm (kg)	24.35	24.44	35.37	29.83	28.01	25.37
N	1.20	1.05	1.45	1.32	1.18	1.18
S3M	0.628	0.888	0.785	0.785	0.777	0.777
Flock productivity	0.33	0.36	0.53	0.51	0.27	0.44

**Overall mean values were used; LSB= litter size at birth; 3mw= weight at three months of age and corrected for milk consumed by producers for AB breed; **=fitting LSB to logistic regression did not significantly improve the model than empty model and mean values were used; PPWm=mean values of post-partum weights; N=number of parturitions per year; S3M= survival rate to three months of age (Temesgen 2016)*

Discussion

In the present study non-genetic factors influencing biological production traits including 3mw, LSB and KI were investigated for three indigenous goat breeds in Ethiopia. Using the estimated parameters as input, productivities flock level was also studied. The effect of year and village of birth were significant on most of the production parameters. Those years and villages of birth characterized by favorable conditions for feed production had significantly better values that were in agreement with available literature (Hailu et al 2005; Meza-Herrera et al 2014; Ndlovu and Simela 1996).

Three month weight

Generally, wet season, male sex and single birth resulted in higher 3mw in the present study in the three breeds. The present result was in agreement with various reports (Meza-Herrera 2014; Hailu et al 2005). In relation to endocrinal system, estrogen hormone has a limited effect on the growth of long bones in females and could be resulted in lighter body weight of females than males (Roshanfekr et al 2011; Rashidi et al 2008). Environmental conditions like temperature, humidity and rains known to have positive influence on live weights (Hailu et al 2005; Ndlovu and Simela 1996) might have been more favorable in the villages, seasons and year with superior 3mw.

Kidding Interval

Year of previous parturition in AB and CH does and village of previous parturition in the AB had significant influence on the KI. The present values of KI for CH and WG were in agreement with values reported by Ndlovu and Simela (1996) for east African goat, Đuričić et al (2012) for Boer goat. The KI of the CH and WG goat breeds were shorter than reports of Marai et al (2002). However, KI of AB breed were longer than the KI values in these report. Availability of feeds has direct influence on ovulation rate and fertility, since the nutritional stress appears to be a prime probable cause of long kidding interval in goats (Bushara et al 2013). Differences in KI could also be attributed to differences in genetic makeup and managements (Gbangboche et al 2006) as well.

Litter size

In agreement with this finding parity of birth affected LSB of kids in Red Sokoto (Awemu et al 1999) where LSB from mid parities were higher than the other parities. However, the values reported in the present study were lower than the values reported (1.57 - 1.77) by Meza-Herrera et al (2014). In general LSB is largely influenced by ovulation rate which was in turn substantially controlled by genotype and environment and can be increased by the pre-mating nutrition management in the case of ewes (Mukasa-Mugerwa and Lahlou-Kassi, 1995) which may also hold true in does.

Goat flock productivity

The flock productivity values in the present study were higher than the flock productivity from Nigerian goat studied by Bosman et al. (1997) that ranged from 0.19 – 0.22 kg. The variation in the productivity indices, generally, could be attributed to the values of the parameters composing the calculation of productivity indices. Higher N, LSB, S3M and 3mw resulted in higher flock productivity and the vice versa. As the result, CH goat breed had the highest productivity. The moderate flock productivity of the AB was due to the correction made to the three month weight by assuming the conversion of milk consumed by households to the live weight of kid.

Conclusions

- Single born and male kids had higher 3mw; locations with wet months of birth and does with higher postpartum weight also resulted in higher 3mw in AB, CH and WG indigenous goat breeds in Ethiopia.

- In general, CH goat breed was found to be the most productive when assessed with the help of flock productivity index. The higher productivity index values for CH breed was associated with higher LSB, S3M, N and 3mw.

- KI in AB breed was longest compared to the other two breeds due to harsh environments not favoring fastest onset of subsequent parturitions.

- Improvements in the production traits and then productivity at flock level could be attained by minimizing the effects of environmental sources.

- When comparison of productivity at flock level is to be made between breeds of multipurpose like AB, correction should be made to growth of kids by considering the amount of milk consumed by owners which would have been consumed by kids.

- The parameters estimated in this paper could be used as benchmark for the anticipated CBBP of goats in the localities.

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References

Abegaz S, Sölkner J, Gizaw S, Dessie T, Haile A, Mirkena T, Getachew T and Wurzinger M 2014 Optimizing alternative schemes of community-based breeding programs for two Ethiopian goat breeds. Acta Agraria Kaposváriensis: Vol 18 Supplement 1, 47-55.

Alubel Alemu 2015 On-farm phenotypic characterization and performance evaluation of Abergelle and Central highland breeds as input for designing community based breeding program. MSc. Thesis. Haramaya University, Haramaya, Pp147.

Awemu, Nwakalora L N and Abubakar B Y 1999 Environmental influences on pre-weaning mortality and reproductive performance of Red Sokoto does. Technical Note. Small Ruminant Research 34:161 - 165.

Aziz M A 2010 Present status of the world goat populations and their productivity. Lohmann information; Vol. 45 (2), Oct. 2010: 42 - 52.

Bosman H G, Moll, H A J and Udo H M J 1997 Measuring and Interpreting the Benefits of Goat Keeping in Tropical Farm Systems Agricultural Systems, 53, pp. 349-372.

Bushara I, Abdelhadi O M A, Elemam M B, Idris A O, Mekki D M, Ahmed M M and Nikhiala A M A 2013 Effect of season of birth and litter size on Taggar goat’s production in western Sudan. Wudpecker Journal of Agricultural Research Vol. 2(4), pp. 128 – 133.

Central Statistical Agency (CSA) 2012 Report on Livestock and livestock characteristics (private peasant holdings). Agricultural sample survey 2011/12[2004 e.c.],Volume II Statistical bulletin 578.

Central Statistical Agency (CSA) 2015 Report on livestock and livestock characteristics (private peasant holdings). Agricultural sample survey 2014/15[2007 e.c.], Volume II Statistical bulletin 573.

Central Statistical Agency (CSA) 2017 Report on livestock and livestock characteristics (private peasant holdings). Agricultural sample survey 2016/17[2009 e.c.], Volume II Statistical bulletin 585.

Devendra C 2012 Dairy Goats in Asia: Multifunctional Relevance and Contribution to Food and Nutrition Security. In: Proceedings of the 1st Asia Dairy Goat Conference, Kuala Lumpur, Malaysia, 9–12 April 2012. Corus Hotel Kuala Lumpur, Malaysia. Available at: http://www.fao.org/docrep/017/i2891e/i2891e00.htm (Accessed on 17th April 2013).

Duguma G, Mirkena T, Haile A, Okeyo A M, Tibbo M, Rischkowsky B, Sölkner J and Wurzinger M 2011 Identification of smallholder farmers and pastoralists' preferences for sheep breeding traits in Ethiopia: Choice model approach. Animal, doi: 10.1017/S1751731111001029.

Đuričić D, Grizelj J, Dobranić T, Harapin I, Vince S, Kočila P, Folnožić I, Lipar M, Gračner G G and Samardžija M 2012 Reproductive performance of Boer goats in a moderate climate zone. Veterinarskiarhiv 82 (4): 351-358, 2012.

FAOSTAT 2014 http://faostat.fao.org/default.aspx.

Gbangboche A B, Adamou-Ndiaye M, Youssao A K I, Farnir F, Detilleux J, Abiola F A and Leroy P L 2006 Non-genetic factors affecting the reproduction performance, lamb growth and productivity indices of Djallonke sheep Small Ruminant Research 64:133 - 142.

Getachew T, Haile A and Rischkowsky B 2018 How to tailor community based breeding programs for small ruminants to pastoral production systems. Proceedings of the World Congress on Genetics Applied to Livestock Production, 11.858.

Gizaw S, Rischkowsky B, Valle-Zarate A, Haile A van Arendonk J A M, Okeyo A M and Dessie T 2014 Breeding programs for smallholder sheep farming systems: I. Evaluation of alternative designs of breeding schemes. J. Anim. Breed. Genet. 131: 341–349.

Haile A, Wurzinger M, Mueller J, Mirkena T, Duguma G, Okeyo M, Sölkner J and Barbara Rischkowsky B 2011 Guidelines for Setting up Community-based Sheep Breeding Programs in Ethiopia. ICARDA - tools and guidelines No.1. Aleppo, Syria, ICARDA.

Hailu D, Mieso G, Nigatu A, Fufa D and Gamada D 2005 The effect of environmental factors on pre-weaning survival rate of Borana and Arsi-Bale kids. *Small Ruminant Research* 66: 291–294.

Kosgey I S and Okeyo A M 2007 Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. Small Ruminant Research 70 (2007): 76–88.

Marai I F M, Abou-Fandoud E I, Daader A H and Abu-Ella A A 2002 Technical note Reproductive doe traits of the Nubian (Zaraibi) goats in Egypt. Small Ruminant Research 46: 201 - 205.

Meza-Herrera C A, Serradilla J M, Munoz-Mejías M E, Baena-Manzano F and Menendez-Buxadera A 2014 Effect of breed and some environmental factors on bodyweights till weaning and litter size in five goat breeds in Mexico. Small Ruminant Research 121: 215 - 219.

Mueller J P, Ansari-Renani H R, Seyed Momen S M, Ehsani M, Alipour O and Rischkowsky B 2015a Implementation of a cashmere goat breeding program amongst nomads in Southern Iran. Small Ruminant Research 129: 69 - 76.

Mueller J P, Rischkowsky B, Haile A, Philipsson J, Okeyo M, Besbes B, Valle Zarate A, Tibbo M, Mirkena T, Duguma G, Solkner J and Wurzinger M 2015 Community-based livestock breeding programmes: essentials and examples, invited review. J. Anim. Breed. Genet. 132: 155–168.

Mukasa-Mugerwa E and Lahlou-Kassi A 1995 Reproductive performance and productivity of Menz sheep in the Ethiopian highlands. Small Ruminant Research 17:167-177.

Ndlovu and Simela 1996 Effect of season of birth and sex of kid on the production of live weaned single born kids in smallholder East African goat flocks in North East Zimbabwe. Small Ruminant Research 22: l-6.

Peacock C 1996 Improving goat production in the tropics. A manual for development worker. FARM-Africa and Oxfam (UK and Ireland).

Peacock C 2005 Goats - A pathway out of poverty. Small Ruminant Research 60:179 - 186.

Rashidi A, Mokhtari M S, Jahanshahi A S and Abadi M R M 2008 Genetic parameter estimates of pre-weaning traits in Kermani sheep, Small Ruminant Research. 74, 165-171.

Roshanfekr H, Mamouei M, Mohammadi K and Rahmatnejad E 2011 Estimation of Genetic and Environmental Parameters Affected Pre-weaning Traits of Arabi Lambs, Journal of Animal and Veterinary Advances. 10: 1239-1243.

Tatek Woldu, André Markemann, Christoph Reiber, Girma T Kassie and Anne Valle Zárate 2019 Combining revealed and stated preferences to define goat breeding objectives in Ethiopia, *Livestock Science*, http://dx.doi.org/10.1016/j.livsci.2016.08.008

Temesgen Jembere 2016 Genetic parameters, productivity indices and breeding plans for designing community-based goat breeding programs in Ethiopia. PhD dissertation, Haramaya University, Haramaya, Ethiopia.

Tesfaye A 2004 Genetic characterization of indigenous goat populations of Ethiopia using Microsatellite DNA markers. PhD dissertation. Division of dairy cattle breeding, national dairy research institute, Harayana, India.

Wurzinger M, Escareño L, Pastor F, Salinas H, Iñiguez L and Sölkner J 2013 Design and implementation of a community-based breeding program for dairy goats in northern Mexico. Tropical and Subtropical Agro-ecosystems.16: 289 - 296.

Zergaw N, Dessie T and Kebede K 2016 Indigenous breeding practices and selection criteria of goat owners in Konso and Meta-Robi districts, Ethiopia: implications for designing community-based breeding strategy. Livestock Research for Rural Development. Volume 28, Article #133

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