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Performance of indigenous sheep breeds managed under community-based breeding programs in the highlands of Ethiopia: Preliminary results

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Contents

Introduction

In developed countries and in high input animal production systems, animal breeding has been traditionally supported by the state and implemented by large national breeding programs. Data recording, channeling of the recorded data towards a data processing centre, estimation of 'breeding values' with complex statistical methods and central decisions about the use of male breeding animals are ingredients of such breeding programs.

In developing countries, the required supportive infrastructure is largely unavailable, so attempts to replicate developed-country approaches have met with little success. As an alternative, centralized breeding schemes, entirely managed and controlled by governments – with minimal, if any, participation by farmers – were developed and implemented in many developing countries through a nucleus breeding unit limited to a central station. These centralized schemes were usually run by a governmental organization attempting to undertake all or part of the complex processes and breeding strategy roles (i.e. data recording, genetic evaluation, selection, delivery of genetic change, and feedback to farmers).

Although well intended, these centralized schemes failed to sustainably provide the desired genetic improvements (continuous provision of a sufficient number and quality of improved males to smallholders) and also failed to engage the participation of the end-users in the process.

Another widely-followed alternative is importing improved commercial breeds in the form of live animals, semen, or embryos. These are crossbred with the indigenous and 'less productive' breeds to upgrade them, but in most cases, it is done without sufficient pre-testing of the appropriateness (suitability and adaptability) of the breeds and their resulting crosses to local production systems or conditions. Where indiscriminate crossbreeding with the local populations has been practiced, genetic erosion of the adapted indigenous populations and breeds has occurred.

A new approach is therefore required. One such approach is a community-based breeding strategy. Programs that adopt this strategy take into account the farmers' needs, views, decisions, and active participation, from inception through to implementation, and their success is based upon proper consideration of farmers' breeding objectives, infrastructure, participation, and ownership (Mueller 1991; Sölkner et al. 1998; Wurzinger et al. 2011).

Cognizant of this, the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Livestock Research Institute (ILRI), and the University of Natural Resources and Life Sciences (BOKU), in partnership with the Ethiopian National Agricultural Research System, have designed and implemented community-based sheep breeding programs in Ethiopia. We report preliminary results from these breeding programs whose objectives were:

1. Evaluate the progress in implementation of community-based breeding programs (CBBPs);
2. Evaluate the growth and reproduction performance of Ethiopian sheep breeds kept under CBBPs;
3. Study the effects of non-genetic factors on performance of sheep breeds in Ethiopia.

Community-based breeding programs

Since 2009, Ethiopian community-based sheep breeding programs are being implemented in three locations with three breeds (Bonga, Horro and Menz) involving more than 8000 sheep. There are six communities in the three locations. Each community has about 60 households.

The goal of the project is to improve the productivity and income of these small-scale resource-poor sheep producers by providing access to improved animals that respond to improved feeding and management, facilitating the targeting of specific market opportunities. There is a governmental rural organization associated with each of the project sites. Local enumerators were recruited for each community to help the research system in animal identification and recording. Indigenous knowledge of the community is considered at each phase of the project. For example, the community decides how rams are managed and how they are shared and used. The core in this project is to get community members working together in ram selection, management and use.

Two stages of selection were applied: initial screening when first sales of young rams occur (4–6 months) and final selection for admission to breeding at 12 months of age. Selection at the first stage is based on lambs of 6 months weight and ewe lambing interval. Additional yearling weight and conformation were considered in the final selection. All young rams are collected at one central place in each community on an agreed screening date. Selection is then carried out based on the data analyzed.

A breeding ram selection committee composed of about 3–5 members elected by the community are involved in the selection. If for example 15 rams were to be selected from 100 candidates, say 20 would be preselected based on their breeding value and the culling of the last five and the ranking of the selected rams would be made by the committee. The committee checks at the conformation, colour, horn type, tail type and other criteria in decision making.

Candidate rams in their holding yards at Horro

Description of the sites and breeds

The community-based breeding programs were set up in four locations representing different production systems and agro-ecology. In each site we had two communities (table 1). However, due to many reasons, we were not successful in Afar (pastoralist) communities. Therefore, we will present results from three sites (Bonga, Horro and Menz). The numbers of households (HH) and mean flock size (SD) in the different locations is presented in Table 1.

Bonga is located in southwest Ethiopia about 460 km from Addis Ababa, with altitudes ranging from 1,000 to 3,400 meters. The temperature in the area can be as high as 24 ºC and can also reach the lowest value of 12 ºC. For the Bonga breed, the tail is wide and long. Both male and female are polled; the ear is long, the hair is short and smooth. The breed is judged as good for traits like growth rate, meat quality, fattening potential, twining rate and temperament (Edea 2008). The prominent farming system is a mixed crop-livestock production.

Rams in Bonga

Horro is located in the western Ethiopian mid-highland region (i.e. 1,600 to 2,800 m altitude) about 310 km from Addis Ababa. Horro is believed to be closer to the epicenter of the Horro sheep breed origin. Horro sheep is a fat-tailed hair-type sheep with bigger growth potential compared with other indigenous breeds in Ethiopia. Farming in the Horro area is dominated by mixed crop-livestock system (Edea 2008).

Menz is located in the Ethiopian highlands at about 280 km north-east of Addis Ababa, with an altitude range of 2,700 to 3,300 m.a.s.l. The Menz area is considered as the epicenter of distribution of the Menz breed. The Menz breed is one of the few coarse woolly fat-tailed sheep types, adapted to the high altitude precipitous terrain with scarcity of feed and where production of crop is limited due to extreme low temperature and drought in the cool highlands. This is a hardy small breed, which controls the level of internal parasite infection and is productive under low input production circumstances of the degraded ecosystems (Getachew et al. 2010).

Table 1. Number of households (HH) and mean flock size (SD) in the different locations

Location	Community	№ of HH	Average flock size (SD)	Range
Bonga	Boqa	63	9.4 (4.98)	4 – 23
	Shuta	64	7.5 (3.85)	4 – 21
	Mean		8.5 (4.53)	4 – 23
Horro	Kitlo	59	18.4 (14.24)	3 – 72
	Lakku-Iggu	63	16.5 (10.01)	4 – 50
	Mean		17.4 (12.23)	3 –72
Menz	Mehal-Meda	64	22.7 (12.95)	4 – 64
	Molale	58	16.5 (9.67)	4 – 41
	Mean		19.8 (11.87)	4 – 64

Livestock grazing in Menz

Data recording, management and analysis

We developed data recording formats and hired enumerators to collect data from each household. The initially agreed traits with the frequency of collection for the three sites are summarized in table 2. However, here we report on weight (at birth, weaning (3 months), and six months) as well as pre and post weaning daily gains for all sites. Additionally, ewe post-partum weight and lambing interval data were available for Menz.

Least squares analysis was carried out to study performance of sheep and examine fixed effects (SAS, 2002). The fixed effects fitted were: year of birth (three to five classes based on sites: 2009, 2010, 2011, 2012, 2013); ewe parity (seven classes: 1, 2, 3, 4, 5, 6 and >=7), lambing season, grouped into two classes, based on the pattern of annual rainfall distribution in the area (October-April: dry period; May to September: wet season); sex (two classes: Male and Female) and litter size (two or three classes: single, twin, triple). A fixed effect model was fitted. The Tukey–Kramer test was used to separate least squares means with more than two levels.

Table 2. Traits recorded in three sheep breed improvement communities in Ethiopia

Traits	Bonga	Horro	Menz
Birth weight	√	√	√
Three months weight	√	√	√
Six months weight	√	√	√
Yearling weight	√	√	√
Lamb survival	√	√	√
Twinning rate	√	√	
Fleece weight (yearling)			√

Results

Management and use of breeding rams

The breeding program involved selection of young rams from the community flocks and subsequent use of these rams communally. Since we started the selection scheme in 2010, we have undertaken six rounds of selection. The number of rams selected and used in the community flocks for the three sites is indicated in Table 3.

Table 3. Number of young rams selected and used in the three sites

Round of selection	Bonga	Horro	Menz
1&2	29	27	50
3	24	16	26
4	33	25	42
5	45	18	32
6	37	8	24
7		14	
Total	168	108	174
Total households	235 (22 female headed)	122 (8 female headed)	120 (12 female headed)

In our communities farmer flocks are quite small, and therefore the flocks were treated as one. Consequently, selection is undertaken at community-flock level, with the selected best rams shared among the community members thereafter. In our communities, a tradition of ram sharing already exists. Therefore, we had consultations to agree on modalities of common use as there is no single arrangement that applies to all situations.

The modalities for ram exchange that were discussed with the communities included:

- Sharing rams based on friendship and trust among members of the breeding group;
- Exchanging rams based on a written agreements;
- Exchanging rams based on purchase between different breeding groups when rams complete the defined service period in a given flocks;
- Advancing some seed money from the project or from members' contributions to purchase the first round of breeding rams, use these, then sell them to generate a revolving fund to purchase the next and subsequent rounds of breeding rams.

It should be noted that one or a combination of the above arrangements may be adopted or used depending on the prevailing circumstances. For us, the last option was chosen. We expected that creating a revolving fund will sustain the program in the long term. This also helps to prevent the negative selection of rams that is a common phenomenon in the communities. Negative selection arises when faster growing males are sold off early before they are of breeding age, leaving the slower growing males as the breeding males in the community flocks. To avert the negative selection, we purchased the best young rams that were owned and used by the community. After two years of service (period agreed with the community), such rams were either sold as breeding animals to other communities or were fattened and sold to support the purchase of the next group of selected rams for the community.

Rams are used communally by forming 'ram-user-groups' and this was based on settlement patterns and the use of communal grazing areas. To minimize inbreeding, a strategy for ram rotation among the ram groups has to be established through a consultative process where a ram is used in flocks for one year after which it is rotated to another ram-group within the community. No additional arrangements were made to manage the selected rams. In most cases, rams are kept in one agreed household and other community members contribute in kind (e.g. feed and veterinary drugs).

A critical issue that needs to be thought through is how to manage the unselected rams. It should be recognized that the unselected rams, especially those young rams that fulfilled the initial requirements but got lower ranks than the selected rams, are better than the rams in neighbouring communities where no selection program exists. Therefore, we advertised the possibility to sell rams and this has taken off very well in Bonga where the breeders' cooperative we established sold 120 breeding rams to different communities at an improved price around Birr 5,000 per ram. Value addition in terms of fattening could be organized for the unselected rams and linked to markets. We set up this in Horro and Menz and, though not in a consistent manner, there were fattening activities in which members sold substantial numbers of animals making reasonable profits (the financial analysis of the fattening scheme still needs to be worked out).

Preliminary indicators for success of the CBBP

- Reverting negative selection: The setup of revolving funds in the communities has tremendously helped in reversing negative selection. This is due to two reasons: first, community members get fairly good prices for their best animals without the hurdle of going to markets. Second, they can also sell anytime of the year if the sheep are good enough. The communities have established a mechanism where a good ram is bought and retained by the cooperative if the owner decides to sell due to financial obligations.

- Progress with the selection scheme: We have done six rounds of selection thus far. The number of candidate rams for each site varied greatly. However, more than 80% of the registered candidates came for selection. Depending on the number of candidates, we set the selection intensity at 10-30%. Except in a few cases where breeding rams either died or were sold, the selected rams were retained and served in the community flock through the originally agreed modalities.

- Recording system: Data recording is still done by the hired enumerators. As the enumerators gained experience, the quality of the data collected has improved. Data collected by enumerators is entered in excel by researchers from our partner institutions.

- Breeding rams: In Bonga, there is huge demand for breeding rams from neighbouring communities as well as by other government offices and NGOs. This is huge success. A breeding ram is now sold for around Birr 5,000 while a meat animal of the same size might fetch Birr 2,000. Over the last three years, the breeders' cooperative in Bonga sold 120 rams.

- Ram sharing (use) and revolving fund: Admittedly, there were some irregularities in ram use and management, particularly during the initial stages of the breeding program. This was mainly related to some members refusing to share selected rams. However, through repeated consultations this has now been minimized. Therefore, the system of ram sharing is working fairly well and there are no major complaints. The full functioning of the revolving fund scheme took longer than we expected. However, in Menz and Bonga, since the fifth round of selection, the communities/cooperatives are purchasing the next rounds of rams through the revolving fund. This came in effect in Horro in the seventh round.

- The cooperatives: Cooperative formation has been difficult in Horro and Menz. The requirements were so stringent that members found them difficult to fulfill. After lengthy negotiation and lobbying, however, we have established cooperatives in these sites. Before the establishment of the cooperatives, the producers had traditional associations where they worked together on common issues related to the functioning of the CBBP. In Bonga, the cooperative is established as a breeders' group and they are very strong both organizationally and financially.

- Gender: We work with both women and men headed households, although the number is not proportional (table 2). The benefits are usually shared among the family members although this needs detailed study.

- Other communities willing to join? One of the challenges we face in our CBBP is accommodating requests to join the breeding communities. The plan has been to test the approach with manageable sizes and to slowly scale it out. In Bonga, through support from the regional government, the breeding program has been scaled out to neighbouring communities keeping the same sheep breed and other districts in the region with other sheep and goat breeds. We don't have any reports suggesting withdrawal of members from the community.

Evaluating our CBBP based on the criteria we set, it is clear that the program is progressing well but needs more time to fully function independently of support from the research system.

Performance of the sheep flock

Growth performance

Birth weight: The birth weight of lambs has not improved over the years in Menz and Bonga. In Horro, there is a slight increase. Given that we have not selected for birth weight in the community flock we did not expect change. However, the lack of significant improvement in birth weight is particularly advantageous because selection for this trait beyond a particular level may be associated with dystocia and loss of productivity. Thus, care should be taken when undertaking selection in birth weight. Indeed, many studies have shown that genetic correlation between birth weight and later weights is weak and this has advantages because selection for each trait could be effected independently of the other and therefore selection for say, weaning weight or gain would not increase birth weight.

Three and six month's weights and gains (pre and post weaning gain): For all three sites, these weights varied over the years. In almost all cases, weights (three and six months weights) were heavier and gains (pre and post weaning weights) were faster (at least $p<0.05$) for the base (2009) year (tables 4, 6 and 7). However, there was no improvement in subsequent years ($p>0.05$). The lack of improvement could be due to two reasons: First, the initial few rounds of ram selection were not done accurately. Data collected by the enumerators during the first few years were, admittedly, not accurate as the team (researchers, enumerators and farmers) was learning how to implement community-based breeding programs. Consequently, follow-up with the farmers, weighing and recording were generally irregular. Second, as ram lambs born to selected rams are a starting service, it would take some time before we see the effect from our selection scheme.

Reproductive performance

Least squares means (and standard errors) for ewe post-partum weight, and lambing interval for the Menz flock is presented in table 5. Ewe post-partum weight was heavier ($p<0.01$) during the 2010 and 2011 years than the base year (2009). This might be related to better management of breeding ewes resulting from training and awareness created in the community. However, the lambing interval was shorter ($p<0.05$) in 2009 compared to 2010 and 2011.

Effects of non-genetic factors

The effects of non-genetic factors (sex, birth season and birth type) on growth performance of sheep flock in Menz, Bonga and Horro sites are presented in tables 4, 6 and 7, respectively.

Sex: Weight differences for the different sexes at three month and yearling as well as pre and post weaning daily gains were non-significant in Menz. However, females were slightly heavier than males at birth and at six months weights. For Bonga, males were heavier and grew faster than females at all age categories, whereas, sex differences were not observed in Horro. Such inconsistent differences are unexplainable. However, some of the results in Menz and all of the Bonga observation concur with results reported in literature that favour male sheep which could obviously be related to inherent physiological variations (Tibbo, 2006; Saghi et al., 2007).

Birth type: This had significant effect on growth performance of sheep across all the sites. Single born sheep had heavier weights at all ages and gained more weight than twins and triples (in Bonga and Horro).

Season of birth: This is a significant source of variation for growth performance as well as weight gains of sheep. In most cases, lambs born in the dry season had heavier weights than those born in the wet season ($p<0.05$). This is indeed unexpected as more feed availability in the wet season should have resulted in more weights and gains. Indeed for birth weight, better feeding in the wet season might have resulted in bigger lambs at birth in the dry season.

These preliminary results are not consistent and in some cases they are unexpected. The breeding programs we set up are new approaches and we are still learning some of the operations. Therefore, more years are needed to get comprehensive results. However, from our personal observations, it is clear that the acute shortage of breeding rams observed previously in flocks of participating communities has been addressed as farmers are now fully aware of the importance of breeding males. There is also increased marketing of lambs as a result of more lamb births and reduced mortality due to the selection program and the project supported interventions (i.e. improved health-care and feeding).

Table 4. Least squares means (± SE) for effects of birth year, birth season, sex, parity and litter size on birth weight, three months weight, six months weight, yearling weight, pre and post weaning daily gain (all in kg) in Menz

Effects and level	BWT	TWT	ADG1	SWT	ADG2	YWT
N	1375	1375	1375	1375	1375	1375
Overall	2.27±0.043	9.3±0.619	0.08±0.007	13.7±0.3	0.04±0.003	16.9±0.45
CV%	15	21	28	19.3	21	16
Birth year	**	**	**	**	**	**
2009	2.34±0.044[a]	12.2±0.273[a]	0.11±0.003[a]	16.0±0.4[a]	0.05±0.004[a]	17.5±0.45
2010	2.29±0.043[b]	9.7±0.0267[b]	0.08±0.003[b]	12.6±0.3[b]	0.03±0.003[b]	16.3±0.48
2011	2.18±0.057[c]	9.2±0.306[b]	0.08±0.003[b]	12.5±0.3[b]	0.04±0.003[c]	--
2012	--	5.9±2.256[b]	0.04±2.025[b]	--	--	
Birth season	NS	*	*	**	**	**
D	2.26±0.044	9.4±0.619	0.08±0.007	14.7±0.3	0.043±0.003	16.1±0.48
W	2.28±0.044	9.1±0.624	0.08±0.007	12.7±0.3	0.038±0.003	17.6±0.46
Sex	**	NS	NS	*	NS	NS
Female	2.29±0.044	9.3±0.623	0.08±0.006	13.9±0.3	0.04±0.003	17.0±0.46
Male	2.25±0.044	9.2±0.621	0.08±0.009	13.6±0.3	0.04±0.003	16.8±0.47
Parity	NS	NS	NS	NS	NS	**
1	2.28±0.05	9.3±0.642	0.08±0.007	13.6±0.4	0.039±0.003	16.8±0.55
2	2.28±0.048	9.2±0.634	0.08±0.007	14.0±0.4	0.043±0.003	17.3±0.49
3	2.27±0.047	9.5±0.632	0.08±0.007	14.0±0.4	0.040±0.003	16.8±0.50
4	2.26±0.047	9.5±0.623	0.08±0.007	13.9±0.4	0.039±0.003	17.6±0.50
5	2.31±0.049	9.5±0.638	0.08±0.007	13.8±0.4	0.039±0.003	16.3±0.53
6	2.26±0.052	9.0±0.647	0.08±0.007	13.2±0.4	0.039±0.004	16.0±0.62
7	2.34±0.058	8.8±0.666	0.07±0.007	13.5±0.4	0.043±0.004	17.4±0.74
Litter size	*	NS	NS	NS	NS	NS
1	2.36±0.044	9.4±0.56	0.08±0.006	13.8±0.1	0.037±0.001	17.2±0.12
2	2.18±0.044	9.1±0.76	0.08±0.009	13.7±0.6	0.044±0.006	16.5±0.88

BWT, birth weight; TWT, three months weight; SWT, 6 months weight; YWT, yearling weight; ADG1, weight gain from birth to 3 months; ADG2, weight gain from 3 months to 6 months.

*p < 0.05; **p < 0.01; NS, Non-significant; Least squares means with same superscript in the same column indicate non-significance.

Table 5. Least squares means (± SE) for effects of birth year, birth season, sex, parity and litter size on ewe post-partum weight and lambing interval in Menz

Effect and level	Ewe post-partum weight	Lambing Interval
N	1375	1375
Overall	23.7±0.39	270±27
CV%	14.3	24
Birth year	**	*
2009	24±0.39[a]	203±39[a]
2010	23±0.39[b]	286±23[b]
2011	25±0.50[c]	321±39[b]
Birth/lambing season	**	**
D	24.0±0.40	256±27
W	23.5±0.40	284±28
Sex of lamb	NS	NS
Female	23.8±0.40	275±27
Male	23.7±0.40	265±28
Parity	**	NS
1	22.7±0.46	248±50
2	23.6±0.43	275±30
3	23.8±0.43	285±30
4	24.5±0.42	282±29
5	23.9±0.45	270±28
6	23.6±0.47	274±28
7	23.9±0.52	256±32
Litter size	**	NS
1	22.0±0.14	239±15
2	25.5±0.76	300±47

*p < 0.05; **p < 0.01; NS, Non-significant; Least squares means with same superscript in the same column indicate non-significance.

Table 6. Least squares means (± SE) for effects of year, birth season, lamb sex and birth type birth weight, three months weight, six months weight, pre and post weaning daily gain in Bonga

Effect and level	BWT	TWT	ADG1	SWT	ADG2
N	2125	1401	1396		
Overall	3.42±0.051	14.8±0.226	0.13±0.002	21.0±0.708	0.05±0.005
CV%	22	20	24	18	41
Year	**	**	**	**	*
2009	3.59±0.064[a]	14.3±0.314[a]	0.12±0.003[a]	19.2±1.22[a]	0.04±0.009[a]
2010	3.22±0.06[b]	15.5±0.265[b]	0.14±0.003[b]	21.3±0.727[b]	0.06±0.005[b]
2011	3.42±0.055[c]	14.5±0.249[a]	0.12±0.003[a]	22.1±0.769[b]	0.06±0.005[b]
2012	3.43±0.058[c]	14.8±0.249[c]	0.13±0.003[a]	21.3±0.736[b]	0.06±0.005[b]
Birth season	**	**	**	**	NS
D	3.33±0.053	14.4±0.232	0.12±0.002	20.4±0.722	0.05±0.005
W	3.5±0.054	15.1±0.249	0.13±0.003	21.6±764	0.05±0.005
Sex	**	**	**	**	**
Female	3.33±0.05	14.1±0.241	0.12±0.003	19.4±0.749	0.05±0.005
Male	3.50±0.053	15.4±0.238	0.13±0.003	22.5±0.732	0.06±0.005
BT	**	**	**	**	NS
1	3.81±0.025[a]	16.6±0.119[a]	0.14±0.001[a]	22.8±0.377[a]	0.06±0.003
2	3.36±0.024[b]	13.7±0.117[b]	0.12±0.005[b]	19.8±0.397[b]	0.06±0.003
3	3.08±0.148[b]	14.0±0.649[b]	0.12±0.003[b]	20.3±1.978[ab]	0.04±0.014

BWT, birth weight; TWT, three months weight; SWT, 6 months weight; ADG1, weight gain from birth to 3 months; ADG2, weight gain from 3 months to 6 months.

*$p < 0.05$; **$p < 0.01$; NS, Non-significant; Least squares means with same superscript in the same column indicate non-significance.

Table 7. Least squares means (± SE) for effects of birth year, birth season, sex, parity and litter size on birth weight, three months weight, six months weight, pre and post weaning daily gain in Horro

Effect and level	BWT	TWT	ADG1	SWT	ADG2
N	491	486	486	486	486
Overall	3.12±0.129	11.7±0.548	0.09±0.006	17.3±0.814	0.06±0.009
CV%	21	19	25	12	50
Birth year	**	**	**	**	**
2011	2.56±0.133	12.6±0.558[a]	0.11±0.006[a]	18.2±0.991[a]	0.08±0.011[a]
2012	3.68±0.134	11.44±0.519[b]	0.09±0.006[b]	17.8±0.824[a]	0.06±0.009[b]
2013	--	11.003±0.755[b]	0.07±0.008[b]	15.8±0.899[b]	0.05±0.01[b]
Birth season	NS	*	**	NS	NS
D	3.08±0.138	12.03±0.527	0.09±0.006	17.15±0.546	0.064±0.009
W	3.16±0.130	11.34±0.622	0.09±0.007	17.36±0.341	0.061±0.009
Sex	NS	NS	NS	NS	NS
Female	3.07±0.135	11.5±0.56	0.09±0.006	16.9±0.833	0.06±0.006
Male	3.16±0.131	11.9±0.56	0.09±0.006	17.6±0.341	0.06±0.015
PARITY	NS	NS	NS	NS	NS
1	3.11±0.152	11.6±0.611	0.09±0.007	16.5±0.91	0.06±0.01
2	3.13±0.143	11.9±0.595	0.09±0.006	17.55±0.875	0.07±0.01
3	3.11±0.147	11.7±0.613	0.09±0.007	16.9±0.959	0.06±0.01
4	2.90±0.133	11.6±0.563	0.09±0.006	17.82±0.858	0.07±0.01
5	3.18±0.153	11.32±0.636	0.09±0.007	16.73±0.978	0.06±0.01
6	3.19±0.164	11.41±0.678	0.09±0.007	17.9±0.912	0.07±0.01
7	3.14±0.154	12.3±0.638	0.09±0.007	17.5±0.946	0.06±0.01
Litter size	**	**	**	NS	NS
1	3.19±0.038[a]	12.8±0.268[a]	0.10±0.003[a]	17.33±0.698	0.048±0.008
2	2.99±0.054[b]	11.9±0.294[b]	0.09±0.003[b]	16.46±0.694	0.047±0.008
3	3.17±0.381[a]	10.4±1.481[b]	0.07±0.016[b]	18.0±1.705	0.092±0.019

BWT, birth weight; TWT, three months weight; SWT, 6 months weight; ADG1, weight gain from birth to 3 months; ADG2, weight gain from 3 months to 6 months.

*p < 0.05; **p < 0.01; NS, Non-significant; Least squares means with same superscript in the same column indicate non-significance.

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