

Effect of Natural and Artificial Sucking on Performance and Mortality of Newborn Assaf Lambs

Wael Halawa¹, Raed M. Al-Atiyat^{2*}, Jamal Abo Omar¹, Faisal S. Rashaydeh³, Fath Ullah⁴, Shakirullah⁵ and Berkant Ismail Yildiz⁶

¹Animal Production, Faculty of Graduate Studies An-Najah National University, Nablus, Palestine

²Genetics and Biotechnology, Department of Animal Science, Mutah University, Karak, Jordan

³Department of Agricultural Biotechnology, Akdeniz University, 07058, Antalya, Türkiye

⁴Livestock and Dairy Development, FATA Secretariate, Warsak Road, Peshawar, Pakistan

⁵Department of Animal and Poultry Production, Faculty of Veterinary and Animal Sciences, Gomal Univeristy, Dera Ismal Khan, Pakistan

⁶Institute of Natural and Applied Sciences, Akdeniz University, Konyaaltı, 07058, Antalya, Turkey

ABSTRACT

The aim of this study was to examine the effect of different suckling methods on newborn Assaf lambs growth performance and mortality. A total of 97 lambs were used in the study, with lambing periods starting from October 2020 to January 2021. Ewes' parities were first, second, and third. After lambing, lambs were randomly distributed according to the suckling method into three groups: natural suckling (G1) (39 lambs), lambs fed completely with milk replacer (G2) (29 lambs), and lambs fed milk replacer at a rate of 4 times per day (G3) (29 lambs). In G1, lambs were 59% twins and 41% single lambs. Lambs from first, second, and third parity were 8, 21, and 28% respectively. Single lambs of G2 were 62%, while twin lambs were 38%. Lambs from first, second, and third parties were 14, 48, and 38%, respectively. However, 69% of G3 were singles. The natural suckling lambs (G1) were kept with their dams for free suckling until weaning at 60 days of age. However, the artificial suckling groups (G2) were isolated from dams and fed milk replacer ad libitum until weaning at 40 days of age. Lambs of the G3 were isolated from mothers and took their milk replacer through an automatic sucking machine four times a day, for half an hour each time, until weaning at 40 days. The results showed that weaning weights at 40 days were 13.7, 12.83 and 13 kg for lambs in G1, G2 and G3, respectively. The suckling method had no effect on mortality ($P>0.05$). The mortality rate decreased from 18% in G1 to 7 and 3.5% in G2 and G3 respectively. Most of the dead lambs were single lambs. Significant cost effects ($P<0.05$) were observed by feeding milk replacer in suckling lambs. The cost of milk per lamb was reduced from 120 to 40 USD. It was determined that feeding milk replacers to nursing lambs will result in significant cost reductions. However, these reductions were expected from the savings in milk expenses and the significant decrease in lambs' mortality rate. We recommend the use of milk replacer in Assaf lambs for better performance and economic cost.

Article Information

Received 08 April 2023

Revised 25 April 2023

Accepted 16 May 2023

Available online 01 September 2023
(early access)

Authors' Contribution

WH and FSR conducted the project and analyzed the sample. RMA and JAO designed the study and analysed the data. FU, S and BIY edited and revised the paper.

Key words

Cross bred, Suckling method, Lamb's performance, Growth rate, Mortality rate, Milk replacer

INTRODUCTION

The livestock sector in Palestinian occupied territories (POT) is of major importance, as it contributes 44.5% of the total current agricultural income. The backbones of this sector are sheep, goats, dairy cattle, and poultry. Livestock in POT is not only an economic or income-generating activity but also a distinctive cultural and traditional way for supporting livelihood of the Palestinian people. It is worthy to mention that small ruminant production has a potential to address the demand and greatly

* Corresponding author: ratiyat@mutah.edu.jo
0030-9923/2023/0001-0001 \$ 9.00/0



Copyright 2023 by the authors. Licensee Zoological Society of Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

increased requirements of animal based food products in rural areas in a manner that is socioeconomically sustainable (Chinnaiyan, 2019). Actually, it provides the main source of income and food security for thousands of Palestinian households in rural areas and Bedouin communities in the POT; West Bank and Gaza Strip (MOA, 2015). Sheep production, in particular, is of great economic and social importance in most rural districts, but it faces several obstacles, such as high feed prices, marketing challenges, a lack of efficient management skills, and low breed productivity. Besides the previous obstacles, the high newborn mortality rate has become one of the main reasons for insufficient farm profitability (MOA, 2013). Meanwhile, low breed productivity is the main reason for insufficient livestock farming profits. In order to assure the stability of small ruminants' populations and wellbeing, it is important to reduce newborns mortality rates through good management practices. It is recommended that good care during nursing and the adoption of new techniques in feeding the newborns should have a positive impact on the health conditions of the newborns and reduce the mortality rate in local sheep and goat herds (Flinn *et al.*, 2020; El-Raghi *et al.*, 2022).

Sheep in OPT is raised under intensive or semiintensive production systems. The intensive production entails confining sheep in narrow spaces, whereas they found in semiintensive production systems more often. Furthermore, sheep farming is characterized by the breeding of fat-tailed local Awassi (AW), Assaf (AF), and AWxAF crossbreds, which are grazed on semi-intensive pastures in late winter and early spring and fed indoors with barley, wheat bran, and hay rest of the year. Sheep in this production system is facing high new-born mortality rate, which causes high losses and affects profitability. In fact, it is one of the most significant barriers to successful small ruminant farming in Palestine, according to a study conducted by the MOA (2013). The main reason for this high rate might be bad management practices. To decrease the new-born mortality rate, it is recommended to use milk replacers that have other sources of protein rather than natural milk casein, (Ministry of Agriculture, 2002). However, it is expected to decrease the mortality rate by at least 10% by targeting farms and. Knowing that the normal rate should not exceed 5%. Sezen and Soner (2013) found that the average daily gain was higher for lambs with natural suckling than for lambs with milk replacer, while the weaning weights for natural suckling lambs and milk replacer lambs at 42 days of age were 12.64 kg and 14.15 kg, respectively. According to Gootwine *et al.* (2008), the average birth weight for Afec-Assaf was 4.5 kg, the average weaning weight was 14.7 kg after 35 days, and the average daily gain for Afec-Assaf and 1/2 Suffolk was

294 g when artificial suckling on milk substitute was used. Vatankhah and Talebi (2009) studied the effect of age of the dam (parity), type of birth (litter size), and six lambs on the lamb's mortality rate and reported that age of the dam and lamb sex have no effect on the lamb's mortality rate, while type of birth affects the lamb's mortality rate and it was higher in twins. On the other hand, the effects of the age of ewes, sex, and birth type of lambs on weaning weight and average daily gain were studied by Ayhan *et al.* (2009) who found significant effects of these factors on the studied traits. It was also found that sex of the lamb, type of birth, age of the dam, and ewe weight were significant sources of variation for lamb weights and daily gains on Bharat Merino (Dixit *et al.*, 2001). It was found that lamb sex has no significant effect on birth weight, weaning weight, and average daily gain from lambing to weaning, while litter size significantly increases in single borne lambs compared to twins (Miguel *et al.*, 2016).

We hypothesize that artificial suckling utilizing milk replacer will decrease Assaf lambs' newborn mortality rate. So that the objective of this study was to investigate the effects of the suckling method on lamb's performance and lamb's mortality rate. Besides that, to study the effects of litter size, dam parity, sex of lambs, dam weight, lamb mortality, and suckling method on total weight gain and the average daily gain of lambs. Also, the cost-effectiveness of feeding milk replacers to nursing lambs was investigated.

MATERIALS AND METHODS

The number of participating Assaf sheep was 300 ewes, and 430 newborn lambs of both sexes (males and females). The lambs were born naturally and left with their mothers. Directly after lambing, lambs were randomly distributed according to the suckling method into three groups. The first group (G1) was natural suckling, in which lambs suckled their mothers; the second group (G2) was completely fed milk replacer; and the third group (G3) was fed milk replacer four times per day (Table I). The lambs of G2 and G3 were separated from their dams immediately after lambing and placed in small wooden boxes heated by heaters, where they were given colostrum three times daily for three days. While the natural suckling lambs of G1 were kept with their dams for free suckling until weaning at 60 days of age. However, the artificial suckling group G2 was isolated from dams and fed milk replacer ad libitum until weaning at 40 days of age. Lambs of the G3 were separated from their mothers and taken away. Lambs were weighted on a digital scale at birth, 40 days, and 60 days. The weight of the lambs in the three groups is taken every three days until the daily weight gain is calculated for each lamb. It is good to mention that the percent of milk powder

to water was 165 g of milk to one litter of water.

The characteristics of lambs sucking naturally and artificially are given in Table I. Ewes were of parity 1, 2, and 3, and most of them had single lambs. The proportion of single lambs in groups 1, 2 and 3 was 59%, 62%, and 69%, respectively. As shown in Table I, the number of lambs born from parity 2 was greater than the number of lambs born from parity 1 and parity 3.

Table I. Number of ewes and lambs and characteristics of lambs suckling naturally and artificially.

	G1 (%)	G2 (%)	G3 (%)
No. of Ewes	30	22	26
No. of lambs	39 (100)	29 (100)	29 (100)
Single	23 (59)	18 (62)	20 (69)
Twins	16 (41)	11 (38)	9 (31)
Parity 1	3 (8)	4 (14)	3 (10)
Parity 2	25 (21)	14 (48)	21 (72)
Parity 3	11 (28)	11 (38)	5 (17)
Single parity 1	1 (3)	2 (7)	1 (3)
Single parity 2	17 (44)	9 (31)	16 (55)
Single parity 3	5 (13)	7 (24)	3 (10)
Twin parity 1	2 (5)	2 (7)	2 (7)
Twin parity 2	8 (21)	5 (17)	5 (17)
Twin parity 3	6 (15)	4 (14)	2 (7)

G1, natural sucking, in which lambs suckled their mothers; G2, lambs completely fed milk replacer; G3, lambs fed milk replacer from times per day.

Milk chemical analysis

Milk and milk replacer samples were taken weekly and stored for later analysis. Samples were analyzed for chemical composition (total solids, fat, protein, solids other than fat, lactose, and ash) as shown in Figure 1.

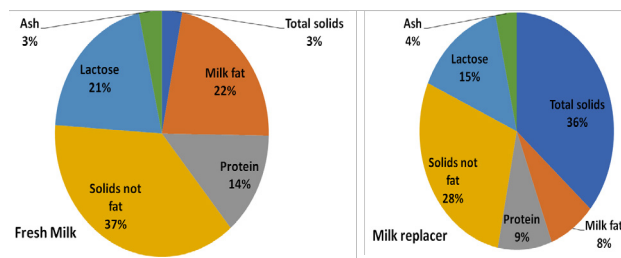


Fig. 1. Chemical composition of fresh milk and milk replacer.

Cost analysis

For the comparison between the three nursing systems,

the costs of nursing, the death of lambs, and operational expenses were calculated. The input parameters were number of lambs, milk consumption, mortality rate from lambing to weaning, total milk yield until 60 days (TMY60), and by group: lambs need 9.68–12.4 kg powdered milk or 80 kg fresh milk from lambing to weaning. Lambs lost, milk consumed, natural milk produced, fresh milk value, weaned lamb value, and powdered milk value are included into profit equation.

Statistical analysis

All traits were analyzed by a univariate general linear model (GLM procedure of SPSS) with explanatory variables as fixed effects. And the following model was used:

$$Y_{ijklm} = \mu + G_i + DW_j + LSk + Sex_l + PR_m + e_{ijklm}$$

Where Y_{ijklm} refers to the observation; μ , the population mean; G_i , the group effect ($i = G1, G2, G3$); DW_j , the effect of dam weight ($j = 50-60, 60-70$); LSk , the effect of litter size ($k = 1, 2$); Sex_l is the effect of lamb sex ($l = M, F$); PR_m is the effect of ewe parity ($m = 1, 2, 3$); and Y_{ijklm} is the random error normally distributed with a mean of 0 and variance s^2_e . Fixed effects for traits and number of records used in the model are in supplementary materials (Supplementary Table S1). The means of the variables analyzed were compared using estimated statistical mean differences (Bonferroni correction option of SPSS). Statistical differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Table II shows lamb performance under various suckling methods. The results of the study showed that the suckling method had no effect on weaning weight at ages of 40 and 60 days for single lambs (Table II). Weaning weights at 40 days were 13.7, 12.83, and 13 kg for lambs in groups 1, 2, and 3, respectively. Similar trends were observed with no significant effect in twin lambs, where average weaning weights were 18.42, 18.28 and 19.29 kg for lambs of G1, G2 and G3, respectively. Sezen and Soner (2013) found that the average daily gain for lambs with natural suckling was less than that for lambs with milk replacer, while the weaning weights for natural suckling lambs and milk replacer lambs at 42 days of age were 12.64 kg and 14.15 kg, respectively. Gootwine *et al.* (2008) reported that the average birth weight for Afec-Assaf was 4.5 kg, the average weaning weight was 14.7 kg at 35 days of age, and the average daily gain was 294 g for the artificial suckling on the milk replacer.

Lambs under different suckling methods had no significant differences of average daily gains (Table

II). Similar findings were reported in previous research (Makovický *et al.*, 2019) where in a trial that was conducted to evaluate the influence of non-genetic factors on lambs' growth during artificial suckling using milk replacer, three groups were introduced to artificial suckling, and the results on weaning weight did not show a significant difference, however, profitability increased from selling fresh milk (Makovický *et al.*, 2019).

Table II. Performance and mortality of lambs under different suckling methods, (kg).

Parameters	G 1*	G2	G3	P value
Weaning wt. singles- at 40 days	13.76	12.83	13	> 0.05
Weaning wt. singles- at 60 days	18.42	18.28	19.29	> 0.05
Weaning wt. twins- at 40 days	13.77	13.17	11.74	> 0.05
Weaning wt. twins- at 60 days	19.16	18.89	17.41	> 0.05
Weaning wt. at 40 days	13.88	13.35	12.98	> 0.05
Weaning wt. at 60 days	19.75	18.9	18.37	> 0.05
Total body gain, kg at 40 days	9.55	8.77	8.06	> 0.05
Total body gain, kg at 60 days	15.85	14.32	13.45	> 0.05
Daily gain, gram at 40 days	0.239	0.219	0.201	> 0.05
Daily gain, gram at 60 days	0.264	0.239	0.224	> 0.05

For details of groups, see Table I.

Table III. Mortality of lambs under different suckling methods, (kg).

Parameter	G 1*	G2	G3	P value
Mortality, %	18	7	3.5	0.85
Mortality, (number)	7	2	1	0.88
Mortality of singles	5	1	0	0.81
Mortality of twins	2	1	1	0.27
Number of live lambs at weaning	32	27	28	0.15

For details of groups, see Table I.

Mortality of lambs under different suckling methods

The fixed-effect factors of lamb's growth rate from lambing to weaning (GRL-W), mortality rate (MR) as determined by milk quality analysis are summarized (P values). There is no significant effect ($P > 0.05$) of solid fat,

solid non-fat, lactose, protein, and, total solids on GR, L-W, or MR. Only the P value percent of milk fat for MR was 0.06, which was close to 0.05. So, more studies are needed to evaluate the effect of milk composition on lambs' mortality rates. Table III show the mortality of lambs under different suckling methods. One of the biggest obstacles to small ruminant farming in Palestine is the high borne mortality rate, which causes high losses and affects profitability. According to a study conducted by the Ministry of Agriculture (MOA, 2013), the new-born mortality rate ranged from 9% to 24%, knowing that the normal rate should not exceed 5%. The main reason for this high mortality rate is bad management. In this experiment, the sucking method affected the rate of mortality. Mortality rates decreased from 18% in G1 to 7 and 3.5% in G2 and G3, respectively (Table II). Most of the dead lambs were single lambs.

Effect of dam weight

The effects of dam weight on lambs' weight, lambs' average daily gain, and lambs' mortality are shown in Table IV. Dam weight had no effect on average daily gain ($P < 0.05$). Similarly, Kuchtk and Dobe (2006) the majority of growth traits were influenced by dam body weight at birth ($P < 0.01$). Furthermore, it was found that ewe weight was a significant source of variation for lamb weights and daily gains on Bharat Merino (Dixit *et al.*, 2001). On the other hand, other studied traits were not affected ($P > 0.05$).

Effect of litter size

The effects of litter size on lambs' weight, lambs' average daily gain, and lambs' mortality are shown in Table IV. Litter size has no significant effect ($P \geq 0.05$) on total weight gain and average daily gain in lambs. Also, mortalities were not affected by these parameters (Table IV). In contrast, as reported by previous research, litter size significantly ($P < 0.05$) increases in single-born lambs compared to twins (Miguel *et al.*, 2016). Vatankhah and Talebi (2009) investigated the effect of type of birth (litter size) on lamb mortality rates and found similar results to ours in that type of birth affects the mortality rate and the lamb mortality rate was higher in twins.

Table IV. The effect of dam weight and litter size on lambs' weight, lambs average daily gain and lamb's mortality on lambs' weight, lambs average daily gain and lamb's mortality.

Trait	Dam weight (50-60kg)	Dam weight (60-70kg)	P values	Litter size 1	Litter size 2	P values
Weight at 40days (kg)	13.42	13	0.512	13.52	12.89	0.275
Weight at 60 days (Kg)	19.09	18.23	0.23	19.12	18.2	0.15
Average daily gain (g)	236	206	0.032	220	223	0.814
Mortality (%)	9.3	7.8	0.85	9.1	8	0.88

Table V. Effect of sex of lambs and ewes' parity on lambs' weight, lambs average daily gain and lamb's mortality.

Trait	Female	Male	P values	Parity 1	Parity 2	Parity 3	P values
Weight at 40 days (kg)	13.23	13.18	0.93	12.9	12.92	13.8	0.37
Weight at 60 days (Kg)	18.78	18.54	0.71	18.06	18.94	18.98	0.68
Average daily gain (g)	229	214	0.24	224	214	226	0.67
Mortality (%)	0.056	0.115	0.39	9	12.3	4.4	0.6

Effect of lamb sex

Table V show the effects of lamb sex on lamb weight, lamb average daily gain, and lamb mortality. The sex of lambs has no significant effect ($P \geq 0.05$) on total weight gain and average daily gain of lambs. Miguel *et al.*, (2016) reported that lamb sex has no significant effect ($P > 0.05$) on birth weight, weaning weight, and average daily gain from lambing to weaning. Vatankhah and Talebi (2009) reported similar results as in our study, where the effect of six lambs has no effect on lamb mortality rate. Furthermore, the sex of the lamb was discovered to be a significant source of variation for lamb weights and daily gains on Bharat Merino (Dixit *et al.*, 2001). The sex of the lamb was significantly ($P < 0.05$) associated with the lamb's birth weight and growth rate from lambing to weaning; the overall least-square means for birth, weaning, and growth rate were 2.18 kg, 10.58 kg, and 98.68 g, respectively (Al-Bial and Singh, 2012). According to Assan and Makuza (2005) sex had significant effects ($P < 0.001$) on weaning weight, and the average males' weights were heavier than females ($P < 0.001$) at weaning in the mutton merino, dropper. Also, single lambs were significantly heavier at weaning compared to twins. Gama *et al.*, (1991) reported that mortality rate for male lambs was higher than that for females, and the viability of lambs increased with prolificacy with lower birth weight.

Effect of ewes parity

The effects of ewes' parity on lambs' weight, lambs' average daily gain, and lambs' mortality are shown in Table V. Ewes' parity has no significant effect ($P \geq 0.05$) on total weight gain and average daily gain in lambs. Vatankhah and Talebi (2009) found similar results to ours when they investigated the effect of the dam's age (parity) on lamb mortality rate and discovered that the dam's age has no effect on lamb mortality rate. Some studies in temperate countries found that parity had an effect on lamb mortality, birth weight, weaning weight, and milk yield in different breeds (Mavrogenis, 1996; de la Fuente *et al.*, 1997; Franci *et al.*, 1999; Ploumi and Emmanouilidis, 1999; Sevi *et al.*, 2000).

Cost of feeding milk replacers and cost analysis

As shown in Table VI, it was found that significant

savings could be achieved by feeding milk replacer to nursing lambs. The cost of milk per lamb was reduced from US\$ 120 to about US\$ 40. The results using milk replacer did not show significant results on weaning weight, however, profitability increased from selling fresh milk. Similar results were reported by Makovický *et al.* (2019).

The net gain (USD) from using milk replacer was \$7073.7. Furthermore, artificial suckling using milk replacer reduces mortality from 19% to 5%. Also, the cost of weaned lamb for artificial and natural suckling was US\$ 48.4 and US\$ 108, respectively. It means that we can save US\$ 59.4 from milk for each lamb when we replace natural suckling with artificial suckling and reduce the lamb mortality rate by 14%. For the comparison between the three nursing systems, the costs of nursing, the death of lambs, and operational expenses were calculated. The input parameters were number of lambs, milk consumption, mortality rate from lambing to weaning, total milk yield until 60 days (TMY60), and by group: lambs need 9.68–12.4 kg powdered milk or 80 kg fresh milk from lambing to weaning. Lambs lost, milk consumed, natural milk produced, fresh milk value, weaned lamb value, and powdered milk value are included into profit equation. The mortality rate ranged from 0.2% to 6% in the groups that were reared in powdered milk and 0.19 in the group reared in fresh mother's milk. Natural milk costs US\$ 1.56/kg. Powdered milk costs US\$ 4.37/kg. Weaned lamb costs US\$ 312.5.

Table VI. Number of lambs, milk consumption, mortality rate from lambing to weaning, by group.

Group*	Milk consumed per lamb (Kg)	Cost/US\$	Weaning cost/US\$
G1	80	1.5	120
G2	9.70	4.24	40
G3	12.40	4.24	52.5

CONCLUSIONS

It was concluded that significant reduction will be achieved through feeding milk replacers to suckling

lambs. These saving is expected from the reduction in milk expenses and the significant reduction of mortalities. Suckling method had no effect ($P>0.05$) on weaning weight at age 40 days and 60 days of single lambs. Weaning weights at 40 days were 13.7, 12.83 and 13 kg for lambs in G1, G2 and G3, respectively. The rate of mortality was affected ($P < 0.05$) by suckling method. Mortality rate decreased from 18% in G1 to 7% and 3.5% in G2 and G3, respectively. Most of dead lambs were in single lambs. Litter size and suckling method had no effects ($P > 0.05$) on total weight gain and average daily gain of lambs. Also, mortalities were not affected by these parameters. Sex of lambs and suckling method had no effect ($P > 0.05$) on total weight gain and the average daily gain. Lambs total gain and average daily gain were not affected ($P>0.05$) by numbers of ewe's parity. It is recommended to adopt the practice of feeding milk replacers to suckling lambs. This practice, strengthening administrative matters and reduce pollution inside the farm, as indicated by this study, assure more return from sheep operations and then improves farms profitability through reducing feeding costs and the reduction of mortality.

ACKNOWLEDGEMENT

Authors acknowledge Animal Production Department and Faculty of Graduate Studies at An-Najah National University in Nablus City of Palestine for supported and help during period of the study. Authors are also thankful to Mr. Rami Sawlha for sampling animal in his farm and Eng. Moayed Salman for logistic and technical support.

Funding

The study have received no external funding.

IRB approval

Institutional Review Board of An-Najah National University, Nablus City, Palestine, Pakistan granted approval of this study (Graduate Studies Approval No.1, Dated: 12-1-2022).

Ethical statement

Animal handling during experimentation was according to the guidelines of Ethical Review Committee, An-Najah National University, Nablus City, Palestine.

Supplementary material

There is supplementary material associated with this article. Access the material online at: <https://dx.doi.org/10.17582/journal.pjz/20230408060410>

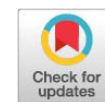
Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

- Agricultural Statistics, 2018/2019. *D.G planning and policies*, MoA. Ramallah, Palestine.
- Al-Bial and Singh, J., 2012. Factors effecting growth traits of Black Boni sheep. *Tamilnadu J. Vet. Anim. Sci.*, **8**: 194-198.
- Assan, N. and Makuza, S.M., 2005. The effect of non-genetic factors on birth weight and weaning weight in three sheep breeds of Zimbabwe. *Anim. Biosci.*, **18**: 151-157. <https://doi.org/10.5713/ajas.2005.151>
- Ayhan, C., Tamer, S. and İsmail, E., 2009. The estimation of variance components for prolificacy and growth traits of Sakız sheep. *Livest. Sci.*, **122**: 68-72. <https://doi.org/10.1016/j.livsci.2008.07.030>
- Chinnaiyan, S., 2019. The potential of small ruminant farming as a means of poverty alleviation in rural southern India. *Trop. Anim. Hlth. Prod.*, **51**: 303-311. <https://doi.org/10.1007/s11250-018-1686-4>
- De la Fuente, L.F., San Primitivo, F., Fuertes, J.A. and Gonzalo, C., 1997. Daily and between-milking variations and repeatability's in milk yield, somatic cell count, fat, and protein of dairy ewes. *Small Rumin. Res.*, **24**: 133-139. [https://doi.org/10.1016/S0921-4488\(96\)00927-3](https://doi.org/10.1016/S0921-4488(96)00927-3)
- Dixit, S.P., Dhillon, J.S. and Singh, G., 2001. Genetic and non-genetic parameter estimates for growth traits of Bharat Merino lambs. *Small Rumin. Res.*, **42**: 101-104. [https://doi.org/10.1016/S0921-4488\(01\)00231-0](https://doi.org/10.1016/S0921-4488(01)00231-0)
- El-Raghi, A.A. and Hashem, N.M., 2022. Maternal, postnatal, and management-related factors involved in daily weight gain and survivability of suckling zaraibi goat kids in Egypt. *Animals*, **12**: 2785. <https://doi.org/10.3390/ani12202785>
- Flinn, T., Kleemann, D.O., Swinbourne, A.M. Kelly, J.M., Weaver, A.C., Walker, S.K., Gatford, K.L., Kind, K.L. and van Wettere, WHEJ., 2020. Neonatal lamb mortality: major risk factors and the potential ameliorative role of melatonin. *J. Anim. Sci. Biotechnol.*, **11**: 107. <https://doi.org/10.1186/s40104-020-00510-w>
- Food and Agriculture Organization, 2018. *FAO Reports 2018*.
- Franci, O., Pugliese, C., Acciaioli, A., Parisi, G. and Lucifero, M., 1999. Application of two models to the lactation curve of Massese ewes. *Small Rumin. Res.*, **31**: 91-96. [https://doi.org/10.1016/S0921-4488\(98\)00130-8](https://doi.org/10.1016/S0921-4488(98)00130-8)

- Gama, L.T., Dickerson, G.E., Young, L.D. and Leymaster, K.A., 1991. Effects of breed, heterosis, age of dam, litter size, and birth weight on lamb mortality. *J. Anim. Sci.*, **69**: 2727-2743. <https://doi.org/10.2527/1991.6972727x>
- Gootwine, E., Reicher, S. and Rosov, A., 2008. Prolificacy and lamb survival at birth in Awassi and Assaf sheep carrying the FecB (Booroola) mutation. *Anim. Reprod. Sci.*, **108**: 402-411. <https://doi.org/10.1016/j.anireprosci.2007.09.009>
- Jesús, M., Víctor, M., José, L. Reyes-C., Miguel, M., Leticia, G. and Ma. de los Ángeles, De. 2015. Effects of non-genetic factors on pre-weaning growth traits in dorper sheep managed intensively in central Mexico. *Ecosist. Recur. Agropecuar.*, **3**: 229-235.
- Knight, T.W., Atkinsoy, Haack, D.S. and Palomar, C.R., 1992. Effects of suckling regime on lamb growth rates and milk yields of Dorset ewes. *N. Z. J. agric. Res.*, **36**: 215-222. <https://doi.org/10.1080/00288233.1993.10417756>
- Kolar, C.W. and Wagner, T.J., 1991. Alternative protein use in calf milk replacer. In: *New trends in veal calf production* (eds. J.H.M. Metz and C.M. Groenestein). Pudoc, Wageningen, pp. 211- 215.
- Kuchtik, J. and Dobes, I., 2006. Effect of some factors on growth of lambs from crossing between the Improved Wallachian and East Friesian. *Czech J. Anim. Sci.*, **51**: 54-60. <https://doi.org/10.17221/3909-CJAS>
- Makovický, P., Čopíková, M.G., Margetín, M. and Nagy, M., 2019. Growth intensity of lambs during artificial milk rearing depending on chosen non-genetic factors. *Iran. J. appl. Anim. Sci.*, **9**: 257-263.
- Mavrogenis, A.P., 1996. Environmental and genetic factors influencing milk and growth traits of Awassi sheep in Cyprus. Heterosis and maternal effects. *Small Rumin. Res.*, **20**: 59-65. [https://doi.org/10.1016/0921-4488\(95\)00782-2](https://doi.org/10.1016/0921-4488(95)00782-2)
- Miguel, M., Macías, U., Avendaño, L., Mellado, J. and García, J.E., 2016. *Growth and pre-weaning mortality of Katahdin lamb crosses*.
- Ministry of Agriculture- State of Palestine, 2013. *Lambs mortality reports*, 2013. Ramallah, Palestine.
- Ministry of Agriculture State of Palestine. *Livestock sector strategy 2015-2019*. Ramallah, Palestine.
- Ministry of Agriculture-State of Palestine, 2014. *Artificial insemination reports*, 2014. Ramallah, Palestine.
- Ministry of Agriculture-State of Palestine, 2019. *Palestinian center for livestock improvement reports*, 2019. Nablus, Palestine.
- MOA (Ministry of Agriculture) 2015. *Livestock Sector Strategy, State of Palestine 2015-2019*.
- MOA (Ministry of Agriculture) Ministry of Agriculture, State of Palestine. 2002. *MoA, reports*, 2002. Ramallah, Palestine.
- Ploumi, K. and Emmanouilidis, P., 1999. Lamb and milk production traits of Serrai sheep in Grece. *Small Rumin. Res.*, **33**: 289-292. [https://doi.org/10.1016/S0921-4488\(99\)00027-9](https://doi.org/10.1016/S0921-4488(99)00027-9)
- Sevi, A., Taibi, L., Albenzio, M., Muscio, A. and Annicchiarico, G., 2000. Effect of parity on milk yield, composition, somatic cell count, renneting parameters and bacteria counts of Comisana ewes. *Small Rumin. Res.*, **37**: 99-107. [https://doi.org/10.1016/S0921-4488\(99\)00133-9](https://doi.org/10.1016/S0921-4488(99)00133-9)
- Sezen, O. and Cankaya, S., 2013. A novel method of analyzing rearing system on lamb growth and farm profitability. *Afr. J. agric. Res.*, **8**: 495-499.
- Vatankhah, M. and Talebi, M.A., 2009. Genetic and non-genetic factors affecting mortality in Lori-Bakhtiari Lambs. *Asian-Aust. J. Anim. Sci.*, **22**: 459-464. <https://doi.org/10.5713/ajas.2009.80318>



Supplementary Material

Effect of Natural and Artificial Sucking on Performance and Mortality of Newborn Assaf Lambs

Wael Halawa¹, Raed M. Al-Atiyat^{2*}, Jamal Abo Omar¹, Faisal S. Rashaydeh³, Fath Ullah⁴, Shakirullah⁵ and Berkant Ismail Yildiz⁶

¹Animal Production, Faculty of Graduate Studies An-Najah National University, Nablus, Palestine

²Genetics and Biotechnology, Department of Animal Science, Mutah University, Karak, Jordan

³Department of Agricultural Biotechnology, Akdeniz University, 07058, Antalya, Türkiye

⁴Livestock and Dairy Development, FATA Secretariate, Warsak Road, Peshawar, Pakistan

⁵Department of Animal and Poultry Production, Faculty of Veterinary and Animal Sciences, Gomal Univeristy, Dera Ismal Khan, Pakistan

⁶Institute of Natural and Applied Sciences, Akdeniz University, Konyaaltı, 07058, Antalya, Turkey

Supplementary Table S1. Fixed factors included in growth rate from lambing to weaning (GRL-W), weight at 60 days of age (W. at 60d), Mortality rate (MR), growth rate from lambing to weaning for group 2 and group 3 (GRL-W for G2 and G3), growth rate from lambing to weaning for group 1 (GRL-W for G1), total milk yield at 60 days (TMY60).

Factor ¹	Number of records for each trait						
	GRL-W ²	W at 60d	MR	GRL-W for G2 and G3	GRL-W for G1	TMY60	
Dam weight	50-60 kg	62	63	70	42	20	37
	60-70 kg	23	23	26	12	11	11
	1	9	9	10	7	2	2
Parity	2	52	52	59	33	19	31
	3	24	25	27	14	10	15
Litter Size	1	54	54	60	36	18	32
	2	31	32	36	18	13	16
Lamb Sex	F	42	43	47	23	19	
	M	43	43	49	31	12	
Suckling	A1	26	27	29			12
Method	A2	28	28	28			14
	N	31	31	39			22
Powder Milk	9.68				28		
consumed (kg)	12.40				26		
Natural milk	70-79					13	
consumed to weaning (kg)	80-91					18	

* Corresponding author: ratiyat@mutah.edu.jo
0030-9923/2023/0001-0001 \$ 9.00/0



Copyright 2023 by the authors. Licensee Zoological Society of Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

¹F, Female; M, Male; G2, artificial suckling 24 h; G3, artificial suckling 4 times per day; G1, natural suckling. ²GRL-W, growth rate from lambing to weaning; W at 60d, weight at 60 days of age; MR, mortality rate; TMY, total milk yield at 60 days.