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EFFECT OF FENCE-LINE WEANING ON EGYPTIAN BUFFALOES' MILK PRODUCTION AND GROWTH PERFORMANCE OF THEIR CALVES

Tamer Mohamed M. HASSAN[1]*, Mayada S. H. MAHMOUD[2], A. S. M. SOLIMAN[1], M. R. EL-MAHDY[1], Hoda Z. HASSAN[2]

[1]Animal Production Department, Faculty of Agriculture, Benha University, Egypt
[2]Buffaloes Breeding Research Department, Animal Production Research Institute, Dokki, Giza, Egypt

ABSTRACT

The objective of the current study was to reduce the stress associated with weaning process for a mother and its weaned calf by increasing the productive performance of the mother and reproductive performance (early return to estrous and conception), increasing the growth rate and some body measurements of calves post-weaning, as well as improving the immunological responses of both mother and calf. Egyptian buffaloes and their calves used in this study (n = 40) were divided into two weaning system groups: 20 buffaloes in fence-line and 20 buffaloes in traditional weaning system. Buffaloes and their calves were placed on opposite sides of strong fence. They had nose-to-nose contact; fence-line visits gradually decreased after the first three days. Milk production and its components were measured. Blood samples were taken for analyzing weekly after calving until 8th week. As a result, regression coefficients of the equation of Wood lactation curve showed that weaning system had different ($P < 0.001$) *a*, *b* and *c* parameters. Buffaloes with fence-line weaning had the highest ($P < 0.001$) milk production and milk component values during 8 months of lactation. Fence-line weaning calves had superior ($P < 0.001$) performance than traditional weaning calves. Immunoglobulin content (immunity) was increased in buffaloes and their calves weaned using the fence-line system. Calves' sex and dams parity effects showed the normal expression. In conclusion, the fence-line system can provide to gain more milk yield, calf growth performance and immunity, and therefore, we recommend this system for buffalo's producers.

Key words: fence-line; milk; calve performance; immune response; Egyptian buffaloes

INTRODUCTION

Weaning time can be stressful for dams and their calves. Under traditional weaning systems, changes in environment, diet composition and pathogen exposure can reduce performance of animals and cause health problems. In response to these challenges, interest in the fence-line weaning has grown in recent years. Fence-line weaning is a management system in which the calves are removed from their dams but are allowed to see, hear and smell their dams. Depending on the fencing used, physical contact may also be possible. It has the potential to reduce stress related to transport, changes in environment and diet adaptation. Fence-line weaning may also reduce labor demands and costs associated with dry lot facilities (Price *et al*., 2003). Preconditioning is implemented around weaning time and is designed to enhance immune system function while minimizing stress (Lalman *et al*., 2002). At two weeks of age, the calf should be introduced to good quality green feed and concentrates formulated to meet the requirements of calves, as a calf starter. This stimulates the rumen

***Correspondence:** E-mail: tamer.mohamed@fagr.bu.edu.eg
T.M.M. Hassan, Animal Production Department, Faculty of Agriculture, Benha University, Egypt

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to grow and function properly. However, the larger period that the calf has an access to the large supply of milk, the less period will be its urge to supplement its diet with other foods; whole milk should be provided to the calf until 15 days of age at a level of 1/10th of the calf's body weight (Salama *et al*., 1989). After feeding the milk, calves are offered a dry calf starter and good quality hay simultaneously from the second week of age.

The objectives of the current study were to reduce the stress associated with weaning process for buffaloes and its weaned calves by increasing milk production of the dams and enhancing the growth performance of calves post-weaning, as well as improving the immunological responses of all experimental animals.

MATERIAL AND METHODS

The present study was carried out at the experimental farm of El Nataf El Kadem in Kafer El-Sheikh Governorate, Buffalo Breeding Research Department, Animal Production Research Institute, Agriculture Research Center, Ministry of Agriculture, Egypt. The field experiment lasted from November 2015 to April 2016. Samples of milk and blood were analyzed at the Buffalo breeding Research Department, Animal Production Research Institute.

Experimental design

Forty native lactating buffalo cows randomly taken after parturition were used in this study. Buffalo dams were balanced in parity and in the quota of nutrition, under the same veterinarian control and were without reproductive diseases.

The experimental animals were divided into two groups: the first groups was fence-line weaning buffalo cows and their newborn and the second was the separated weaning calves which stayed after parturition with their mothers and took colostrum through the first three days after birth; then they were separated from their mothers.

Weaning strategies

Usually, the calves were weighed immediately after birth and every week until weaning at 3.5 months of age. After weaning, the calves were weighed monthly for 3 months (until 5-6 months of age).

Traditional weaning

Buffalo-cows were kept together with its calf in the same place where their calves will stay. Then buffalo-cows were removed to a new location out of the vision and sound of their calves, but the calves were left in familiar surroundings.

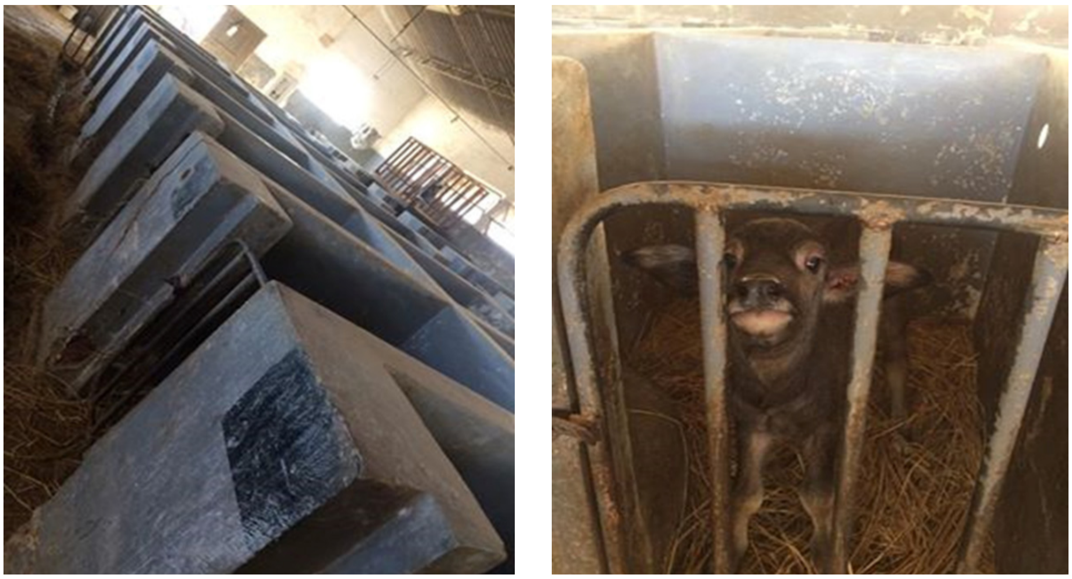

Figure 1. Traditional weaning system

Fence-line weaning system

The current study describes the progressive weaning system (fence-line), as well as the growth rate of calves during weaning and post-weaning phase (6 months) compared to the traditional weaning system. There are many ways to wean calves, but not all methods used are created equally. Traditional calf weaning models can cause high stress in calves and later lead to the reduced appetite, loss weight and suppressed the immunity. Fence-line weaning offers an effective strategy to reduce stress and side effects that come with it during this critical time with fence-line weaning, calves and cows are kept in the same barn. They are separated by a barrier but they can hear and see each other.

Calf feeding system

Calves were artificially fed whole buffalo milk twice a day till weaning age, according to the schedule shown in Table (1). Calves were weaned when their consumption of dry matter from roughage and calf starter per head reached 2 % of birth weight according to Salama and Mohy-El Deen (1996).

At the second week of age clover hay and calf starter were offered *ad libitum*, with clean water and salt lick block until weaning age. Calf starter was composed of 25 % corticated cottonseed meal, 20 % yellow corn, 26 % wheat bran, 15 % linseed meal, 4 % rice bran, 7 % molasses, 2 % limestone and 1 % common salt. Chemical composition of buffalo milk, clover hay and calf starter is shown in Table (2).

The experimental ratios used after weaning were formulated from Concentrate Feed Mixture, CFM (as the concentrate part of the ratios, 75 % of Total Digestible Nutrients, TDN), clover hay (12.5 % of TDN) and rice straw (12.5 % of TDN). The chemical composition of feed stuffs used for formulating the experimental ratios presented after weaning are shown in Table (3). Animals were fed to concentrate feed mixture, clover and rice straw according to NRC (1985) recommendations for the requirements of growing calves.

CFM (concentrate feed mixture) consisted of undecorated cotton seed cake (20 %), linseed cake (15 %), wheat bran (12 %), yellow corn (30 %), rice bran (16 %), limestone (2 %), molasses (3 %), salt (1 %) and vitamins A, D, E (1 %).

Calf diets were weighed and offered to the animals twice daily at 8:00 am and at 4:00 pm with allowance of 15 % refusal in equal quantities for each group. Both of the consumed diets and

Figure 2. Fence-line weaning system

Table 1. Feeding system (amount of buffaloes milk, kg/day/calf)

Item	Calf age (weeks)													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Morning	2.3	2.7	2.7	2.7	2.3	2.3	1.8	1.8	2.7	2.3	1.8	1.4	1.3	0.85
Evening	2.3	2.3	2.7	2.3	2.3	1.8	1.8	1.4	_	_	_	_	_	_

Table 2. Chemical composition of buffalo milk, clover hay and calf starter

Item	Buffalo milk	Clover hay	Calf starter
Moisture	84.90	9.71	11.07
Dry matter	15.05	88.94	90.66
Crude protein	25.52	12.30	18.60
Crude fiber	-	28.50	3.25
Ether extract	43.17	2.70	2.93
NFE	25.41	44.00	68.68
Ash	5.90	12.50	6.54

Table 3. Chemical composition of the concentrate feed mixture, clover hay and rice straw (on Dry Matter, DM basis)

Feedstuffs	DM	On DM basis (%)					
		OM	CP	CF	EE	Ash	NFE
CFM	93.94	89.94	14.45	13.34	2.98	10.06	59.17
Clover	91.09	88.45	14.29	28.89	1.62	11.55	43.65
Rice straw	90.56	81.60	2.42	36.76	1.38	17.40	42.04

refusals, if any, were recorded daily. Clean and fresh water with salt lick were also offered *ad libitum*. All calves were weighed individually to the nearest kg in the morning before feeding throughout the experimental period (from birth to six months of age). Birth, weaning age (at 3.5 months of age) and six month body weight were recorded. Average daily weight gain, total feed intake, feed conversion ratio and economical feed efficiency were then calculated by following equation: Feed conversion = total feed intake / body weight gain, kg.

Economical feed efficiency = benefit of body weight gain, $ / cost of feed consumed, $. The date were based on the prices of calves and feed ingredients in the market during the experimental period.

Buffaloes' diet

Dam buffaloes were feeding Egyptian clover (*Trifolium alexandrium*), when available, in addition to rice straw and different amounts of integrated concentrate feed mixtures (48 % decorticated cotton seed cake, 21 % wheat bran, 20 % maize, 5 % rice polish, 3 % molasses, 2 % limestone and 1 % sodium chloride) according to the norms established by the Animal Production Research Institute.

In the summer, Egyptian clover (*Trifolium alexandrium*) was replaced with a silage. Amounts of rations given to the animals were determined according to animal body weight and its level of milk production. The ration was offered twice daily. Buffaloes were feeding individually, according to Animal Production Research Institute norms (APRL, 1997).

Milk sampling and analysis

Approximately 20 ml of milk samples were pre-warmed at 40 °C in water bath and thoroughly mixed in clean glass beaker. Milk analysis was carried out for total solids, fat, proteins, lactose, and non-fat solids using Milk-Scan kit (Lactostar™, Funk Gerber, Germany) at the Dairy Services Unit, Animal Production Research Institute, Sakha, Kafr El-Sheikh Governorate.

Blood samples and analysis

Blood samples were collected in heparinized test tubes, after collection the blood samples were centrifuged at 4000 rpm for 15 minutes. The clear plasma was then aspirated and stored at -20 C˚, until assay for blood immunoglobulin. The single radial immune diffusion technique was used to quantify total immunoglobulin IgG in blood plasma (Bind ARIDtm Binding site limited, Birmingham, UK) according to the method described by Fahey and McKelvey (1965). The method of IgG quantification involves antigen diffusing radially from cylindrical well through an agarose gel containing an appropriate non-specific antibody. Antigen antibody complexes are formed as a precipitation ring. The ring size increases until an equilibrium. There is a linear relationship between the ring diameter and antigen concentration using (IgG) liquicolor® Kit (traceable to ERM470 (CRM470) from BEN-biochemical Enterprise (Milano, Italy).

Estimating the curve parameters of milk production

In this work, the shape of the curve parameters of milk production of Egyptian buffaloes was studied using the gamma type function (Wood, 1967), which was described as sufficiently good for modeling extended lactations (Abdel-Salam *et al*., 2011). The following gamma-type function was used for describing the lactation curve of all parameters: $Y_n = an^b e^{-cn}$

The constants a, b and c were calculated by using a general linear model (GLM) procedure of SAS software (SAS, 2004); where Y_n – is the test-day milk (kg), in the n^{th} month of lactation, *a* – is the initial yield, *b* – describes the rate of production increase up to the peak during the ascending phase, *c* – describes the rate of yield decrease during the descending phase, and *e* – is a base of natural logarithms. The NLIN procedure of SAS software was used for fitting the gamma type function according to Wood (1967).

Statistical Analysis

Buffalo milk components

Statistical analysis of data was carried out applying the SAS package (2008), according to the following model:

$$Y_{ijkl} = \mu + X_i + M_j + Sex_k + P_L + (XWSP)_{ijkL} + B(X)_{ijkL} + E_{ijkLm}$$

Where:

Y_{ijkl} – is the dependent variable (studied traits; fat, protein, lactose, total solid and solides not fat) of the m^{th} record on the L^{th} parity, k^{th} calf sex, j^{th} test day and i^{th} fence-line and traditional weaning;

μ – the overall mean of studied trait;

X_i – the effect of the i^{th} fence-line and traditional weaning, i = 1 and 2;

M_j – the effect of the j^{th} month of lactation, j = 1, … and 8;

S_k – the effect of the k^{th} calf sex, k = 1 and 2;

P_L – the effect of the L^{th} parity, L = 1, 2 and 4;

$b_{y/x}$ – the regression coefficient of the studied trait on dam birth weight;

$(XWSexP)_{ijkL}$ X_i – the effect of the fence-line and traditional weaning;

TD_j – the effect of the test day;

S_k – the effect of the calf sex;

P_L – the effect of the parity;

E_{ijklm} – random error assumed N.I.D. (0, $\sigma^2 e$).

Differences among means were checked according to Duncan (1955).

Calf performance

Statistical analysis of data was carried out applying the SAS package (2008), according to the following model:

$$Y_{ijkl} = \mu + X_i + W_j + S_k + P_L + (XWSP)_{ijkL} + B(X)_{ijkL} + E_{ijkLm}$$

Where:

Y_{ijkl} – is the dependent variable (studied traits) of the m^{th} record on the lth parity, k^{th} sex, j^{th} sampling week and i^{th} fence-line and traditional weaning;

μ – the overall mean of studied trait;
X_i – the effect of the i[th] fence-line and traditional weaning, i = 1 and 2;
W_j – the effect of the j[th] sampling week, j = 1[st], … and 8[th];
S_k – the effect of the k[th] calf sex, k = 1 and 2;
P_L – the effect of the l[th] parity, L = 1[st], 2[nd] and 4[th];
$b_{y/x}$ – the regression coefficient of the studied trait on birth weight;
$(XWSexP)_{ijkL}$ X_i – the effect of the fence-line and traditional weaning;
W_j – the effect of the sampling week;
S_k – the effect of the calf sex;
P_L – the effect of the parity;
E_{ijklm} – random error assumed N.I.D. (0, σ^2e).

Differences among means were checked according to Duncan (1955).

RESULTS

Lactation curve

Regression coefficients of the equation of lactation curve (Wood, 1967) showed that weaning system had different (P < 0.001) *a*, *b* and *c* parameters. Buffaloes with fence-line weaning had the highest (P < 0.001) milk production during 8 months of lactation (Table 4). Figure 3 shows the lactation curve of Egyptian buffaloes according to weaning system (fence-line and traditional weaning system).

Milk components

Buffaloes that weaned their calves by fence-line weaning system tended to have the highest milk components (fat, lactose, total solids and solids-not-fat) than that weaned their calves by traditional weaning system. The differences between means of buffaloes milk components due to weaning system effect were highly significant (P < 0.001). Buffaloes milk fat and total solids during the eighth month of lactation were higher and significant (P < 0.001) than other months of lactation. It could be seen that second, seventh and eighth parities of buffaloes had a higher (P < 0.01) milk fat (9.15 %) than buffaloes at first (8.69 %) and second (8.04 %) parities. Buffaloes that born male calves had a higher (P < 0.01) milk protein and solids-not-fat (4.15 and 10.03 %, respectively) than those born female calves (3.82 and 9.81 %, respectively), as shown in Table 5.

Calf growth performance

It could be seen from Table 6 that the differences between means of buffalo calf body weight at weaning and sixth month of age, due to weaning system effect, were highly significant (P < 0.001), but there is no significant effect for calf birth weight. Calves that weaned by fence-line weaning system had a higher body weight at weaning (3.5 months of age) and sixth month of age (109.31 and 155.47 kg, respectively) than that weaned by traditional weaning system (99.23 and 143.56 kg, respectively). Male calves had almost heavier body weight at birth, weaning and sixth month of age (34.73, 104.69 and 150.06 kg, respectively) than female calves (34.59, 104.28 and 149.38 kg, respectively). Calves from fourth or more parities had a heavier (P < 0.01) body weight at birth, weaning and sixth month of age (35.44, 110.04 and 155.44 kg, respectively) than calves from second

Table 4. Regression coefficient of the equation of Wood lactation curve by buffaloes calves weaning system

Item	*a* (kg)	*b*	*c*
Weaning system			
Fence-line weaning	5.2[a]	0.58	-0.25
Traditional weaning	4.7[b]	0.43	-0.21

Means within a column with different letters differ (P < 0.05); *a* – is the associated parameters with the initial milk production; *b* – is the associated parameter with the rise in milk production to peak lactation; *c* – is the associated parameter with the decrease in milk production from the peak to the end of lactation.

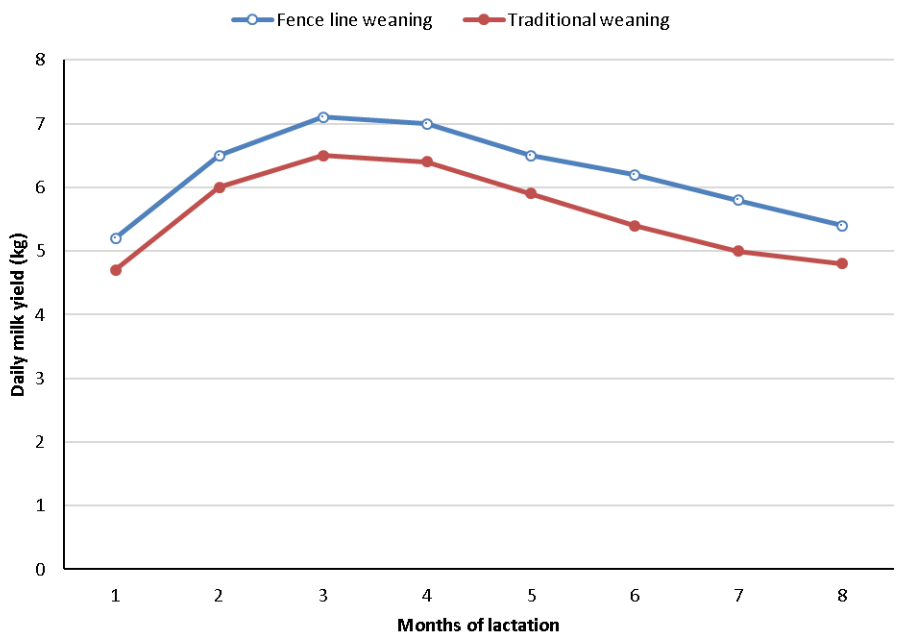

Figure 3. Lactation curve of Egyptian buffaloes according to weaning system

Table 5. Least-squares means and standard errors (LSM ± SE) of buffalo milk components (%)

Classification	N	Fat	Protein	Lactose	Total solids	Solids-not- fat
Weaning system						
Fence-line	122	8.93 ± 0.32	3.712 ± 0.07[b]	5.762 ± 0.05[a]	19.15± 0.33[a]	10.21± 0.09[a]
Traditional weaning	130	8.65 ± 0.20	4.257 ± 0.04[a]	4.538 ± 0.03[b]	18.27 ± 0.2[b]	9.61 ± 0.06[b]
Month of lactation						
First	40	8.01 ± 0.29[b]	4.01 ± 0.06	5.09 ± 0.05	17.92 ± 0.30[c]	9.89 ± 0.09
Second	40	9.51 ± 0.29[a]	3.97 ± 0.06	5.18 ± 0.05	19.47 ± 0.30[a]	9.95 ± 0.08
Third	40	8.15 ± 0.29[b]	4.05 ± 0.06	5.08 ± 0.05	18.07 ± 0.30[b]	9.91 ± 0.08
Fourth	36	8.51 ± 0.31[b]	4.00 ± 0.07	5.16 ± 0.05	18.47 ± 0.32[b]	9.96 ± 0.09
Fifth	36	7.99 ± 0.31[c]	3.94 ± 0.07	5.03 ± 0.05	17.76 ± 0.32[c]	9.76 ± 0.09
Sixth	28	8.53 ± 0.49[b]	4.06 ± 0.11	5.23 ± 0.08	18.57 ± 0.51[b]	10.04 ± 0.15
Seventh	18	9.17 ± 0.56[a]	3.93 ± 0.12	5.08 ± 0.09	18.96 ± 0.58[b]	9.79 ± 0.17
Eighth	14	9.10 ± 0.81[a]	3.90 ± 0.18	5.34 ± 0.14	19.13 ± 0.83[a]	10.03 ± 0.25
Parity number						
First	100	8.69 ± 0.22[b]	4.11 ± 0.05[a]	5.11 ± 0.04	18.76 ± 0.23	10.07 ± 0.07[a]
Second	52	8.04 ± 0.39[a]	4.12 ± 0.09[a]	5.14 ± 0.07	18.04 ± 0.41	10.01 ± 0.12[a]
Fourth or more	100	9.15 ± 0.29[a]	3.73 ± 0.06[b]	5.19 ± 0.05	18.83 ± 0.31	9.68 ± 0.09[b]
Sex of calf						
Male	152	8.59 ± 0.22	4.15 ± 0.05[a]	5.08 ± 0.04[b]	18.63 ± 0.23	10.03 ± 0.07[a]
Female	100	8.65 ± 0.27	3.82 ± 0.05[b]	5.22 ± 0.05[a]	18.46 ± 0.27	9.81 ± 0.08[b]

[a, b, c] Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of milk samples

parity (35.08, 102.09 and 147.37 kg, respectively) and calves from first parity (33.44, 101.34 and 146.36 kg, respectively).

Calves that weaned by a fence-line system had a higher average daily gain from birth to 6 months of age than by using traditional weaning system (670.71 vs 607.50 grams). The differences between means of calf's average daily gain from birth to 6 months of age due to weaning system effect were highly significant ($P < 0.001$). Male calves exceeded female calves in average daily gain from weaning to 6 months of age (650.00 vs. 600.00 grams). Calves from fourth or more parities had a higher ($P < 0.001$) average daily gain than calves from second and first parity (670 and 620 grams, respectively), as presented in Table 7.

Calves that weaned by the fence-line system had a higher, but not significant, total feed intake from birth to 6 months of age than by the traditional weaning system (539.78 vs. 520.57 kg), except for total feed intake from birth to weaning ($P < 0.001$). Total feed intake was higher for male calves than for females

Table 6. Least-squares means and standard errors (LSM ± SE) of buffalo calf body weight (kg)

Classification	N	Birth weight	Weaning weight	Six months weight
Weaning system				
Fence-line	20	34.76 ± 0.53	109.31 ±1.39[a]	155.47 ± 1.46[a]
Traditional	20	34.56 ± 0.39	99.23 ± 1.04[b]	143.56 ± 1.09[b]
Calf sex				
Male	24	34.73 ± 0.36	104.69 ± 0.96	150.06 ± 1.01
Female	16	34.59 ± 0.53	104.28 ± 1.42	149.38 ± 1.49
Parity number				
First	14	33.48 ± 0.45[b]	101.34 ± 1.17[b]	146.36 ± 1.23[b]
Second	10	35.08 ± 0.53[a]	102.09 ± 1.39[b]	147.37 ± 1.46[b]
Fourth and more	16	35.44 ± 0.55[a]	110.04 ± 1.45[a]	155.44 ± 1.53[a]

[a, b] Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of calves

Table 7. Least-squares means and standard errors (LSM ± SE) of buffalo calf average daily gain (grams)

Classification	N	Birth to weaning	Weaning to six months	Birth to six months
Weaning system				
Fence-line	20	710.00 ± 12.60[a]	615.00 ± 1.00[a]	670.61 ± 7.00[a]
Traditional	20	620.00 ± 9.00[b]	591.00 ± 1.00[b]	607.50 ± 5.00[b]
Calf sex				
Male	24	670.00 ± 8.00	650.00 ± 0.87[a]	640.00 ± 4.00
Female	16	660.00 ± 12.00	600.00 ± 1.00[b]	640.00 ± 5.00
Parity number				
First	14	650.00 ± 7.00[b]	600.00 ± 1.00[b]	620.00 ± 5.00[b]
Second	10	640.00 ± 8.00[b]	610.00 ± 1.00[a]	620.00 ± 5.00[b]
Fourth and more	16	710.00 ± 9.00[a]	610.00 ± 1.00[a]	670.00 ± 6.00[a]

[a, b] Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of calves

(547.55 vs 536.45). Calves from four and more parities had a higher total feed intake than calves from second and first parities (546.21, 540.23 and 531.44 kg, respectively), as shown in Table 8.

Calves that weaned by the fence-line system had an optimum feed conversion ratio from birth to 6 months of age than weaned by the traditional weaning system (4.47 vs. 4.76). The differences between means of buffalo calves feed conversion ratio, due to weaning system effect, were significant ($P < 0.05$), except for feed conversion ratio from birth to 3.5 months of age. Male and female calves had nearly the same feed conversion ratio from birth to 6 months of age (4.74 vs. 4.67). Calves from different parities had the same feed conversion ratio (4.73, 4.78 and 4.55, for second, third and fourth or more parity, respectively), as presented in Table 9.

Calves that weaned by the fence-line system had almost the same economical feed efficiency of calves that weaned by traditional weaning system (1.35 vs. 1.24). The differences between means of calves' economical feed efficiency due to weaning

Table 8. Least-squares means and standard errors (LSM ± SE) of buffalo calf total dry matter feed intake (kg)

Classification	N	Birth to weaning	Weaning to six months	Birth to six months
Weaning system				
Fence-line	20	268.68 ± 0.15[a]	270.80 ± 1.11	539.78 ± 1.01[a]
Traditional	20	246.82 ± 0.11[b]	273.75 ± 0.82	520.57 ± 0.74[b]
Calf sex				
Male	24	276.37 ± 0.11	271.18 ± 0.77	547.65 ± 0.69
Female	16	266.93 ± 0.16	269.52 ± 1.13	536.55 ± 1.01
Parity number				
First	14	266.21 ± 0.14[c]	265.23 ± 0.99	531.44 ± 0.89[b]
Second	10	269.21 ± 0.16[b]	270.86 ± 1.14	540.23 ± 1.03[ab]
Fourth and more	16	273.15 ± 0.17[a]	273.95 ± 1.23	546.21 ± 1.11[a]

[a, b] Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of calves

Table 9. Least-squares means and standard errors (LSM ± SE) of buffalo calf feed conversion ratio (feed intake / weight gain)

Classification	N	Birth to weaning	Weaning to six months	Birth to six months
Weaning system				
Fence-line	20	3.61 ± 0.11	5.87 ± 0.01[b]	4.47 ± 0.02[b]
Traditional	20	3.79 ± 0.09	6.18 ± 0.008[a]	4.76 ± 0.02[a]
Calf sex				
Male	24	3.95 ± 0.08	5.98 ± 0.008	4.74 ± 0.01
Female	16	3.83 ± 0.12	5.97 ± 0.012	4.67 ± 0.02
Parity number				
First	14	3.92 ± 0.104	5.90 ± 0.011	4.73 ± 0.025
Second	10	4.02 ± 0.120	5.98 ± 0.012	4.78 ± 0.08
Fourth and more	16	3.65 ± 0.129	6.03 ± 0.013	4.55 ± 0.031

[a, b] Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of calves

system effect were significant ($P < 0.05$), except from birth to 3.5 months of age. The differences between means of calves economical feed efficiency due to sex and parity effects were not significant, as presented in Table 10.

Immune response of buffaloes and their calves

Buffalo dams that weaned their calves by the fence-line system had a stronger immunity than those weaned their calves by traditional weaning system. The differences between means of buffalo dams' immunoglobulin, due to weaning system

Table 10. Least-squares means and standard errors (LSM ± SE) of economical feed efficiency (benefit of weight gain, $ / cost of feed consumed, $)

Classification	N	Birth to weaning	Weaning to six months	Birth to six months
Weaning system				
Fence-line	20	1.07 ± 1.77	2.55 ± 0.31^{a}	1.35 ± 0.42^{a}
Traditional	20	0.96 ± 1.31	2.42 ± 0.12^{b}	1.24 ± 0.31^{b}

$^{a, b}$ Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of calves

Table 11. Least-squares means and standard errors (LSM ± SE) of dams and calves' immunoglobulin (IgG) concentration

Classification	N	Dams	Calves
Weaning system			
Fence-line	160	588.51 ± 5.76^{a}	522.91 ± 3.59^{a}
Traditional	160	435.28 ± 4.74^{b}	451.32 ± 3.76^{b}
Sampling time			
First week postpartum	40	520.41 ± 8.37^{ab}	473.69 ± 7.74^{b}
Second week postpartum	40	512.38 ± 8.37^{ab}	482.66 ± 7.74^{b}
Third week postpartum	40	531.66 ± 8.37^{a}	475.11 ± 7.74^{b}
Fourth week postpartum	40	515.04 ± 8.37^{ab}	490.14 ± 7.74^{ab}
Fifth week postpartum	40	510.66 ± 8.37^{ab}	496.26 ± 7.74^{ab}
Sixth week postpartum	40	497.04 ± 8.37^{b}	510.21 ± 7.74^{a}
Seventh week postpartum	40	498.26 ± 8.37^{b}	509.79 ± 7.74^{a}
Eighth week postpartum	40	509.71 ± 8.37^{b}	487.75 ± 7.74^{b}
Parity number			
First	112	517.56 ± 4.89	488.69 ± 2.89
Second	80	508.85 ± 7.06	490.54 ± 5.54
Fourth and more	128	509.27 ± 6.49	482.11 ± 4.36
Sex of calf			
Male	192	510.78 ± 4.02	488.10 ± 2.32
Female	128	513.01 ± 5.92	486.13 ± 3.71

$^{a, b}$ Means within any classification, followed by different letters are significantly different ($P < 0.05$)
N – number of calves

effect were highly significant (P < 0.001). Calves that weaned by the fence-line system had stronger (P < 0.001) immunity defense mechanism than those weaned by traditional weaning system. The differences in mean values of immunoglobulin between dams and calves, due to sampling time effect were significant (P < 0.001). Third week postpartum showed higher level of dam's immunoglobulin than other weeks postpartum, while sixth and seventh weeks postpartum showed higher levels of calf's immunoglobulin. The differences between means of buffalo's immunoglobulin, due to parity and sex of calf, were not significant, as shown in Table 11.

DISCUSSION

Lactation curve

Lactation curve shows that fence-line weaning system was better in in Egyptian buffalo milk production than traditional weaning system. Many investigators obtained similar results. In particular, Tonhati *et al*. (2008) have found that milk yield in dairy buffaloes, mainly during the first six months of lactation, could be adopted as a selection criterion to increase total milk yield. Ibrahim (2012) analyzed lactation curve of Egyptian buffaloes and has found that increasing enrollment period increases daily milk yield and total milk yield, according to the regression line. Also, Kisac *et al*. (2011) stated that stay of calves with their dams within 21 days after birth is not recommended for high-yielding dairy cows.

Milk components

Fence-line weaning had a significantly (P < 0.01) positive effect on milk components (fat, protein and lactose), as observed by Bampidis *et al*. (2012) on Greek buffaloes. Similarly, Kisac *et al*. (2011) observed that the weaning of calves from mother at different ages significantly affected (P < 0.05) milk composition (fat, protein, lactose and total solids). Gajbhiye *et al*. (2019) found that stage of lactation and parity number had a significant effect on Gir cow's milk fat (P < 0.05). Third parity cows of Sheko cattle in Ethiopia had the higher (P < 0.01) milk components than the cows of other parities (Bayou *et al*., 2015).

Growth performance of calves

The superiority of fence-line weaned calves in body weight could be due to decreasing of stress factors, which reflected in a better health and increase in the solid feed consumption compared to the traditionally weaned calves. These results agree with those reported by Kisac *et al*. (2011), who concluded that the calves reared with their mothers for a longer time reached higher live weight at weaning and at the age of 90 days. It is so, because native milk suits the animals and calves receive it according to their needs. Brown (2013) stated that fence-line weaning can decrease the stress and increase the performance in growing calves. Baily *et al*. (2016) observed that growing calf performance during the feedlot receiving period was improved by pasture weaning in combination with fence-line contact with dams compared to a dry lot weaning plus dam separation. Kumar *et al*. (2017) observed that average birth weight of Murrah Buffalo did not differ significantly (P > 0.05) for weaned and suckled calf groups. However, average body weight at 90 days of age was significantly (P < 0.05) higher in the suckled group (122.77 kg) compared to those in the weaned group (113.12 kg) calves. Also, Yilmaz *et al*. (2013) found that male calves had heavier body weight at birth than the average of female ones (40.541 vs. 38.375 kg). Parity number of dam had a significant (P < 0.01) effect on calves' body weight at birth, weaning and sixth month of age (Bayou *et al*., 2015). Fence-line weaning enhanced average daily weight gain in calves. The present results agree with the finding of Price *et al*. (2003), who observed an increase in average daily gain of Angus cattle calves, which had been weaned by fence-line system, compared to calves being completely separated from their dams. Kisac *et al*. (2011) reported that average daily gain is affected (P < 0.01) by weaning the calves from mother at different ages (7, 14 and 21 days); the third group had the optimum average daily gain from birth to 90 days of age (550, 660 and 740 grams, respectively). Brown (2013) concluded that fence-line weaning system can cause an increase in calf performance compared to other traditional weaning systems. Bailey *et al*. (2016) have found that calves with fence-line weaning had the highest average daily gain than those with a dry lot weaning.

Immune response of buffaloes and their calves

The superiority of fence-line weaned dams and calves in immune response could be due to decreasing of stress factors which, which was reflected in a better health and increasing performance of its calves compared to the traditionally weaned calves (Brown, 2013). Also, Coleman *et al*. (2015) concluded that immunoglobulin (IgG) can be used as a predictor for early growth and high milk production in dairy cattle.

CONCLUSION

Fence-line weaning reduces the stress associated with weaning process for both buffaloes and its weaned calves, which is resulted in the improving milk production and calf growth performance as well as in the enhancing immune response. Thus, we recommend that buffalo producers should wean their calves by the fence-line system to gain more milk production, calf growth performance and immune response.

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