

*Full length Research paper*

# Response of dairy cows (Friesian-Kenana crosses) to feeding on two rations with alfalfa supplementation under dryland conditions in Sudan

Mohamed O. Ali<sup>1</sup>, Mitsuru Tsubo<sup>2</sup>, Yasunori Kurosaki<sup>2</sup>, Amir M.S. Mukhtar<sup>1</sup>, Mahgoub G. El-Hag<sup>1</sup>, Khaleel I. Jawasreh<sup>3</sup>, Imad-eldin A. Ali-Babiker<sup>4</sup> and Faisal M. El-Hag<sup>2,4,\*</sup>

<sup>1</sup> Faculty of Animal Production, University of Khartoum, Sudan

<sup>2</sup> Arid Land Research Center (ALRC), Tottori University, 1390 Hamasaka, Tottori 680-0001, Japan.

<sup>3</sup> Department of Animal Productions, Faculty of Agriculture, Jordan University of Science and Technology, Jordan.

<sup>4</sup> Agricultural Research Corporation (ARC), Khartoum, Sudan

Accepted 2nd February, 2021

A dairy ration based on sugarcane byproducts (Kenana ration) was compared with a conventional one (control ration), using fourteen dairy cows (Friesian-Kenana crosses) at different parities, under dryland farming conditions in Sudan. The cows were divided into two similar groups, randomly assigned to the two rations, kept in separate barns and individually fed. Alfalfa forage was supplemented to both groups: at 5 kg/cow/day for those on Kenana ration and ad libitum for controls. The trial was laid out as a randomized complete block design in different factorial arrangements and lasted for twenty-one weeks during January-June 2019. Cows on Kenana ration had higher ( $P<0.01$ ) daily feed intake ( $P<0.01$ ), lower daily milk yields (15.6 vs. 18.4 liter/cow) and less efficient ( $P<0.001$ ) in converting feed to milk (FCR 1.300 vs. 0.875 kg feed/liter of milk) compared with those on the control ration. The 3rd parity cows had the highest ( $P<0.01$ ) milk yields. Alfalfa supplementation was beneficial in adjusting protein contents of dairy rations. More research work is needed to evaluate different feed resources in dairy cattle feeding, together with assessing the economics of the different dairy processes.

**Keywords:** dairy cows, dryland farming, alfalfa forage, milk yield, parity, protein content

## INTRODUCTION

Milk production in Sudan is estimated at over seven million metric tons annually. Nonetheless, probably less than one quarter of this total production is available to the population (Wilson, 2018). Major causes are that most livestock in the country are raised under natural rangeland dryland farming conditions away from urban centers and that the poor infrastructures do not allow for quick handling and transport from production areas to consumers centers (Wilson, 2018). Endeavors to solve milk shortage in urban highly populated areas started since the colonial times. Some smallholder and large dairy enterprises have flourished around main towns and cities in Sudan where dairy cows are mostly exotic breeds or their crosses (Hassan et al., 2019).

The characteristic feature of dairy production in Sudan is the dependency on purchased feeds, crop residues, with limited grown forages. Dairy production under dryland farming conditions is constrained by local physical and biotic environments (Bosire et al., 2019), feeding management and animal health care (Almensch et al., 2017). This study was carried out with the objectives of evaluating two dairy rations supplemented with alfalfa forage, under dryland farming conditions in Sudan. One ration was based on sugar industry by-products (bagasse and molasses) while the other used conventional feed ingredients commonly used to feed livestock in Sudan.

## MATERIALS AND METHODS

**Ethical approval:** Animals Use in Research was according to the committee of the University of Khartoum

\*Corresponding author email: [faisalelhag@hotmail.com](mailto:faisalelhag@hotmail.com)

regulations. The guidelines and regulations set out by the Sudan Veterinary Council were strictly followed during animal handling and sampling.

All experimental protocols used are approved by the University of Khartoum and in accordance with the University of Khartoum Laboratory Authority guidelines.

### Study Area

This study was conducted at Kenana Sugar Company Dairy Farm, under dryland farming conditions, on the eastern side of the White Nile River (latitudes 14°03'-14°16'N; longitudes 33°17'-33°10'E), Sudan. Soils in the area are dark cracking vertisols with over 90.0% clay content. Average minimum and maximum temperatures vary between 27-35°C in winter (November-February), and 37-45°C in summer (March-June). The rainy

season extends from July to October with a long term mean annual rainfall of 450mm (Salih and Hamid, 2017).

### Rations and their Ingredients

Two rations were used in this study. One was based mainly on sugarcane byproducts (bagasse and molasses) designated as Kenana ration (experimental ration) while the other was formulated based on conventional feed resources with minimal inclusion of molasses labeled as control ration (Table 1). The ingredients were ground and processed using the mills of the Kenana Feed Factory. Samples of ingredients were analyzed for proximate chemical composition (Table 1).

**Table 1:** Ingredients and % inclusion into the two dairy rations

Ingredient	Control Ration	Kenana (Experimental Ration)
Bagasse	0.0	21.5
Molasses	9.5	28.0
Sorghum grains	33.0	22.0
Groundnut seed cake (GNSC)	29.5	19.0
Wheat bran	22.0	5.0
Calcium carbonate (CaCO <sub>3</sub> )	3.0	2.0
Common salt	1.0	1.0
Phosphoric acid	1.0	0.5
Urea	1.0	1.0

  

Feed ingredients chemical composition (%DM-basis)								
Chemical composition	DM	OM	Ash	CF	CP	EE	NFE	ME (MJ/kg)
Molasses	74.9	62.7	12.2	0.0	5.1	0.0	85.1	13.9
Bagasse	87.8	80.3	7.5	41.6	3.4	1.04	32.7	8.3
Sorghum grains	94.5	92.3	2.2	2.5	11.8	3.1	74.9	11.8
Groundnut seed cake (GNSC)	95.4	91.7	8.3	9.7	48.3	6.1	27.6	11.8
Wheat bran	89.1	84.3	4.8	18.0	14.2	3.45	48.6	10.5
Alfalfa hay	90.3	79.3	11.0	32.8	19.2	2.64	56.4	8.2

### Experimental Dairy Cows and Treatments

Fourteen dairy cows (Friesian-Kenana crosses), at different parity were used in this trial. The cows were divided into two similar groups based on their initial body weight, milk yield, stage of lactation and parity (calving number). One group was randomly assigned to Kenana ration, while the other was fed on the control one.

The cows were kept in separate pens and individually fed. Average initial body weight per cow of the control and Kenana groups were 459.3 and 464.3 kg, respectively, whereas respective days in lactation for two groups were 177 and 171 days. Alfalfa hay was supplemented to both groups. However, cows on Kenana ration group were given a fixed quantity of 5 kg of alfalfa per day whereas cows on the control ration were supplemented with alfalfa *ad libitum*.

### Data Recorded

Daily feed and alfalfa consumption were recorded for each cow separately. Cows in both groups were weighed weekly. The feed was offered at 7:00 am and refusals from previous day were collected and weighed before offering the next day feed and alfalfa supplement. Daily feed and alfalfa samples were collected and analyzed for proximate chemical entities (AOAC, 2016). Feed energy (MJ ME/kg DM) was calculated as (Suliman and Mabrouk, 1999):

$$\text{ME (MJ/kg DM)} = (0.012 \text{ CP} + 0.031 \text{ EE} + 0.005 \text{ CF} + 0.014 \text{ NFE})$$

Nutrient and energy (NRC, 2001) consumption were calculated through deducting nutrients in refusals from these of feed and alfalfa offered. The trial lasted for twenty-one weeks during January-June of 2019.

The cows were milked using machine-milking three times a day; early morning, at noon and in the evening. Daily milk yield (liter) was measured for each cow separately. Milk recording continued throughout the

twenty-one weeks of the experimental period. Feed conversion ratio (FCR; kg feed/liter of milk) was calculated through dividing feed consumption by milk yield. Separate measurement of milk yield at the different milking times was recorded for only the first four weeks of the experimental period.

### Experimental Design and Statistical Analyses

Data for feed consumption, nutrient intake, milk yield and feed conversion ratio (FCR, kg feed/liter milk) were analyzed as randomized complete block design (Steel and Torrie, 1980) with seven replications (each two cows of the same parity and similar initial milk yield comprising a replicate). The data were then arranged in a 2x4 factorial experiment to study the effects of ration and parity (2 rations and 4 parities) on feed consumption, nutrients intake and FCR. Data on feed consumption, nutrients intake and milk yield for the first four weeks were arranged in 2x4x3 factorial experiment (2 rations, 4 parities, 3 milking times) in a completely randomized design to study the effects of ration, parity, and milking times on dairy cow performance. SPSS software program (Ver. 24) was used for the statistical analyses.

## RESULTS AND DISCUSSION

### Feed Chemical Composition

The control and Kenana (experimental) dairy rations had comparable DM and OM contents, but differing in their CF, NFE, CP and ME contents (Table 2). Differences in nutrients contents of the two rations could be attributed to the different ingredients used (Table 1). The Kenana ration was based on sugarcane by-products (Bagasse and molasses) and bagasse had higher CF and lower energy density while the control ration used higher proportions of sorghum grain and groundnut seed cake (GNSC)(Table 1) that had their effects on energy and CP contents (Table 2). Further, EE contents of the control ration was five-times that of Kenanaration which was reflected in its higher energy content. Wilkinson et al. (2020) pointed to the need for assessing feed quality for dairy cattle and that forage testing is critical to the success of dairy cattle feeding programs, because of the high variability in quality of feed ingredients encountered.

**Table 2:** Rations and alfalfa chemical composition (%DM-basis)

Chemical entities	Kenana (Experimental) Ration	Control Ration	Alfalfa
Moisture (%)	4.99	9.91	45.00
Dry matter (DM%)	95.01	90.09	55.00
Organic matter (OM%)	87.78	83.52	42.81
Crude protein (CP%)	17.57	25.55	21.25
Ether extract (EE%)	1.81	9.42	1.47
Ash (%)	7.23	6.57	12.19
Crude fiber (CF%)	22.32	4.31	28.46
Nitrogen free extractives (NFE%)	46.08	44.24	36.63
Metabolizable energy (ME MJ/kg DM)	10.24	12.40	9.56

### Dairy cow performance

Control cows consumed more ( $P < 0.01$ ) total, weekly and daily feed quantities in comparison with cows on Kenanaration with respective daily feed consumption of 19.04 and 17.4 kg/cow/day (Table 3). Ingredients used in formulating the two rations could probably be responsible for this disparity in feed consumption of the two dairy cow groups. Cows offered forage-based diets may need to consume a greater physical quantity of bulky forages than those offered concentrate-based diets to achieve a given level of ME intake (Dong et al., 2015). Ertl et al. (2016) investigated the effects of a complete substitution of common cereal grains and

pulses with a mixture of wheat bran and sugar beet pulp in a high forage diet on cow performance, production efficiency and feed intake. They found that dietary treatment did not affect milk production, milk composition and feed intake. In contrast, Enriquez-Hidalgo et al. (2020) found that forages, such as legumes, reduced dry matter intake when incorporated into the diet of dairy cows. Kenanaration contained bagasse (Table 1) which might have resulted in that the ration being bulky, hence led to reduced feed intake in this cow group compared to those on the control ration (Table 3).

**Table 3:** Dairy cow average feed consumption and total nutrients consumption from basal and supplemental alfalfa over the twenty-one weeks of the experimental period

Parameter	Control Group	Kenana (Experimental) Group	SE±
No. of cows	7	7	
Weeks on test	21	21	
<b>Feed consumption:</b>			
Average total feed consumption(kg/cow/21week)	2798.9	2554.2	115.6NS
Average weekly feed consumption (kg /cow/week)	133.3	121.6	5.51
Average daily feed consumption (kg /cow/day)	19.04	17.4	0.79*
<b>Total crude protein consumption (kg/cow/21weeks):</b>			
Ration feed contribution	263.5	371.3	19.70**
Alfalfa contribution	375.6	93.7	8.82***
Average total CP consumption	659.1	465.1	19.62*
<b>EE consumption (kg/cow/21 weeks):</b>			
Ration feed contribution	97.2	38.2	2.38***
Alfalfa contribution	25.9	6.5	0.61***
Average total EE	123.1	44.7	2.48***
<b>Ash consumption (kg/cow/21 weeks):</b>			
Ration feed contribution	67.8	152.8	8.35***
Alfalfa contribution	215.5	53.8	5.1***
Average total ash	283.3	206.6	8.25***
<b>CF consumption (kg/cow/21 weeks):</b>			
Ration feed contribution	44.5	471.7	27.24***
Alfalfa contribution	503.03	125.5	11.8***
Average total CF	547.53	597.2	26.77***
<b>NFE consumption (kg/cow/21 weeks):</b>			
Ration feed contribution	456.3	973.8	53.1***
Alfalfa contribution	647.4	161.5	15.2 ***
Average total NFE	1103.7	1135.3	52.71**
<b>ME consumption (MJ/cow/21 weeks):</b>			
Ration feed contribution	12788	21639.2	1161.3**
Alfalfa contribution	16897.3	4216	396.7***
Average total ME	29685.3	25855.2	1.16**

\*significant at  $P < 0.05$ , \*\*highly significant at  $P < 0.01$  and \*\*\*very highly significant at  $P < 0.001$

Dairy cows on the control ration had higher ( $P < 0.05$ ) average total, weekly and daily milk yields in comparison with those on the Kenana one (Table 5). This could be attributed to higher nutrients contents of the control ration compared with those on Kenana ration (Table 2). This was in line with Darabighane et al., (2020) who ascribed the higher milk yields to a response to the extra dry matter intake, energy and nutrients consumed (Table 4) by the supplemented cows.

Parity main effects on milk yield per cow were significant ( $P < 0.01$ ), with comparatively highest milk yield for cows at their 3<sup>rd</sup> parity and the lowest was recorded by those at their 2<sup>nd</sup> parity (Table 5).

First-parity cows had much lower yield at the beginning of lactation compared with pluriparous cows (Niozas et al., 2019), with maximum milk yield occurring in the third lactation cows (Vijayakumar et al., 2017) and usually significant effects due to season or lactation number are detected (Singh et al., 2015). In this study no seasonal effects on milk yield have been investigated.

No significant ( $P > 0.05$ ) main effects on cow milk yield were found among morning, noon and evening milking times (Table 5). The frequency of milking will affect milk production per day and would result in increased milk production (Mačuhová et al., 2020; Khaskheli, 2020).

**Table 4:** Main effects of ration and parity on feed and nutrients intake (kg/cow/21 weeks) of dairy cows

Factor	N	Av. Total feed intake	CP intake	EE Intake	Ash intake	CF intake	NFE intake	ME intake	FCR
<b>Ration:</b>									
Control	7	2798.9	639.1	123.1	283.2	547.5	1103.7	29686.0	0.875
Kenana	7	2554.2	465.0	44.7	206.5	597.2	1135.3	25855.1	1.300
SE± (Ration)		65.35**	13.09*	3.30**	5.10***	13.06**	31.20**	0.75**	0.12***
<b>Parity:</b>									
1 <sup>st</sup> parity	3	2618	545.7	84.2	243.7	559.6a	1086.1	27171.3	1.33
2 <sup>nd</sup> parity	5	2531.7	524.3	80.5	232.7	540a	1056.5	26284.6	1.28
3 <sup>rd</sup> parity	3	2569.5	536.6	83.8	238.8	546.2a	1066.3	26704.2	0.95
4 <sup>th</sup> parity	3	2940	594.8	86.4	262.8	635.2b	1244	30417.8	1.30
SE± (Parity)		91.83ns	18.39ns	4.64ns	7.16ns	18.36*	55.5ns	1.05ns	0.99ns
<b>Ration x Parity interaction:</b>									
Control -1 <sup>st</sup> parity	1	2700.4ab	676.6a	128.8	301.5a	585.7a	1168.5a	31411ab	1.04a
Control -2 <sup>nd</sup> parity	3	2363.8b	617a	119.6	272.6a	525.5a	1065.5a	28666.4a	0.81b
Control-3 <sup>rd</sup> parity	2	2216.8ab	667.5a	129	295.4a	570.5a	1152.7a	31007ab	0.82b
Control-4 <sup>th</sup> parity	1	2681.3ab	611.3a	116.3	272.4a	529.4a	1055.7a	28377.8a	0.83b
Kenana -1 <sup>st</sup> parity	2	2967.9a	414.8a	39.6	185.9b	533.5b	1003.7b	22931.6b	1.62c
Kenana -2 <sup>nd</sup> parity	2	2268.2b	431.5a	41.3	192.8b	554.6b	1047.5b	23902.9c	1.74c
Kenana -3 <sup>rd</sup> parity	1	2922.4a	405.7a	38.6	182.2b	521.9b	979.9b	22401.2c	1.08d
Kenana -4 <sup>th</sup> parity	2	3198.7c	578.3b	56.4	253.2b	741.1c	1432.4c	32457.9d	1.76c
SE± (Interaction)		128.23*	25.69*	6.48ns	9.98*	25.63*	67.97*	1.47*	0.062**

a,b,c,d, Means in the same column under the same factor with no letter in common are significantly different according to Duncan Multiple Range Test (DMRT) (ns not significant at P > 0.05, \* significant at P < 0.05 and \*\* highly significant at P < 0.01)

**Table 5:** Main effects of ration, milking time and parity on milk yield of dairy cows

Factor	N	Total yield/cow (liter/cow/21 wks)	milk yield/cow (liter/cow/wk)	Daily milk yield/cow (liter/cow/day)
<b>Ration:</b>				
Kenana (Experimental)	7	2298.9	109.5	15.6
Control	7	2845.1	135.5	19.4
SE± (Ration)		121.9*	5.8*	.83*
<b>Parity:</b>				
1 <sup>st</sup> parity	3	2214.9	105.5	15.1
2 <sup>nd</sup> parity	5	2974.4	141.6	20.2
3 <sup>rd</sup> parity	3	2702.2	128.7	18.4
4 <sup>th</sup> parity	3	2511.8	119.6	17.1
SE± (Parity)		227.1**	10.8**	1.5**
<b>Milking time:</b>				
Morning	14	155.1	38.8	5.5
Noon	14	160.4	40.1	5.7
Evening	14	154.3	38.6	5.5
SE± (Milking time)		7.57ns	1.89ns	0.27ns
<b>Ration x Parity Interaction:</b>				
Control- 1 <sup>st</sup> parity	1	2224.9a	106.0a	15.1a
Control- 2 <sup>nd</sup> parity	3	2642.2b	125.8b	18.0b
Control- 3 <sup>rd</sup> parity	2	1780.8c	84.8c	12.1c
Control- 4 <sup>th</sup> parity	1	3054.d	145.5d	20.8d
Kenana - 1 <sup>st</sup> parity	2	1738.5c	82.8c	11.8a
Kenana- 2 <sup>nd</sup> parity	2	2579.a	122.8a	17.5b
Kenana - 3 <sup>rd</sup> parity	1	2349.3a	111.9a	16.0bc
Kenana - 4 <sup>th</sup> parity	2	1628.9d	77.6d	11.1d
SE± (Ration x Parity interaction)		12.92**	3.23**	0.42**
Ration x Milking time SE±		10.70ns	2.67ns	0.38ns
Parity x Milking time SE±		14.01ns	3.76ns	0.54ns
Ration x Parity x Milking time SE±		22.38ns	5.59ns	0.80ns

abcd, Means in same column under the same factor with no letter in common are significantly different according to Duncan Multiple Range Test (ns not significant at P > 0.05, \* significant at P < 0.05, \*\* highly significant at P < 0.01 and \*\*\* very highly significant at P < 0.001)

## Correlations among Milk Production and Nutrients Intake

Milk yield/cow was positively correlated with CP, NFE and ME intake and negatively correlated with EE and CF intake (Table 6). It is well-known that DMI is negatively related to CF (NDF) content in high producing dairy cows, which may reduce energy (McDonald et al. 2006). Minimal oil and fat contents in diets are necessary for appetite, but higher levels usually depress intake with a resultant overall reduction in performance (McDonald et al. 2006).

## CONCLUSIONS

It was concluded that dairy cattle performance, in terms of milk production and feed conversion into milk, was affected by feed composition and nutrients densities. Alfalfa forage supplementation to dairy cows was beneficial in adjusting protein contents of the dairy ration. However, more research work is needed to test the effects of different feed resources in dairy cattle feeding, together with the economics of the different dairy processes.

## Authors' Contributions

MOA laboratory work, data analysis and wrote the draft manuscript, MT supervision, YK design and review, AM SM design and data analysis, MG EL- Project administration, KIJ laboratory work and data analysis, IA A-B design and analysis, FM EI- design and data analysis. All authors read and approved the final manuscript.

## Competing Interests

The authors declare that they have no competing interests.

## ACKNOWLEDGEMENTS

Financial support was from the University of Khartoum Research funds (2018-2019). The technical assistance of El-Obeid Research Station, Agricultural Research Corporation (ARC), Sudan is highly appreciated.

## REFERENCES

- Almensch FA, Ibrahim B, Assefa DL (2017). Reproductive performance of crossbred dairy cows under smallholder condition in Asella town, Ethiopia. *International Journal of Dairy Science and Technology*, 3 (4):190-193.
- AOAC (2016). *Official Methods of Analysis* (20<sup>th</sup> edition). Association of Official Analytical Chemists (AOAC). AOAC International Suite 300 2275 Research Blvd Rockville, Maryland 20850–3250, USA.
- Bosire CK, Rao EJO, Muchenje V, Van Wijk M, Ogutu JO, Mekonnen MM, Auma JO, Lukuyu B, Hammond J (2019). Adaptation opportunities for smallholder dairy farmers facing resource scarcity: Integrated livestock, water and land management. *Agriculture, Ecosystems and Environment*, 284. <https://doi.org/10.1016/j.agee.2019.106592>
- Darabighane B, Aghjehgheshlagh FM, Mahdavi A, Navidshad B, Bernard JK (2020). Replacing alfalfa hay with dry corn gluten feed alters eating behavior, nutrient digestibility, and performance of lactating dairy cows. *Italian Journal of Animal Science*, 9(1):1264-1274.
- Dong LF, Ferris CP, McDowell DA, Yan T (2015). Effects of diet forage proportion on maintenance energy requirement and the efficiency of metabolizable energy use for lactation by lactating dairy cows. *J. Dairy Sci.*, 98:8846-8855.
- Enriquez-Hidalgo D, Teixeira DL, Pinheiro Machado Filho LC, Hennessy D, Toro-Mujica P, Williams SRO, Pereira FC (2020). Incorporating a Fresh Mixed Annual Ryegrass and Berseem Clover Forage into the Winter Diet of Dairy Cows Resulted in Reduced Milk Yield, but Reduced Nitrogen Excretion and Reduced Methane Yield. *Front. Vet. Sci.*, 7:576944. doi: 10.3389/fvets.2020.576944
- Ertl P, Zebeli Q, Zollitsch W, Knaus W (2016). Feeding of wheat bran and sugar beet pulp as sole supplements in high forage diets emphasizes the potential of dairy cattle for human food supply. *J. Dairy Sci.*, 99:1228-1236.
- Hassan SA, Abdelaziz HH, Ibrahim AH, Musa KSM (2019). Milk Production Forecasting in Khartoum State, Sudan. *Journal of Agriculture and Research*, 4(12): 6-13.
- Khaskheli AA (2020). Influence of dietary manipulation and milking frequency on production of dairy cows. *Online Journal of Animal and Feed Research*, 10(4): 180-184.
- Mačuhová L, Tančin V, Mačuhová J (2020): The effect of milking frequency on milk yield and milk composition in ewes. *Czech J. Anim. Sci.*, 65: 41–50.
- McDonald P, Greenhalgh JFD, Edwards R, Morgan CA (2006). *Animal Nutrition* (6<sup>th</sup> Rev. Ed.). Amazon Books, UK. 844pp.
- Niozas G, Tsousis G, Steinhöfel I, Brozos C, Römer A, Wiedemann S, Bollwein H, Kaske M (2019). Extended lactation in high-yielding dairy cows. I. Effects on reproductive measurements. *J Dairy Sci.*, 102(1):799-810.
- NRC(2001). *Nutrient requirements of dairy cattle* (7<sup>th</sup> Rev. Ed.). National Research Council (NRC), National Academy of Sciences, Washington, DC., USA.
- Salih AAM, Hamid AA. (2017). Hydrological studies in the White Nile State in Sudan. *The Egyptian Journal of Remote Sensing and Space Sciences*, 20: S31-S38

- Singh VP, Dubey M, Chaubey AK (2015). Seasonal Influence on Milk Production Performance in Different Breeds of Dairy Cows. *Environment and Ecology*, 33(1A):371-374.
- Steel RGD, Torrie JH (1980). *Principles and Procedures of Statistics: A biometrical approach*. McGraw-Hill Co., New York, USA. 633 pp.
- Suliman YR, Mabrouk AA (1999). Nutrients Composition of Sudanese Animal Feeds. *Bulletin III. Central Animal Nutrition Laboratory, Anim. Prod. Res. Center, Kuku, Khartoum North, Sudan*. 24 pp.
- Vijayakumar M, Park JH, Ki KS, Lim DH, Kim SB, Park SM, Jeong HY, Park BY, Kim T (2017). The effect of lactation number, stage, length, and milking frequency on milk yield in Korean Holstein dairy cows using automatic milking system. *Asian-Australas J Anim. Sci.*, 30:1093-1098.
- Wilkinson JM, Lee MRF, Rivero MJ (2020). Some challenges and opportunities for grazing dairy cattle on temperate pastures. *Grass Forage Sci.*, 75:1–17.
- Wilson RT (2018). Livestock in the Republic of the Sudan: Policies, production, problems, and possibilities. *Anim. Husb. Dairy Vet Sci.*, 2(3): 1-12.