Arab Universities Journal of Agricultural Sciences
(2023) 31 (2) 223-230
Website: http://ajs.journals.ekb.eg

Effect of Total Mixed Rations *Versus* Traditional Feeding of Concentrate and Roughage Rations on Dairy Cattle Performance in Sudan

Mahgoub G El Hag*, Bedria A Mohammed, Mohmed A Sayed, Mohmed Y Abdulla, Mayser A Abdulla, Yassin Y Abakar
Alzaem Alazhari University, Khartoum-North, Sudan

*Corresponding author: abusara67@yahoo.com

https://doi.org/10.21608/AJS.2023.226641.1531

Received 13 August 2023; Accepted 17 October 2023

Keywords:

Traditional feeding,
TMR,
Concentrate rations,
Roughage,
Dairy cattle,
Milk yield,
Milk composition

Abstract: Dairy cattle in Sudan are traditionally fed on separate concentrate and roughage diets. Because of the high cost of forages, feeding strategies should be attempted to reduce feeding costs. A traditional dairy ration (As-fed), composed of 49% sorghum grains (SG), 29.4% groundnut seed cake (GSC), 19.6% wheat bran (WB), 1% limestone (LS) and 1% salt (NaCl), was used as a control. The test ration was a total mixed ration (TMR) composed of 40% SG, 23% groundnut seed hulls (GSH), 20% GSC, 15% WB, 1% LS and 1 % NaCl. The control traditional ration was fed at 10 Kg/cow/day together with 7 Kg sorghum chaff. Two levels of TMR were used with alfalfa hay (AH); (17 Kg TMR + 1 Kg AH/cow/day and 15 Kg TMR + 2 Kg AH. Three cross-bred dairy cows (European x Local) were used with the feeding regimes in a 3x3 Latin square design. Cows consumed similar amounts of DM, CP and ME and produced similar quantities of milk ($P > 0.05$). TMR had no effects ($P > 0.05$) on the composition of milk. The cost for TMR was decreased by 19%.TMR was thus effective in reducing feeding costs without affecting milk production and composition.

1 Introduction

The increasing population in Khartoum state was coupled with an increased demand for animal protein, particularly milk. In recent years, the prices of milk and milk products have remarkably increased whereas during the last three years, prices of milk increased by more than 100%. Dairy production in Khartoum state is run mostly by smallholder dairy farmers using stall-feeding and zero-grazing. The dairy farms are scattered in small groups in rural areas of Khartoum, Khartoum N. and Omdurman localities. Few cattle owners may grow forages; however, the majority of owners depend on traditional feeding of commercial or farm-mixed dairy concentrate rations together with separate feeding of purchased green or dry off-farm forages (including berseem, *sorghum biocolor*, Sudan grass, Rhodes grass and pioneer corn-forage in addition to some other grasses) with small amounts of agro-industrial by-products and crop residues (El Hag et al 2018). The quality of the forage used in feeding dairy cows is quite variable and depends on the availability, supply and prices as they are not produced in the farm where the cows are kept. The quality or the value of the forage fed to the dairy animal depends to a greater extent on its ME

value, CP as well as vitamins and minerals (Ali et al 2021). Milk production is largely dependent on feed quality and intake in addition to the genetic make-up of the dairy animal, health and other factors such as husbandry and management practices carried by the dairy farmer. Of the many factors affecting milk production, the supply of a balanced diet is crucial for milk production, welfare and sustainability of dairy enterprise (Sova et al 2014). Feeding of dairy cattle in Khartoum state is largely based on the traditional methods of separate feeding concentrate and roughage diets. Concentrates are either purchased or mixed in the farm whereas most of the roughages (green or dry) are purchased. The dairy farmers believe that their cows must be daily fed on green forages together with concentrates. Unfortunately, the cost of green forages in Khartoum state is very high and even higher than the dairy concentrates. This abnormal situation has escalated the cost of feeding and consequently cost of milk production in the state. The total mixed ration (TMR) is an alternative strategy to solve the problem of the availability of forages to dairy animals (Karunanayaka et al 2022). Coppock et al (1981) defined TMR as the preparation of a complete single ration (containing both concentrate and roughage components) by mixing different feed ingredients to satisfy the nutritional amount and improve the feed utilization efficiency (Mendoza et al 2016, Beigh et al 2017, Premarathne and Samarasinghe 2020). The total mixed ration improved feed intake, digestibility and rumen function resulting in improved milk production by dairy cows (Wongnen et al 2009). Mohammad et al (2017) reported that TMR feeding resulted in more milk than normal traditional feeding. Many researchers also reported that TMR feeding has no significant effects on milk production and composition when compared to pasture-fed dairy cows (Schroeder et al 2003, Teshome et al 2017). The overall objectives of this study were to evaluate the effects of feeding TMR compared to traditional separate feeding of concentrate and roughage diets on milk production and composition as well as to demonstrate and train smallholder dairy farmers in Khartoum state of how to formulate TMR from available cheap local agro-industrial by-products and crop residues and to spare costly irrigated forages.

2 Materials and Methods

2.1 Study area

This study was conducted in a private smallholder dairy farm located South of Khartoum state, Gerif West in a place locally known as Nifasha. The study was carried out by coordination and cooperation between the farm owner and the team of researchers from the Faculty of Agriculture, Alzaem Alazhari University in Khartoum N. Sudan. The dairy farmer provided the animals, pens and laborers while the researchers provided the feed ingredients for the formulation of the test TMR rations, the formulation of the rations, the design of the trial and the laboratory analysis of feeds and milk.

2.2 Experimental animals and arrangement

Three cross-bred dairy cows (Two Friesian x Local and one cross-bred Jersey x Local) at different parity were used. The cows ranged in weight between (400, 450 and 490 Kg). The three cows (cow #1, cow #2 and cow #3) were switched over, using three feeding regimes and three feeding periods in a 3x3 Latin square design (summarized in **Table 1**) as follows: A traditional feeding regime (control) using separate amounts of concentrate and roughage diets. The control concentrate ration (**Table 2**) was farm-mixed, and the roughage diet was sorghum chaff (husks). Each of the cows fed on the control ration received, fixed daily amounts of 10 Kg concentrate ration + 7 Kg of the roughage diet. The two feeds were divided into two halves and offered twice at milking time (3 a.m. and 3 p.m.), milking was by hand. Two test-feeding regimes were used (**Table 2**) with very minimal quantities of Berseem (Alfalfa) hay: One test-feeding regime was based on 17 Kg of the TMR + 1 Kg BH daily and the 2nd test-feeding regime was based on 15 Kg + 2 Kg BH daily, as shown in **Table 2**. Three feeding periods were used; each feeding period was extended for 18 days (4 days adaptation - period and 14 days experimental period). The adaptation period was intended to clean the digestive system from the previous feeds and to adapt rumen microbes for the new ration. In period 1, which started on 12/2/2023 and extended up to 1/3/2023, cow #1 was fed on the control ration. Cow #2 was fed on TMR 17 Kg + 1kg BH while cow #3 was fed on TMR 15 Kg + 2 Kg BH. During period 2 which started on: 2/3/2023 up

Table 1. The layout of the trial (3x3 Latin square design)

Periods	Cows		
	Cow # 1	**Cow # 2**	**Cow #3**
Period1:12/2 to 1/3/2023 (18 days) 4 days adaptation + 14 days Experimental	Control ration	TMR 17 Kg + 1 Kg BH	TMR 15 Kg + 2 Kg BH
Period 2 :2/3 to 19/3/2023 (18 days) 4 days adaptation + 14 days Experimental	TMR 15 Kg + 2 Kg BH	Control ration	TMR 17 Kg + 1 Kg BH
Period 3 : 20/3 to 6/4/2023 (18 days) 4 days adaptation + 14 days Experimental	TMR 17 Kg + 1 Kg BH	TMR 15 Kg + 2 Kg BH	Control ration

Table 2. Ingredients Composition (% As-fed) of the Traditional Concentrate (Control) and Total Mixed Ration (TMR) used in the study

Ingredient	Traditional Concentrate ration (control)	Total Mixed Ration (TMR)
Sorghum grains	49.0	40.0
Groundnut seed cake	29.4	20.0
Wheat bran	19.6	15.0
Groundnut Hulls	—	23.0
Limestone	1.0	1.0
Salt (NaCl)	1.0	1.0
Total	100	100

to 19/3/2023, cow #1 was switched to TMR 15 Kg + 2 Kg BH; cow #2 was switched to the control ration and cow #3 was switched to TMR 17 Kg + 1 Kg BH. During period 3 which was started on 20/3/2023 up to 6/4/2023, cow #1 was switched to TMR 17 Kg + 1 Kg BH; cow #2 was switched to TMR 15 Kg + 2 Kg BH and cow #3 was switched to control diet. Accordingly, during the three feeding periods, each of the three cows was fed by the three feeding regimes. The cows were housed in individual pens and fed separately. All three cows consumed their allocated amounts of feed and in the case of remaining feeds, they were incorporated in the next day's meal. Daily feed intake and daily milk production were weighed and recorded daily during the entire length of the trial which lasted for 54 days.

2.3 Rations and their feed ingredients

Two rations were formulated in this study. One was a control traditional concentrate dairy ration based on SG and GNC and the second was the test ration which was a total mixed ration (TMR) containing the same feed ingredients plus GNH which is a high-fiber by-product feed available in huge quantities in Sudan with a cheap price (**Table 3**). All the feed ingredients used for the formulation of the experimental rations were purchased in the ground form from a local market and were weighed and mixed in the quantities stipulated in **Table 2**. The rations were manually mixed using shovels in a large metal container. Each of the two rations was mixed separately and prepared to satisfy the quantities needed for feeding the cows during each feeding period (18 days). Samples from the ingredients and the

rations were taken and analyzed for Proximate analysis for each feeding period and were pooled for the three feeding periods and the averages were taken and listed in **Table 3.** Milk samples were also taken from the 3 cows in the different feeding regimes for every feeding period separately and analyzed for the physicochemical composition of milk. Both feed and milk composition were analyzed according to AOAC (2005).

2.4 Experimental design and statistical analysis

The design of the study was a 3x3 Latin square design (Three cows, three feeding regimes and three feeding periods). Data for milk production, physicochemical composition of milk and feed conversion ratio (FCR: Kg feed/Kg milk) were - analyzed as a Latin square design using the statistical model:

$$yijk = \mu + `\alpha i + \tau j + \beta k + \epsilon ijk$$

where: yijk is the observation on the trait under study (Milk production, milk composition or feed conversion ratio). μ is the baseline mean, αi is the cow effect associated with row i, βk is the feeding period effect associated with column k, τj is the j th feeding regime effect, and ϵijk is a random error which is assumed to be IIDN(0, σ^2). ijkϵ; (Steel and Torrie 1981).

3 Results and Discussion

3.1 Rations composition and Nutritive value

The control and TMR rations were composed of similar ingredients, except that TMR contained GSH which is a fibrous, cheap by-product of groundnut seed in the Sudan. The GSH was mainly used to supply the fiber and to reduce the cost of TMR. Both the control and TMR were based on SG and GSC as energy and protein sources. Commercial mineral blocks were used to supplement the macro and micro minerals needed by dairy cattle, (**Table 2**). GSC is very rich in protein and energy while SG was the richest in energy (**Table 3**). The by-product feeds (GSH and sorghum chaff) were very similar in nutritive value (CP, CF and ME). WB is similar in CP content to AH but has a lesser amount of CF and a higher content of ME than the latter. The control and TMR were similar in CP and ME contents with slightly higher values than those of the control ration. However, the TMR was very high in CF content compared to the control ration (21.0 *vs* 10.6%), almost double the amount in the control ration.

3.2 Dairy cow performance

Cows fed on control and TMR 15 Kg + 2 Kg AH consumed more or less similar amounts of DM, CP, CF and ME (**Table 4**). However, cows fed on TMR 17 Kg + 1 Kg AH consumed the highest amounts of DM, CP, CF and ME compared to those on the other feeding regimes. This was expected as the cows were deliberately given more amounts of feed (18 Kg *vs* 17 Kg). The cows were given 17 Kg of TMR similar to the other two feeding regimes, but were given an extra 1 Kg of AH as a source of vitamin A and to provide roughage factor to the cows on this feeding regime.

Cows fed on the different feeding regimes produced similar amounts of milk with no significant differences ($p > 0.05$) and also had similar feed conversion rates (FCR), (**Table 5)** with no significant difference ($p > 0.05$). Also feeding TMR had no effect on the different chemical components of milk ($p > 0.05$), except for total solids (**Table 6**) which was significantly higher ($p < 0.05$) in TMR (17 Kg +1 Kg AH). than the other feeding regimes. It seems that TMR-feeding had no significant effects on milk production and composition. Those findings were in agreement with the findings of Schroeder et al (2003), Mohammad et al (2017), and Teshome et al (2017). The nutritive value of the feed ingredients (SG, GSH, WB) used in the formulation of the experimental rations was within the range reported by previous studies Ali et al (2021). The milk production of the cows fed by the different regimes in this study was very similar and ranged between 11.6 ± 1.8 and 12.1 ± 1.7 Kg/day and was similar to values reported for cross-bred (Friesian x Local kenana) cows fed on rations containing similar energy and protein values (Ali et al 2021). The chemical compositions of the milk produced by the dairy cows fed on the different regimes were very similar and not affected by the feeding regime (type of feeding). Those results were in agreement with the findings of Schroeder et al (2003), Mohammad et al **(**2017), and Teshome et al 2017). The values of the chemical composition of milk reported in this study were within the range reported for cross-bred European and Local cows fed by traditional feeding systems (Pasture and concentrate rations) in Kenya (Nyokabi et al 2022) who reported values for fat not less than 3.25%, protein not less than 3.5%, solids not fat not less than 8.5% and density ranging between 1.028 and 1.036 g/ml, which agrees with the Kenyan dairy standards.

Table 3. Chemical Composition (%DM-basis) of the different feed ingredients used in the study

Type of Feed	Chemical Composition (%DM-basis)							
	DM	OM	CP	CF	EE	Ash	NFE	ME(R):MJ/Kg DM*
Sorghum Grains	92.6	97.1	6.0	3.1	3.4	2.9	84.6	13.8
Groundnut seed cake	93.3	93.3	42.8	11.8	7.8	6.7	30.9	12.5
Wheat Bran	93.4	96.5	18.0	13.7	4.6	3.5	60.2	12.7
Groundnut seed Hulls	92.5	85.5	5.9	33.0	5.3	14.5	41.3	9.76
Alfalfa Hay	93.0	88.5	19.0	33.8	4.6	11.5	31.1	9.8
Sorghum Chaff or Husks *(Saemama*)	92.3	90.5	5.7	34.3	1.2	9.5	49.3	9.7
Traditional Concentrate (Control ration)	93.5	93.7	21.0	10.6	2.7	6.3	59.4	12.2
Total Mixed Ration (TMR)	93.5	93.8	19.5	21.0	4.7	6.2	48.6	11.65

* ME(R) values were calculated from Proximate analysis values, using the generalized Rostock equation given in Technical Bulletin (MAFF 1975). ME(R) = 0.012 CP + 0.031 EE + 0.005 CF + 0.014 NFE.Using the analysis expressed as g / kg DM gives ME(R) values direct as MJ / kg DM

Table 4. Amounts of daily consumed dry matter (DMI, Kg/Cow/Day), metabolizable energy, CP and CF for the control and TMR rations during the experimental period

Parameter	Feeding Regime		
	Traditional Feeding: Control (Separate Concentrate + Roughage)	TMR (17 Kg) + 1 Kg Roughage	TMR (15 Kg) + 2 Kg Roughage
No. of cows	3	3	3
Days on test	54	54	54
Concentrate / TMR	10 (9.35) *	17 (15.9) *	15 (14.0) *
Roughage			
Sorghum Chaff (Husks)	7 (6.46)*	_____	_____
Alfalfa Hay	_____	1 (0.93)*	2 (1.86)*
Total feed Intake	17(15.81)*	18 (16.83)*	17 (15.86)*
Concentrate: Roughage ratio	47:53	59:41	55:35
ME-Consumption (MJ/ Cow/ day)	176.7	196.0	181.3
CP(Kg/Cow/Day)	2.33 (14.7%)	3.27(19.4%)	3.08(19.4%)
CF (Kg/Cow/Day)	3.2 (20%)	3.65 (21.7%)	3.56 (22.4%)

*Numbers between brackets (designate quantity on DM-basis)

Table 5. Average daily milk production (Kg/cow/day) and feed conversion ratio (FCR) of feed to milk in the different feeding regimes during the study

Parameters Studied	Feeding Regime		
	Traditional Feeding: Control (separate concentrate + roughage)	**TMR (17 Kg) + 1 Kg Roughage**	**TMR (15 Kg) + 2 Kg Roughage**
Daily Milk Yield (Kg/Day) : (NS)	12 ± 1.4	12.1 ± 1.7	11.6 ± 1.8
Feed-intake:			
Concentrate/TMR	10 (9.35)*	17 (15.9)*	15 (14)*
Roughage:			
Sorghum Chaff (Husks)	7(6.45)*	_____	_____
Berseem Hay	__	1(0.93)*	2 (1.86)*
Total	17(15.81)*	18(16.83)*	17 (15.86)*
FCR** (NS)	1.3	1.4	1.37

Numbers between brackets (designate quantity on DM-basis)
FCR** = Kg DM/ Kg milk produced
(NS) : No significant differences ($p > 0.05$)

Table 6. The physicochemical composition of milk as affected by the different feeding regimes during the study

Parameters Studied	Feeding Regime		
	Traditional Feeding-Control : (Separate Concentrate + Roughage)	**TMR (17 Kg) + 1 Kg Roughage**	**TMR (15 Kg) + 2Kg Roughage**
Lactose	3.8 ± 0.06	4.2 ± 0.2	4.0 ± 0.2
Protein	3.9 ± 0.3	4.1 ± 0.1	3.9 ± 0.4
Fat	4.8 ± 0.1	4.7 ± 0.1	4.6 ± 0.01
Ash	0.86 ± 0.02	0.86 ± 0.02	0.85 ± 0.02
Total Solids	13.3^{a} ± 0.1	13.9^{b} ± 0.4	13.4^{a} ± 0.5
Solids Non-Fat	8.5 ± 0.2	9.2 ± 0.3	8.8 ± 0.3
pH	6.4 ± 0.2	6.5 ± 0.2	6.4 ± 0.2
Density (g/ml)	1.03 ± 0.01	1.03 ± 0.01	1.02 ± 0.01

^{a,b}Numbers with different superscripts are significantly different ($p < 0.05$)

The low cost of TMR provides a good and reasonable strategy to reduce the cost of feeding without negatively affecting milk production or its composition. Additional research is needed to try other available cheap agro-industrial by-products in Sudan such as sugarcane-bagasse, wheat and sorghum straws, groundnut haulms and sugarcane molasses to formulate cheaper TMR and to decrease the cost of feeding and milk production.

4 Conclusions

It was concluded that TMR feeding could have a promising potential as a feeding strategy to lower the cost of feeding and milk production as compared to traditional feeding of concentrate and roughage diets practiced by the smallholder dairy farmers in Khartoum state. The smallholder dairy farmer who participated positively in this research applauded the strategy of feeding TMR and was determined to adopt it instead of traditional feeding methods of concentrate and roughage diets. Many cheap agro-industrial by-products and crop residues are available in Khartoum state and can be tried for the formulation of TMR for feeding dairy cows.

Acknowledgments

The help and support given by Mr. Yaser A. Rahim, the smallholder dairy farmer is highly appreciated for the provision of animals, infrastructure and laborers.

References

Ali MO, Tsubo M, Kurosaki Y, et al (2021) Response of dairy cows (Friesian-Kenana crosses) to feeding on two rations with alfalfa supplementation under dryland conditions in Sudan. *International Journal of Dairy Science and Technology* 5, 238-244. https://rb.gy/q3bag https://rb.gy/x8vm0

AOAC (2005) Official Methods of Analysis. 18th ed, Hortwitz W, Latimer G W, AOAC-Int. Suite 500, 481 North Frederick Avenue, Gaithersburg, Maryland, USA.

Beigh YA, Ganai AM, Ahmad HA (2017) Prospects of complete feed system in ruminant feeding: A review. *Veterinary World* 10, 424-437. https://doi.org/10.14202/vetworld.2017.424-437

Coppock CE, Woelfel CG, Belyea RL (1981) Forage and feed testing programs-problems and opportunities. *Journal of Dairy Science* 64, 1625-1633. https://doi.org/10.3168/jds.S0022-0302(81)82736-1

EL Hag M, Mohamed AAS, Bakhit HAH, et al (2018) Effects of supplementation of bagasse with urea and molasses on milk production of crossbred friesian cows in Khartoum State, Sudan. *Sudanese Journal of Agricultural Sciences* 4, 23-35.

Karunanayaka RHWM, Liyanage RTP, Nayananjalie WAD, et al (2022) feeding total mixed ration (tmr) on production and reproductive performance of lactating dairy cows: A review. *Agricultural Reviews* 43, 29-37. https://doi.org/10.18805/ag.R-208

MAFF (1975) Energy Allowances and Feeding Systems for Ruminants. (Ministry of Agriculture, Fisheries and Food, Great Britain), Department of Agriculture for Northern Ireland & Great Britain. Department of Agriculture and Fisheries for Scotland. London, *Technical Bulletin* 33, 34-36 https://catalogue.nla.gov.au/catalog/2420574

Mendoza A, Cajarville C, Repetto JL (2016) Short communication: Intake, milk production and milk fatty acid profile of dairy cows fed diets combining fresh forage with a total mixed ration. *Journal of Dairy Science* 99, 1938-1944. https://doi.org/10.3168/jds.2015-10257

Mohammad EMA, Gorgulu M, Goncu S (2017) The effects of total mixed ration and separate feeding on lactational performance of dairy cows. *Asian Research Journal of Agriculture* 5, 1-7. https://doi.org/10.9734/ARJA/2017/33663

Nyokabi NS, Luning PA, Phelan JA, et al (2022) Intra-annual variation in feed and milk composition in smallholder dairy farms in Kenya, NJAS*: Impact in Agricultural and Life Sciences* 94, 137-155. https://doi.org/10.1080/27685241.2022.2135391

Premarathne S, Samarasinghe K (2020) Animal feed production in Sri Lanka: Past, Present and Future. In: Marambe B, Weerahewa J, Dandeniya W (Eds) Agricultural Research for Sustainable Food Systems in Sri Lanka Springer, Singapore. 277-301. https://link.springer.com/chapter/10.1007/978-981-15-2152-2_12

Schroeder GF, Delahoy JE, Vidaurreta I, et al (2003) Milk fatty acid composition of cows fed a total mixed ration or pasture plus concentrates replacing corn with fat. *Journal of Dairy Science* 86, 3237-3248. ttps://doi.org/10.3168/jds.S0022-0302(03)73927-7

Sova AD, LeBlanc SJ, McBride BW, et al (2014) Accuracy and precision of total mixed rations fed on commercial dairy farms. *Journal of Dairy Science* 97, 562-571. https://doi.org/10.3168/jds.2013-6951

Steel RGD, Torrie JH (1981) Principles and Procedures of Statistics. A Biometrical Approach. 2nd ed., McGraw Hill Book Co. Inc., New York.

Teshome D, Fita L, Feyissa F, et al (2017) Effect of Total mixed ration on dry matter intake, milk yield and composition of early lactating jersey cows. *Journal of Biology, Agriculture and Healthcare* 7, 19-24.

Wongnen C, Wachirapakom G, Patipan C, et al (2009) Effects of fermented total mixed ration and cracked cottonseed on milk yield and milk composition in dairy cows. *Asian-Australasian Journal of Animal Sciences* 22, 1625-1632. https://doi.org/10.5713/ajas.2009.80668