Effect of confinement area on production, physiological parameters and behaviour of Friesian cows during winter in a temperate climate

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In mild climatic regions, open camp systems (dry lots) may be used for dairy cattle. These have a lower capital investment cost than intensive housing systems although the management of open camps is more difficult. The effect of (a) an earthen mound within an open camp and (b) different camp sizes on the production performance, some physiological parameters and behaviour of Dutch-type Friesian cows were determined over two winter seasons. The feed intake of cows in the earthen mound camp was higher ($P < 0.05$) than that of cows in the smaller camp. Production and physiological parameters of cows, however, did not differ ($P > 0.05$) between camps with and without an earthen mound. Similarly production and physiological parameters of cows in camps of different sizes (100 vs 200 m^2/cow) did not differ ($P > 0.05$). The ground surface of the large camp was drier than that of the small camp resulting in cleaner cows ($P < 0.01$) while the washing time of udders at milking was shorter ($P < 0.01$). Cows in the small camp stood for longer periods ($P < 0.01$) to avoid lying down in wet areas. Cows in the large camp spent more time ($P < 0.01$) lying down. Although no difference in production parameters was observed in both trials, an earthen mound and camps of at least 100 m^2/cow may be necessary in high rainfall areas.

Melkkoeie kan in 'n omgewing met 'n gematigde klimaat in oopkampstelsels aangehou word. Dit het 'n laer kapitale insetkoste in vergelyking met intensiewe behuisingstelsels maar die bestuur daarvan is moeiliker. Die invloed van (a) 'n grondhoop binne 'n oop kamp en (b) kampe van verskillende groottes op die melkproduksie, enkele fisiologiese parameters en gedrag van Hollandse tipe Frieskoeie is gedurende twee winterperiodes bepaal. Koeie met toegang tot die grondhoop in die oop kamp het hoër ($P < 0.05$) voerinnames gehad as koeie sonder 'n grondhoop. Produksie- en fisiologiese parameters van koeie met of sonder die grondhoop het nie verskil nie ($P > 0.05$). Soortgelyke parameters het ook nie verskil ($P > 0.05$) tussen koeie wat in kampe van verskillende groottes (100 vs 200 m^2/koei) aangehou is nie. Die grondoppervlak van die groter kamp was droër as die kleiner kamp sodat koeie skoner ($P < 0.01$) was, terwyl die wastyd van uiers met melking korter was ($P < 0.01$). Koeie in die kleiner kamp het vir langer periodes ($P < 0.01$) gestaan om nat toestande te vermy. Koeie in die groot kamp het vir langer periodes gelê ($P < 0.01$). Hoewel produksieparameters in albei ondersoeke nie verskil het nie, mag 'n grondhoop in kampe en kampe van ten minste 100 m^2/koei in dele met 'n hoë reënval noodsaaklik te wees.

Keywords: Dairy cows, feed intake, earthen mound, dry lots, camp size, temperate climate.

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Introduction

Climate, herd size and cost influence the type of dairy housing facility on a particular farm (Bath *et al.*, 1978). A dairy housing system should be designed and constructed in such a way that cows are properly fed, handled, observed for heat and protected against adverse climatic conditions (Larson, 1974). Open camp systems (dry lots) are being used mainly in the southern states of the USA where climatic conditions during winter are not extreme. In 1978 Bath *et al.* reported that in Florida, Texas and California more than 50% of all dairies use open camps while in Arizona this figure is 90%. An open camp system has a considerably lower capital investment in the fixed assets of a dairy operation (Jarrett, 1986). However, this type of housing system presents a special challenge to management in order to maintain animals in a healthy environment.

Under semi-arid conditions, Wiersma *et al.* (1984) recommend a pen space of 50 m^2/cow. Bath *et al.* (1978) suggest a pen space of only 33 m^2 and Babson (1976) maintains that a space of between 32 to 65 m^2/cow, depending on soil conditions and rainfall should be sufficient. Open camps should be sloped away from the feeding trough while the surface be cleaned at least twice annually (Wiersma *et al.*, 1984). Manure should be removed from the camp during the dry season when the material is easier to handle due to less volume. At the same time holes formed around the feed and water troughs should be filled up with fresh soil.

In the Western Cape dairy cows are also kept mainly in open camps with feed being provided to them in feed troughs on a daily basis. Owing to economic reasons, the number of cows on most farms has increased. This was done without adequate consideration being given to either layout or construction of facilities. These factors together with the highly concentrated rainfall during winter create various problems in the open camp systems with cows being exposed to unfavourable conditions. These conditions are thought to adversely affect the production and health of dairy cows, with mastitis being a major concern.

It has been suggested (Massie & Brevik, 1982) that earthen mounds constructed within open camps should improve drainage, thereby creating a drier and cleaner environment for cows. Earthen mounds have been used to keep feedlot cattle out of muddy conditions, resulting in improved feed efficiency and faster daily gains. Increasing pen size may also improve conditions although excessive-sized pens will increase movement time of cows to and from the milking parlour as well as increase construction cost and maintenance (Jarrett, 1986).

Two studies were therefore undertaken to investigate over a period of two years the effect of (a) an earthen mound within an open camp and (b) different camp sizes on the production performance, some physiological parameters and behaviour of Friesian cows during winter in die Western Cape.

Materials and methods

The studies were conducted at the Elsenburg Experimental Station of the Western Cape Department of Agriculture. Elsenburg is situated approximately 50 km east of Cape Town at an altitude of 177 m, longitude 18°50′ and latitude 33°51′. The area has a winter rainfall pattern with 60% of the annual rainfall of 650 mm occurring from May to August. The effect of an earthen mound on production performance was determined during the winter of 1985 (Experiment 1). This study was repeated during the winter of 1986, but it was terminated early when abnormally high rainfall at the onset of the experiment caused conditions in the smaller camp to be extremely poor. As these conditions did not represent a typical farming situation, this trial was abandoned. The effect of camp size on production performance was determined during the winter of 1987 (Experiment 2). Experimental periods started on 19 June 1985 and 5 June 1987, and lasted for 76 and 60 days respectively.

Primi- and multiparous Dutch-type cows from the Elsenburg Friesland herd that were at least four weeks but not more than 180 days into lactation were divided into two groups according to stage of lactation and average daily milk production during a three-week preliminary period. This was necessary to ensure that none of the cows needed to be dried off before the end of each experimental period. In both years groups were randomly allocated to the two treatments. Average daily milk production (± SD) of cows during the preliminary period was 20.3 ± 7.1; 20.6 ± 8.06 kg in 1985 and 18.0 ± 6.7; 17.3 ± 3.6 kg in 1987. The average stage of lactation of the various groups during the respective experimental periods was 110 ± 68, 115 ± 70 and 130 ± 38, 131 ± 38 days respectively. During the preliminary period cows received the same feeding, management and housing. During the 1985 and 1987 experimental periods milk production and milk composition data of 18 and 14 cows, respectively, were used.

Cows were kept under zero grazing conditions in two adjacent open camps. In 1985 cows had access to open camps that provided space of 25 m^2 and 75 m^2/cow with a constructed earthen mound within the camp. For the 1987 experimental period the earthen mound was removed and the open camps were enlarged to provide space of at least 100 and 200 m^2/cow respectively. Each open camp had a slope of approximately 5% away from the fence line feeding trough. Feeding space of 700 mm was provided for each cow at the feeding trough. A 3 m-wide concrete floor served as a feeding apron along the feed trough.

In both experimental periods complete diets consisting of lucerne hay, wheat, maize, wheat bran and fish-meal providing 135 g crude protein (CP) and 9.6 MJ ME/kg were provided *ad libitum* twice a day in the feed troughs of both groups. Fresh feed was provided after refusals of the previous feeding had been removed. Fresh feed and refusals were weighed at each feeding. A sample of both fresh feed and refusals was taken at each feeding and the dry-matter (DM) content determined. In this way daily DM intakes of the cows in the different experimental groups were determined on a group basis. Cows were milked twice daily at 05:00 and 15:30 in a milking parlour approximately 150 m from the open camps. Milk production of each cow was recorded at each milking. Total daily milk production was regarded as the amount of milk produced at the morning and afternoon milking. Milk samples from each cow were collected every day during each experimental period and analysed for fat, protein and lactose content with a Milko-scan Infrared Analyzer. The somatic cell count of the milk was determined for each cow on 15 occasions (morning and afternoon milking combined) with a Fossomatic cell counter.

During the 1987 experimental period, five cows from each treatment were subjectively scored on 24 occasions while they were in the open camps to assess the degree of soiling of cows according to a method of Faye & Barnouin (1985). A predetermined scoring system based on the amount of dirt attached to five different areas on a cow's body (ano-genital area, rear udder, lower leg, fore udder and outer side of the upper leg) was used. For each of these areas the following index values were used:

0: clean
0.5: very little dirt
1: some dirt covering less than 50% of the area
1.5: more dirt covering more than 50% of the area
2: a thick dirty mat covering the whole area.

Totalling the score of the five areas gave the degree of cleanliness (0: clean; 10: very dirty) of cows. The time spent washing the udders of cows with running water before morning and afternoon milking was also determined on 48 occasions (24 morning and 24 evening milkings) during the 1987 experimental period.

For 49 and 28 days during the 1985 and 1987 experimental periods respectively, blood samples from the external jugular vein of experimental animals (10 during 1985 and 8 during 1987) were taken daily at 15:15, just before milking. The same collecting and analysis procedures for cortisol and thyroxine levels as previously described (Muller *et al.*, 1994) were used.

Continuous observations of cows in the 100 and 200 m^2/cow camps were done by the same observers on two separate 24-hour periods during August 1987. Each cow's daily activity concerning feeding, standing and lying down was observed and noted down to the nearest minute.

Average daily milk production and milk composition of cows in both experiments were compared between the groups, using a three-week preliminary period as covariate. The average daily feed intake of cows in the two groups in both years was compared by pairwise T-test procedures (Snedecor & Cochran, 1980). Blood cortisol and thyroxine concentrations of cows in different confinement areas in both experiments were compared by analysis of variance using the Genstat-5 statistical package. The degree of soiling of cows, washing time of udders and udder health of cows of both groups were averaged for each cow and compared by analysis of variance. Differences between cows in time spent feeding and standing and lying down in different camps were similarly compared by analysis of variance.

Results and discussion

Climatological conditions

Climatological conditions recorded at Elsenburg during the two experimental periods are presented in Table 1. Conditions were very similar to long-term weather data (pers. comm. J. Myburgh, Private Bag X1, Elsenburg, 1993). Although it seems that the rainfall per day was only about 10 mm/day, it must be kept in mind that little evaporation (on average 2.35 mm/day during July and August) took place from the camp surface during winter. This resulted in extremely wet conditions for a considerable length of time after raining. This, combined with the high (88%)

moisture content of manure, caused very wet conditions in the open camps during winter. These conditions became extreme when a large number of animals were concentrated on a relatively small area.

Ambient temperatures experienced during the experimental periods were relatively cool although the wind chill factor may have caused lower temperatures in the open than temperatures recorded inside a Stevenson screen where instruments were protected against radiation and wind. Rainfall was the highest during July when the lowest maximum and minimum temperatures were recorded.

Experiment 1

The daily feed intake, milk production, milk composition and blood plasma levels of thyroxine and cortisol are presented in Table 2. Cows in the larger camp with the earthen mound had higher ($P < 0.01$) feed intakes than cows in the smaller camp. Production and physiological parameters of cows, however, did not differ ($P > 0.05$) between camps. This was contrary to expectations as conditions in the smaller camp were extremely poor. The relatively short period of the experiment probably prevented adverse effects being manifested. Very little information is available regarding the effect of pen surface on milk production. Albright (1987) observed that for as long as cattle have been milked, the art of cow care has resulted in more milk from healthier, contented cows. The dairy cow's productivity can be adversely affected by discomfort. Therefore cows should be kept out of the mud when dry lot systems are being used. White *et al.* (1989) showed that the feed intake and average daily gains of feedlot cattle (Hereford and Angus crossbred steers) during summer were improved ($P < 0.05$) by pen surface (concrete vs dirt). Erasmus (1978) found no effect ($P > 0.05$) on the cortisol levels of different beef-type animals being confined in a kraal providing only 4.6 m^2/animal in comparison to veld conditions. In the present trial it was noted that cows did not readily make use of the earthen mound to avoid muddy areas. Notwithstanding the lack of scientific evidence indicating an advantage for earthen mounds, it has been used for some time in various areas of the USA to keep cows out of the mud. Such a structure would especially be needed in a high rainfall area.

Table 1 Mean (± SD) climatological conditions during the winter experimental periods

Parameter	Experimental period 1985	1987
Max. temperature (°C)	17.9 ± 4.2	17.8 ± 4.1
Min. temperature (°C)	7.6 ± 2.9	7.9 ± 2.8
Total precipitation (mm)	248.3	182.8
Ave. precipitation/day (mm)	10.3	8.7
Number (%) of rainy days	24 (32%)	21 (35%)
Wind (km/24 h)	161.9 ± 106.6	105.7 ± 114.5

Table 2 Production parameters and plasma concentrations of thyroxine and cortisol of cows in open camps with and without an earthen mound

Parameter	A	B	SE_d	Significance level (P)
Feed intake (kg DM/cow/day)	20.0	21.3	0.29	0.001
Milk production (kg/day)	19.7	19.2	1.02	0.64
Fat %	3.65	3.64	0.17	0.97
Protein %	3.65	3.74	0.06	0.18
Lactose %	4.96	4.81	0.05	0.01
SCC (× 1000)	386	454	58.2	0.26
Cortisol concentration (nmol/*l*)	19.2	18.7	1.75	0.80
Thyroxine concentration (nmol/*l*)	64.0	66.1	3.51	0.56

A: 25 m^2/cow
B: 75 m^2 + earthen mound
SE_d:Standard error of difference
SCC:Somatic cell counts

Experiment 2

The effect of camp size on production parameters and plasma cortisol and thyroxine concentrations is presented in Table 3. The feed intake of cows in different camps varied ($P < 0.05$) while production parameters indicated no apparent advantage for camps in excess of 100 m^2/cow. Snoek (1991) also found little difference in feed intake, milk yield, fat content and somatic cell count of milk between two groups of cows under normal and crowded (30% less cubicles and feed space/cow) housing conditions. Although not directly comparable, Hoffman & Self (1970) found that feedlot surface (concrete vs dirt) did not affect ($P > 0.05$) the rate of gain of feedlot cattle.

Christison & Johnson (1972) noted that stress conditions activate the hypothalamic-pituitary-adrenal axis. Blood plasma cortisol concentrations of cows in the smaller camp of both trials were higher although not significant ($P > 0.05$). This is not a clear indication that crowding of experimental animals results in higher stress levels. It is however interesting to note that absolute blood plasma cortisol levels were higher during 1985 when both open camps were smaller than during 1987.

There was also no difference ($P > 0.05$) in blood thyroxine concentration due to the camp size (Table 3). Erasmus (1978), however, found a significant ($P < 0.05$) effect of pen conditions

Table 3 Production parameters and plasma concentrations of thyroxine and cortisol of cows kept in open camps of different sizes during winter

Parameter	A	B	SE_d	Significance level (P)
Feed intake (kg DM/cow/day)	19.6	19.2	0.30	0.16
Milk production (kg/day)	15.5	14.9	1.72	0.70
Fat %	4.08	4.01	0.31	0.81
Protein %	4.13	4.06	0.13	0.56
Lactose %	5.03	4.97	0.08	0.44
Cortisol concentration (nmol/*l*)	11.7	10.0	1.63	0.32
Thyroxine concentration (nmol/*l*)	72.7	73.3	4.66	0.90

A: 100 m^2/cow
B: 200 m^2/cow
SE_d:Standard error of difference

on thyroxine levels for different beef type animals. Stressful agents and adrenocortical hormones have a depressing effect on the activity of the thyroid gland (Erasmus, 1978). This was, however, not found in this experiment. The lack in response in thyroxine concentration could possibly be ascribed to the relatively short duration of the trials as well as mild conditions during winter.

Degree of soiling of cows, washing time of udders and udder health

Degree of soiling of cows, washing time of udders and udder health (somatic cell counts/ml) of cows in different open camps during 1987 are presented in Table 4.

From these data it seems that cows in the large (200 m^2/cow) camp were significantly ($P < 0.01$) cleaner than cows in the smaller camp. However, cows were not very dirty, as indicated by the relatively low scores (3.2 and 1.6). A score higher than 7.5 would have indicated dirt covering more than 50% on five different areas of the cow's body. Different housing systems influence the degree of soiling and udder health of dairy cows. Petersen *et al.* (1988) found the highest degree of soiling of cows and the highest straw requirements with a bedded-pack (deep litter) barn in comparison with a stall barn and free stall barn where udder health, as determined by somatic cell count, was best in the free-stall barn and poorest in the stall barn. With this degree of soiling scoring system it is possible to take note of the housing conditions of animals on a fixed day of the month during milking or while they are being weighed and condition scored (Faye & Barnouin, 1985). There was no difference ($P > 0.05$) in somatic cell counts between confinement areas. At evening milking, more ($P < 0.05$) time was spent washing udders of the small camp cows, while the same trend ($P = 0.09$) was observed at morning milking.

Daily behaviour pattern

Climatic conditions on observation days were typical of winter. Maximum and minimum temperatures were on average 13.6 and 8.4°C respectively. Average rainfall on test days was 11 mm per day with little sunshine (1.5 h). The time spent on daily activities is presented in Table 5.

There was no difference ($P > 0.05$) in total feeding time during the day although cows in the larger camp spent more time ($P < 0.01$) feeding at night. Cows in the small camp had more ($P < 0.05$) feeding periods during a 24-hour period (9.2 vs 7.4) while the duration of feeding periods was shorter (20.4 vs 30.7 min; $P < 0.01$). The time dairy cows spent eating in intensive housing systems is not influenced to a great extent by space restriction when feeding level is high (Wierenga, 1981). A restriction of the number of feeding places results in a strong increase in aggression at the feeding site as well as lowered productivity in Holstein cows (Metz, 1981). Such behaviour was however not observed in this trial. Cows in the small camp spent more time ($P < 0.01$) standing during the day and night periods. There was no difference ($P > 0.05$) in the number of standing periods between cows in the two camps while the duration of standing periods was longer ($P < 0.05$) for cows in the small camp (63.5 vs 35.9 min).

Cows in the large camp spent more ($P < 0.01$) time lying down during both the day and night. This is possibly due to poor surface conditions in the small camp as cows generally will stand to avoid wet and muddy lying-down areas (Albright, 1987). Metz (1985) noted that the well-being of cows is seriously impaired when lying time is restricted for several hours.

Table 4 Degree of soiling of cows, washing time of udders and udder health (SCC) of cows in different confinement areas during the winter of 1987

Parameter	A	B	SE_d	Significance level (P)
Degree of soiling	3.23	1.62	0.10	0.001
Washing time (sec/cow):				
Morning milking	29.4	26.5^a	1.57	0.09
Evening milking	26.9	23.7^b	1.10	0.01
SCC (× 1000)	130	216	89.8	0.36

A: 100 m^2/cow
B : 200 m^2/cow
a,b: Values in columns with different superscripts differ significantly ($P < 0.05$)
SE_d:Standard error of difference
SCC:Somatic cell counts

Table 5 Daily feeding, standing and lying down activities of cows in open camps of 100 and 200 m^2/cow during winter

Activities	100 m^2/cow	200 m^2/cow	SE_d	Significance level (P)
Total feeding time (min)				
Day	102.8	101.4	17.8	0.94
Night	85.0	125.8	0.3	0.004
Total	187.8	227.2	22.8	0.123
Total time standing (min)				
Day	376.2^a	212.8^a	17.8	0.001
Night	507.0^b	317.0^b	43.5	0.002
Total	883.2	529.8	52.7	0.001
Total time lying down (min)				
Day	14.4^a	180.4^a	13.4	0.001
Night	201.6^b	334.6^b	35.0	0.005
Total	216.0	515.0	35.3	0.001

SE_d:Standard error of difference
a,b: Values within columns with different superscripts differ significantly ($P < 0.01$)

Conclusions

There were no significant differences ($P > 0.05$) for the various production parameters for cows in different confinement areas. The expected adverse effects of a smaller camp and environmental conditions on production did not manifest over the short experimental periods of 76 and 60 days respectively. Cows in the larger camp were cleaner ($P < 0.01$) than cows in the small camp, while washing time of udders was also shorter. There were no differences in cortisol and thyroxine concentrations between cows in the different confinement areas. Cows in the larger camp spent more time ($P < 0.01$) feeding at night while duration of feedings was longer ($P < 0.01$). Cows in the smaller camp spent more time ($P < 0.01$) standing during the day and night. Cows in the larger camp spent more ($P < 0.01$) time lying down during both the day and night. It seems that under local climatic conditions an earthen mound or open camps larger than 100 m^2 would not be necessary.

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References

ALBRIGHT, J.L., 1987. Dairy animal welfare: current and needed research. *J. Dairy Sci.* 70, 2711.

BABSON BROS. CO. ORGANIZATION, 1976. Open air corral systems. In: The way cows will be milked on your dairy tomorrow. Oak Brook. Illinois, USA.

BATH, D.L., DICKINSON, F.N., TUCKER, H.A. & APPLEMAN, R.D., 1978. Facilities, equipment, and technological developments. In: Dairy cattle: principles, practices, problems, profits. Lea & Febiger. Philadelphia, USA.

CHRISTISON, G.I. & JOHNSON, H.D., 1972. Cortisol turnover in heat-stressed cows. *J. Anim. Sci.* 35, 1005.

ERASMUS, J.A., 1978. Influence of stress on adrenal cortex and thyroid activity of *Bos indicus* and *Bos taurus* heifers under kraal and veld conditions. M.Sc. thesis, University of Orange Free State, Bloemfontein.

FAYE, B. & BARNOUIN, J., 1985. Objectivation de la propreté des vaches laitières et des stabulation — L'indice de propreté. *Bull. Tech. C.R.Z.V. Theix, I.N.R.A.* 59, 61.

HOFFMAN, M.P. & SELF, H.L., 1970. Shelter and feedlot surface effects on performance of yearling steers. *J. Anim. Sci.* 31, 967.

JARRETT, J.A., 1986. Maintain corrals during the dry season. *Hoards Dairyman* 131, 10.

LARSON, S.A., 1974. An overview of dairy housing in the U.S. In: Ch. 35 Large Dairy Herd Management. Ed. by C.J. Wilcox & H.H. van Horn. University Press of Florida, Gainesville, USA.

MASSIE, L.R. & BREVIK, T.J., 1982. Earthen mounds can keep your herd high and dry. *Hoards Dairyman* 127, 740.

METZ, J.H.M., 1981. Social reactions of cows when crowded [Abstr.] *Appl. Anim. Ethol.* 7, 384.

METZ, J.H.M., 1985. The reaction of cows to short-term deprivation of lying. *Appl. Anim. Behav.* 13, 301.

MULLER, C.J.C., BOTHA, J.A., COETZER, W.A. & SMITH, W.A., 1994. The effect of shade on various parameters of Friesian cows in a Mediterranean climate in South Africa. 2. Physiological responses. *S. Afr. J. Anim. Sci.* 24, 56.

PETERSEN, P.H., KONGGAARD, S.P., MOLLER-MADSEN, A. & JENSEN, H., 1988. Influence of three housing systems on the environment and udder health of the dairy cow and on the bacteriological quality of the milk. [Abstr.] *Dairy Sci. Abstr.* 50, 185.

SNEDECOR, G.W. & COCHRAN, W.G., 1980. Statistical methods (7th ed.) Iowa State University Press, Ames.

SNOEK, H., 1991. Effects of overcrowding in dairy cattle. [Abstr.] *Dairy Sci. Abstr.* 53, 434.

WHITE, T.W., HEMBRY, F.G. & SAXTON, A.M., 1989. Influence of shade and pen surface on performance of steers fed forage diets. [Abstr.] *J. Anim. Sci.* 67 (Suppl. 1), 443.

WIERENGA, H.K., 1981. Consequences of space restriction on the behaviour of loose-housed dairy cows. [Abstr.] *Appl. Anim. Ethol.* 7, 385.

WIERSMA, F., ARMSTRONG, D.V., WELCHERT, W.T. & LOUGH, O.G., 1984. Housing systems for dairy production under warm weather conditions. *Wo. Anim. Rev.* 50, 16.