used to measure the fat content in the samples can be simplified and improved by freeze-drying the samples before extracting the fat.

Fortin *et al.* (1981) pointed out that the prediction of carcass composition using the specific gravity technique is too variable to allow for comparisons on an individual animal basis, although the technique is quite suitable for group comparisons. Likewise, a comparison of the chemical composition of sawdust among treatment groups would probably be more reliable than the evaluation of carcasses on an individual basis, considering that variation in fat content of carcasses at the end of a feeding trial would probably be less than the variation used in the present investigation.

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Effect of shelter on the performance of Friesian cows during winter in a mediterranean climate

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The effect of different shelters, that is, a shade structure (3.5 m high) in a dry lot and a tie-stall barn in comparison to a dry lot with no protection against climatic conditions (rain and wind), on the milk production and some physiological parameters of Dutch-type Friesian cows was determined over 53 days during winter in a temperate climate zone. A complete diet (13.5% CP and 9.6 MJ ME/kg DM) was fed ad libitum daily to cows. Ambient temperatures recorded during the trial were within the thermoneutral zone for dairy cattle (18.5 ± 4.0 and 8.7 ± 2.6 °C for maximum and minimum temperatures respectively). Total rainfall during the trial period was 180.6 mm. Daily precipitation higher than 5.0 mm was recorded on 12 days. Although dry matter intake differed ($P < 0.01$) between treatments, it was not related to treatment. Daily milk production and milk composition did not differ ($P > 0.05$) between treatments. Plasma cortisol and thyroxine levels of cows in the different housing systems also did not differ ($P > 0.05$), indicating no advantage in providing elaborate housing facilities for dairy cows under these climatic conditions.

Die invloed van verskillende beskuttingsfasiliteite, naamlik 'n skaduwee-afdak (3.5 m hoog) in 'n oop kamp en 'n intensiewe behuisingstelsel in vergelyking met 'n oop kamp waarin geen beskutting teen klimaatstoestande (reën en wind) verskaf is nie, op die melkproduksie en sekere fisiologiese maatstawwe van Hollandse tipe Frieskoeie is oor 'n periode van 53 dae gedurende die winter in 'n gebied met 'n gematigde klimaat bepaal. 'n Volledige dieet (13.5% RP en 9.6 MJ ME/kg DM) is op 'n *ad libitum*-basis daagliks aan koeie voorsien. Omgewingstemperature gedurende die proefperiode was binne die gemaklikheidsone vir melkkoeie (18.5 ± 4.0 en 8.7 ± 2.6 °C vir maksimum en minimum temperature onderskeidelik). Die totale hoeveelheid reënval gedurende die periode was 180.6 mm. 'n Daaglikse neerslag van hoër as 5.0 mm is op 12 dae aangeteken. Hoewel daaglikse droëmateriaal-innames tussen behandelings verskil het ($P < 0.01$), kan dit nie aan die behandelings toegeskryf word nie. Melkproduksie en melksamestelling van koeie binne die drie behuisingstelsels het nie verskil nie ($P > 0.05$). Bloedplasmapeile van kortisol en tiroksien het ook nie tussen die behandelings verskil nie ($P > 0.05$). Resultate dui op geen voordele in die voorsiening van uitgebreide behuisingsfasiliteite vir melkkoeie onder hierdie klimaatstoestande nie.

Keywords: Milk production, dry lot, tie-stall barn, shade structure, tyroxine, cortisol, temperate climate.

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Various factors such as climate, herd size, cost, management style and tradition influence dairy housing facilities (Larson, 1978). Although climatic conditions in South Africa during winter are relatively mild, dairy farmers are becoming increasingly more concerned about the negative effects of adverse climatic conditions that do occur and are therefore considering different sheltering facilities. In the Western Cape dairy cows are kept under zero grazing conditions in open camps (dry lots) with feed being provided to them on a daily basis. This area has a temperate climate with hot, dry summers and cool, wet winters. Almost 60% of the annual rainfall occurs during the winter (May to August). Wind and rain are significant components determining the coldness of an environment. The insulative value of an animal's hair coat is reduced by wind and rain while the surface heat exchange is increased (Webster, 1981). No information concerning the effect of various shelters on the milk yield of dairy cows is available in South Africa. A study was therefore conducted to determine the effect of providing protection during winter on the production performance of Friesian cows. Physiological parameters such as blood serum concentrations of thyroxine (T_4) and cortisol were also determined to evaluate the physiological responses to protection of cows during winter.

The study was conducted in the Winter Rainfall Region at the Elsenburg Experimental Station situated approximately 50 km east of Cape Town at an altitude of 177 m, longitude 18°50' E and latitude 33°51' S. The trial started on 15 July 1986 and lasted 53 days. Eighteen Dutch-type Friesian cows were divided into three groups according to stage of lactation and average daily milk production during a three-week preliminary period. During this period all cows received the same treatment in terms of feeding and housing. At the start of the experiment cows were at least four weeks but not more than 165 days into lactation, to ensure that none of the cows needed to be dried off before completion of the experimental period. Average daily milk production during the preliminary period was 22.8 ± 11.2; 23.4 ± 9.2 and 24.2 ± 8.8 kg for the three experimental groups. The average stage of lactation at the start of the experimental period was 93 ± 55; 96 ± 55 and 92 ± 55 days. Groups were allocated randomly to the different treatments. Treatments were (a) a earthen dry lot providing space of 75 m^2/cow with no protection against rain and wind; (b) a similar earthen dry lot with a shade structure; and (c) a tie-stall barn with a concrete floor. In the barn, wheat straw was used as bedding material. Stalls were cleaned every day. The shade structure was 4.5 m wide, 16.5 m long and 3.5 m high orientated lengthwise in a north-south direction located near the centre of the dry lot. An additional shade structure providing 2.5 m^2 shade/cow was also provided over the feed trough. Unshaded water troughs, 2.0 × 0.5 × 0.4 m were provided in each camp while each cow in the tie-stall barn had access to a water trough.

While the cows were in the milking parlour, a complete diet consisting of lucerne hay, wheat, maize, wheat-bran and fishmeal providing 135 g CP/kg and 9.6 MJ ME/kg DM, was fed *ad libitum* in the feed troughs to the cows after removing refusals of the previous feeding. Feed and refusals were sampled and the DM content determined. In this way daily DM intakes were determined on a group basis for cows in the dry lots while the intakes of cows in the tie-stall barn were determined individually. Cows were milked twice daily at 05:00 and 15:30 in a milking parlour approximately 150 m from the dry lots. Milk production of each cow was recorded at every milking. Individual milk samples from cows were collected according to standard milk recording procedures at each milking on 12 non-consecutive days during the trial and analysed for fat, protein and lactose content with a Milko-scan Infrared Analyser. The somatic cell count of the milk of each cow was determined on the same sample with a Fossomatic cell counter. Daily maximum and minimum temperatures were recorded with a standard thermohydrograph inside a Stevenson screen at a weather station of the Agrometeorology Section of the Soil and Irrigation Research Institute located approximately 1.0 km from the experimental facilities. For 18 days (from day 33 to 50) during the experimental period, blood samples from the external jugular vein of cows in the different housing systems were collected daily at 15:15 just before milking. From the start of the experimental period cows had been accustomed to the procedure by taking them through the collecting chute and neck clamp daily. Heparinized vacutainers (10 cc) were used for blood sampling. Samples were kept in an ice bath until centrifugation to recover plasma. The plasma was then stored in a frozen state at –20 °C until analysed for thyroxine (T_4) and cortisol using Amerlex-M Radio-Immunoanalysis kits.

Differences between milk production and milk composition parameters were compared by analysis of variance using the Statgraphics statistical package. A three-week preliminary period was used as covariate for milk production and milk composition parameters. Body mass, feed intake, thyroxine and cortisol concentrations of blood plasma were compared by analysis of variance.

Climatological conditions during the trial were consistent with long-term weather data. Average daily maximum and minimum temperatures were 18.5 ± 4.0 and 8.7 ± 2.6 °C respectively. Ambient temperatures experienced during winter were within the thermoneutral zone for dairy cattle (–5 to 21 °C) (Johnson, 1985). Thermal fluctuations outside the thermoneutral (comfort) zone occurred on a short-term basis only. Rain was recorded on 22 days for a total rainfall of 180.6 mm during the experimental period. The average daily wind run was 100 ± 102.5 km/24 h indicating little wind overall. On rainy days, however, the daily wind run was higher (154.4 vs. 64.3 km/24 h) than on days with no rain. Owing to the wind chill factor, animals outside during winter may experience lower temperatures than recorded air temperatures. Skin temperatures recorded at the rump, flank and shoulder of cattle kept outside during winter in Scotland suggested that animals were still above their critical temperatures during daylight hours (Mitchell & Broadbent, 1983). Production parameters of cows in the different sheltering systems are presented in Table 1. Cows in the dry lot with a shade structure had higher ($P < 0.01$) feed intakes than cows in the dry lot with no protection and cows in the tie-stall barn. This is probably related to other factors like body mass rather than treatment. Except for the protein content of the milk of cows in the tie-stall and dry lot with a shade structure which differed ($P < 0.05$), there were no significant differences between treatments for milk production and milk composition.

Table 1 Average (SE) body mass, daily feed intake and production parameters (adjusted by covariates) of dairy cows in different sheltering systems during winter in a temperate climate

Parameter	Dry lot	Dry lot with shade structure	Tie-stall barn	*P*	LSD
Body mass (kg)	543.5 (31.5)	627.5 (43.6)	595.8 (35.2)	0.29	111.9
Feed intake (kg DM/day)	21.42 (0.26)^{a,b}	23.00 (0.18)^{a}	20.18 (0.16)^{c}	0.001	0.57
Milk production (kg/day)	23.94 (1.09)	23.25 (1.09)	23.86 (1.09)	0.89	3.30
Milk composition (%)					
Fat %	3.77 (0.19)	3.62 (0.19)	3.60 (0.19)	0.78	0.56
Protein %	3.45 (0.07)^{a,b}	3.63 (0.07)^{a}	3.37 (0.07)^{b}	0.07	0.22
Lactose %	5.04 (0.04)	5.11 (0.04)	5.06 (0.04)	0.43	0.11
SCC (× 1 000)	84.3 (24.7)	132.3 (44.0)	136.0 (70.5)	0.72	150.9

SCC: Somatic cell counts; SE: standard error; *P*: significance level; LSD: least significant difference; ^{a,b,c}: values in rows with different superscripts vary significantly ($P < 0.05$)

Although not significantly, SCC were higher in the tie-stall barn and dry lot with a shade structure, probably indicating poor environmental conditions in the barn and underneath the shade structure. This seems to indicate that these sheltering facilities had, under local climatic conditions during winter, no advantage in terms of milk production and milk composition. This is in agreement with results obtained by Moran (1989) who found that food intake, milk yield and energetic efficiencies did not differ between cows in open lots or free stalls in a Mediterranean climate in Australia.

The annual milk yields of dairy cows in Chile in an experiment with three winter management systems, that is, no barn; cows kept in a barn at night and cows kept in a barn day and night, were 3 014, 3 430 and 2 897 kg ($P < 0.05$) respectively, indicating that lack of a barn is not a limiting factor on milk production during winter (Ljubo Goic, 1989). Although results are not directly comparable, feedlot cattle with access to an overhead shelter during winter in Iowa, USA, gained ($P < 0.01$) 0.17 kg/day faster and more efficiently (4.15 vs. 4.77 kg feed/kg gain) than cattle without shelter (Hoffman & Self, 1970). No effect on average daily feed intake (12.08 vs. 12.12 kg/day) was however observed. They concluded that heavy rainfall might reduce food intake, but that cattle find it possible to compensate for this reduction. Only heavy rainfall over long periods might depress feed intake to a marked degree. Morrison *et al.* (1970) showed that during periods of mild weather during winter in California, a minimal difference in weight gain was observed. The greatest differences in performance occurred when wind and/or precipitation accompanied low temperatures. These authors therefore suggest that the value of an overhead shelter is questionable in areas where storms are short or relatively mild. In Canada feedlot cattle gained weight more rapidly when a windbreak fence or a shed was provided while no effect from shelter was found under winter conditions in California (Givens *et al.*, 1967 as cited by Hoffman & Self, 1970). The different results in Canada and California were probably due to differences in the length and intensity of winter storms in the two areas (Hoffman & Self, 1970). It seems that weather (temperature) *per se* determines the benefit of shelter on gain more than does month or season (Self, 1972).

It seems that the average daily milk production of cows was affected negatively only on days when highly concentrated rainfall (average 21.2 mm/day over four days) occurred (Figure 1). On days with less rain, milk production was in some cases also negatively affected. Dragovich (1980) found no differences in milk production on days with rain and days without rain for grazing dairy cows on farms in a warm temperate climate in Australia. This response was attributed to the absence of extremely cold conditions (with regard to the comfort zone for dairy cows) and relatively brief duration of rain and cold conditions. The magnitude of production changes between the periods before, during and after low temperature stress periods was very small and the direction of change was also not consistent. A similar pattern was observed in the present trial.

The average plasma cortisol and thyroxine (T_4) concentrations of cows in the different sheltering systems are presented in Table 2. There were no significant ($P > 0.05$) differences between treatments for these physiological parameters. This is in contrast to Alvarez & Johnson (1973) who found that cattle exposed to acute cold had increased concentrations of plasma corticosteroids. According to Danzer & Mormède (1983) environmental stress activates the release of adreno-

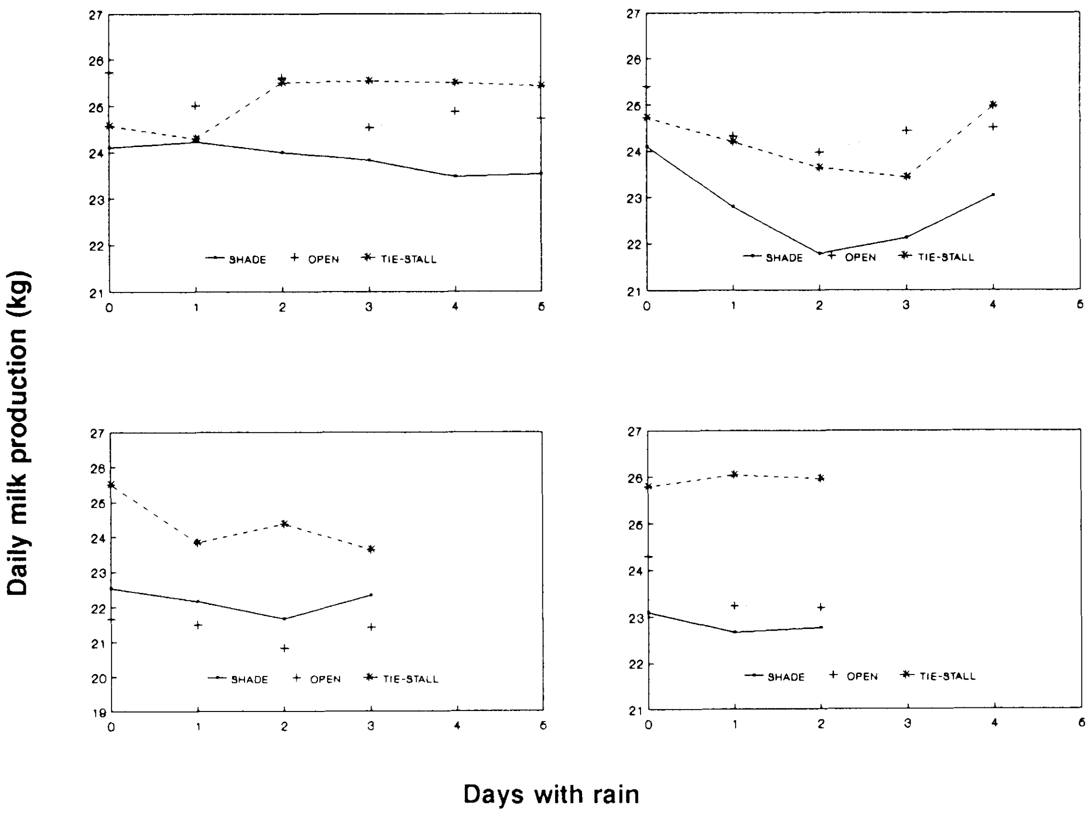

Figure 1 Effect of rain on a different number of days on the milk production of dairy cows in a temperate climate

Table 2 Average (SE) plasma cortisol and thyroxine (T_4) concentration of cows in different sheltering systems during winter in a temperate climate

Parameter	Open camp	Shade structure	Tie-stall barn	*P*	LSD
Cortisol (n mol/l)	27.19 (2.20)	25.30 (1.81)	28.24 (1.89)	0.58	5.95
Thyroxine (n mol/l)	65.50 (4.04)	70.08 (6.11)	73.53 (4.42)	0.53	15.89

SE: Standard error; *P*: Significance level; LSD: Least significant difference

corticotropic hormone (ACTH) which in turn activates the release of corticosteroids. It has therefore been proposed that animals that exhibit higher plasma corticosteroid concentrations are in a state of stress. With this information as background it seems that animals in the open camp with no protection against winter climatic conditions were not stressed more than cows with access to an overhead shelter or to cows inside a tie-stall barn.

Secretion of the thyroid hormone is increased in a cold environment (Thompson, 1973). Pratt & Wettemann (1986) found that in Angus × Hereford steers thyroid function changed at least two days after a change in air temperature occurred. Yousef & Johnson (1965b) as cited by Thompson (1973) also reported that the effect of an environment of 1 °C took about 36 hours to develop a change in thyroid activity. Thyroxine administration increases resistance to cold (Young, 1981). Increases in thyroid activity during cold depend on the severity and duration of cold stress. It seems therefore that, although cows in the present trial might have experienced cold stress when it rained, these periods were of short duration resulting in little effect on feed intake and stress levels.

A lack of response is probably an indication of how farm animals have developed effective ways of adapting to climatic stress (Danzer & Mormède, 1983). Farm animals adapt to cold by eating more and increasing heat production (Blaxter, 1977). Dairy cows are ruminants and therefore produce energy, methane gas and heat through fermentation. This heat is used to maintain body temperature in cold conditions. Dairy cows also have large muscle groups, good subcutaneous fat stores and thick hides while insulation is increased by developing thick winter hair coats (Blaxter, 1977; Broadbent, 1984). Experimental animals in this study were Dutch-Friesians which are large-framed animals. Their production were not as likely to be affected by low temperatures than would be the case for smaller framed animals like Jerseys (Dragovich, 1980). Under experimental conditions, in climatic chambers under constant cold conditions, it was found that the milk yield of Holstein-Friesian cattle fed *ad libitum* began to decline at environmental temperatures below −4 °C (Thompson, 1973). However, under natural conditions during winter days environmental temperature rarely falls below −4 °C, resulting in little reduction in milk yield. Webster (1981) maintains that low air temperatures *per se* are unlikely to cause intolerable stress on dairy cows in the temperate zones of the world. There are therefore no sound economic reasons for providing more environmental control than protection against excessive air movement and rain (Webster, 1981; Broadbent, 1984). A primary need for dairy cows is a liquid-free lying area. Cows will often choose to lie in a dry area exposed to the weather rather than to lie in a sheltered but wet area (Broadbent, 1984).

The effect of different shelters during winter on milk production, milk composition and some physiological parameters of Dutch-type Friesian cows was determined. Although feed intake differed between experimental groups, shelters had no effect on milk production and milk composition. Cortisol and thyroxine levels in the blood of cows in the different sheltering systems were also not affected ($P > 0.05$). The lack of response in production and physiological parameters could possibly be ascribed to the relatively mild climatic conditions usually experienced during the winter in the Western Cape. These results should however not be regarded as support for the poor environmental conditions that dairy cows in the Western Cape experience resulting from bad management and poor planning of dry-lot facilities. While climatic conditions are relatively mild and therefore may not directly affect milk production, the large number of cows in open camps and the concentrated rainfall during winter create poor conditions resulting in production losses from mastitis. Sufficient space for clean and dry sleeping areas for cows should be provided in dry-lot systems.

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