S. Afr. J. Anim. Sci. 12, 71 - 78 (1982)

STRESS AND ADAPTATION IN BEEF HEIFERS:

1. EFFECT OF PEN CONDITIONS ON ADRENAL CORTEX ACTIVITY OF SHORTHORN, AFRIKANER AND BONSMARA HEIFERS

Receipt of MS: 12-04-79

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(Key words: *Heifers, cortisol, pen conditions)*
(Sleutelwoorde: *Verse, kortisol, ingekraalde toestande)*

OPSOMMING:

SPANNING EN AANPASBAARHEID BY VLEISRASVERSE:
1. EFFEK VAN INGEKRAALDE TOESTANDE OP BYNIERSKORTEKSAKTIWITEIT VAN KORTHORING-, AFRIKANER- EN BONSMARAVERSE

Agtien verse, elk van die *Bos taurus* (Korthoring), *Bos indicus* (Afrikaner) en intermediêre (Bonsmara) tipe, is ingekraal teen 'n vloerspasie van 4,6 m^2 per vers. Dieselfde aantal verse op die veld het as kontrole gedien. Profiele van kortisolpeile is gedurende die winter- en somerseisoen verkry. Ingekraalde toestande het geen betekenisvolle effek op kortisolsekresie gedurende die winterseisoen gehad nie. Die ingekraalde verse het gedurende hierdie tydperk effense hoër waardes in die kraal as op die veld gehandhaaf. Daar was ook geen betekenisvolle verskille tussen rasse waargeneem nie alhoewel die Afrikanerverse oor die algemeen die hoogste kortisolwaardes in die kraal gehad het. Kortisolpeile van die Bonsmaraverse het egter die meeste variasie in die kraal en op veld getoon. Gedurende die somerseisoen het ingekraalde toestande ook geen effek op plasma kortisolpeile van die vleisrasverse gehad nie. Die Afrikaner- en Bonsmaraverse het hoër waardes op die veld as in die kraal gehandhaaf. Die teenoorgestelde het by die Korthoringverse voorgekom. 'n Verlenging van die ingekraalde periode vanaf 7 tot 14 weke het geen bykomende verskille in kortisolsekresie tussen behandelingsgroepe by Afrikaner- en Bonsmaraverse veroorsaak nie. Daarenteen het ingekraalde Korthoringverse veral gedurende die laaste 2 weke, hoër waardes as verse op die veld getoon.

SUMMARY:

Eighteen beef heifers, representing the *Bos taurus* (Shorthorn), *Bos indicus* (Afrikaner) and intermediate (Bonsmara) types, were confined to a pen with floor space of 4,6 m^2 per heifer. A similar number of heifers on the veld served as a control. Profiles of cortisol levels were obtained during the winter and summer seasons. Pen conditions had no significant effect on cortisol secretions of beef heifers during the winter. The heifers had slightly higher values in the pen than on the veld. No significant differences between breeds were noted, although the Afrikaner heifers generally tended to have the highest cortisol values under pen conditions. Cortisol levels of the Bonsmara heifers fluctuated the most in the pen and on the veld. Similarly, pen conditions had little effect on plasma cortisol concentrations during the summer season. Penned Afrikaner and Bonsmara heifers had higher levels than their counterparts on the veld, but the opposite was true in respect of the Shorthorn heifers. By extending the penning period from 7 to 14 weeks, cortisol levels in Afrikaner and Bonsmara heifers were not raised. During the last 2 weeks, however, cortisol differences between treatments were noted in Shorthorn heifers.

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Intensive beef production is defined as the growing and/or feeding of cattle under conditions of confinement in which all feed is carried to the animals (Preston & Willis, 1970). With an ever-increasing world population, available land for ranching, especially in developed countries, is decreasing and denser stocking or confinement of farm livestock has become a common feature of present-day animal production.

The tendency to intensify is already well-known to the pork and poultry farmers in the Republic of South Africa. It has been established, however, that increased animal density causes hypertrophy of the adrenals (Siegel, 1959a, b; 1960) or the occurrence of gastric ulcers (Selye, 1956; Kowalczyk, 1969) in pigs. The effect of increased density on beef animals and their responses, is not clear. Under higher animal density stress may exist, and may lead to a decrease in production (Coleman & Kaiser, 1974) or reproduction (Lockley, 1961). The aim of this study is to determine whether penning of beef heifers leads to stress, as indicated by plasma cortisol concentrations.

Procedure

Heifers between 15 and 18 months of age, and representing the Shorthorn (*Bos taurus*), Afrikaner (*Bos indicus*) and Bonsmara (intermediate) breeds were used in a switchback experimental design (Cochran & Cox, 1957) with 18 animals per treatment (Table 1). The design include 3 period and 2 treatments. The treatments represented either penned or free-grazing on a four-camp sourveld (veld type 44 : Acocks, 1975) grazing system. Half the number of animals were allocated to sequence $P_1V_2P_3$ representing a penned-veld-penned situation, while the other half were allocated to sequence $V_1P_2V_3$, or a veld-penned-veld situation. The suffixes indicated the periods. The animals were allocated at random to the treatments after being blocked for age and mass. The duration of each treatment lasted 7 weeks, and treatments were alternated during a 21-week trial period. The latter represented a winter period, from 2nd June to 26th October 1976.

In order to obviate a compensatory growth response in the summer, due to treatment differences during the winter, the animals were re-allocated to treatments before the start of the summer grazing period. Half the number of animals from each breed in treatment P_3 were allocated to treatment P_4, while the other half were allocated to treatment V_4. At the same time, animals from treatment V_3 were similarly allocated to treatments P_4 and V_4. The duration of the summer period also extended over 21 weeks, from 27th October 1976 to 22nd March 1977.

The group of heifers under pen conditions was kept in a kraal of 83 m^2. It was attempted to feed these animals in such a way that they maintained a body mass similar to those animals on the veld. *Eragrostis curvula* hay, as well as maize silage, were fed for this purpose. The results are illustrated in Fig. 1.

Blood samples were collected prior to commencement of the trial, directly after each period, and on day 2, 21 and 49 of each period. Care was taken to minimise distur-

Table 1

Experimental design

	WINTER SEASON (2 June 1976 – 26 October 1976)						SUMMER SEASON 27 October 1976 – 22 March 1977)					
	Treatment 1			Treatment 2			Treatment 1			Treatment 2		
	Period			Period			Period			Period		
	1	2	3	1	2	3	1	2	3	1	2	3
Shorthorn	P_1	V_2	P_3	V_1	P_2	V_3	P_4	V_5	P_6	V_4	P_5	V_6
Afrikaner	P_1	V_2	P_3	V_1	P_2	V_3	P_4	V_5	P_6	V_4	P_5	V_6
Bonsmara	P_1	V_2	P_3	V_1	P_2	V_3	P_4	V_5	P_6	V_4	P_5	V_6

P = Pen conditions

V = Veld conditions

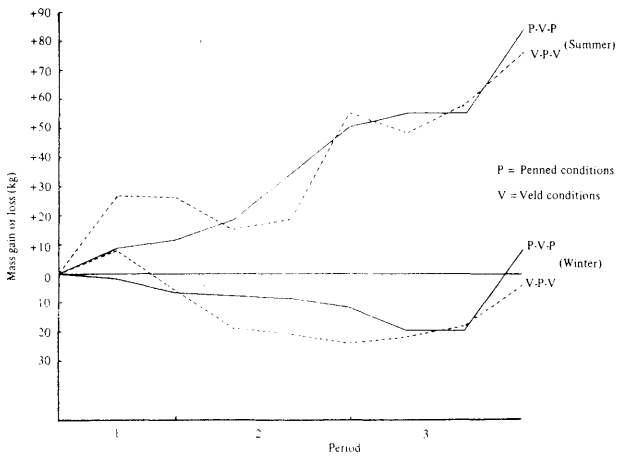

Fig. 1 *Mass gain or loss of beef heifers under penned and veld conditions*

bance of the heifers during sampling. Blood samples, taken from the jugular vein of the animals at 09h00, were collected in glass bottles containing heparin. The plasma was stored at $-15^{o}C$ until assayed for plasma cortisol concentrations by the competitive protein binding assay technique (Cortpac kits)*.

Results

Winter season

At the onset of the experiment in the winter the mean cortisol concentrations of the plasma of Shorthorn, Afrikaner and Bonsmara heifers were 30,1; 40,0 and 41,7 ng/ml, whilst the body masses were 276, 235 and 290 kg respectively. The animals lost 7% of their initial body mass on average, and were in a state of sub-maintenance nutrition for 87% of the 21 week trial period (Fig. 1). At termination, Afrikaner heifers had lost 8,5 kg, whilst the Shorthorn and Bonsmara heifers gained 13,3 and 11,2 kg per heifer respectively.

Although the plasma cortisol concentration of Shorthorn, Afrikaner and Bonsmara heifers confined to pen conditions of 4,6 m^2 per animal were respectively 2,5; 6,8 and 2,1 ng/ml higher than those under veld conditions, these differences were not significant. Mean cortisol levels for each period are presented in Table 2.

The variation in plasma cortisol concentration for the 3 breeds between periods of confinement and periods of extensive grazing is presented in Fig. 2, whereas a comparison of the breeds is shown in Fig. 3. These figures indicate that penning tended to increase cortisol levels whereas veld grazing resulted in a decrease during the sequence of penning, veld grazing, penning.

Summer season

With the continuation of the experiment at the onset of the summer season, the respective body masses for Shorthorn, Afrikaner and Bonsmara heifers were 289, 227 and 301 kg. The animals gained on average 26% in body mass with individual breed gains being 74, 67 and 73 kg respectively at the termination of the summer phase of the experiment.

Table 2

Comparison of cortisol levels between heifers in the and on the veld (ng/ml) – winter season

Breed	No	Treatment	Period 1	Period 2	Period 3
Shornhorn	6	Kraal	27,517 ± 4,869	24,517 ± 6,163	21,333 ± 5,776
	6	Veld	28,583	17,2167	16,917
		Significance	N.S.	N.S.	N.S.
Afrikaner	6	Kraal	29,583 ± 2,093	23,667 ± 3,950	21,533 ± 3,161
	6	Veld	32,233	21,283	17,017
		Significance	N.S.	N.S.	N.S.
Bonsmara	6	Kraal	31,350 ± 5,366	17,283 ± 3,236	23,933 ± 4,242
	6	Veld	31,067	19,533	17,617
		Significance	N.S.	N.S.	N.S.

N.S. = non significant

*The Radiochemical Centre, Amersham, U.K.

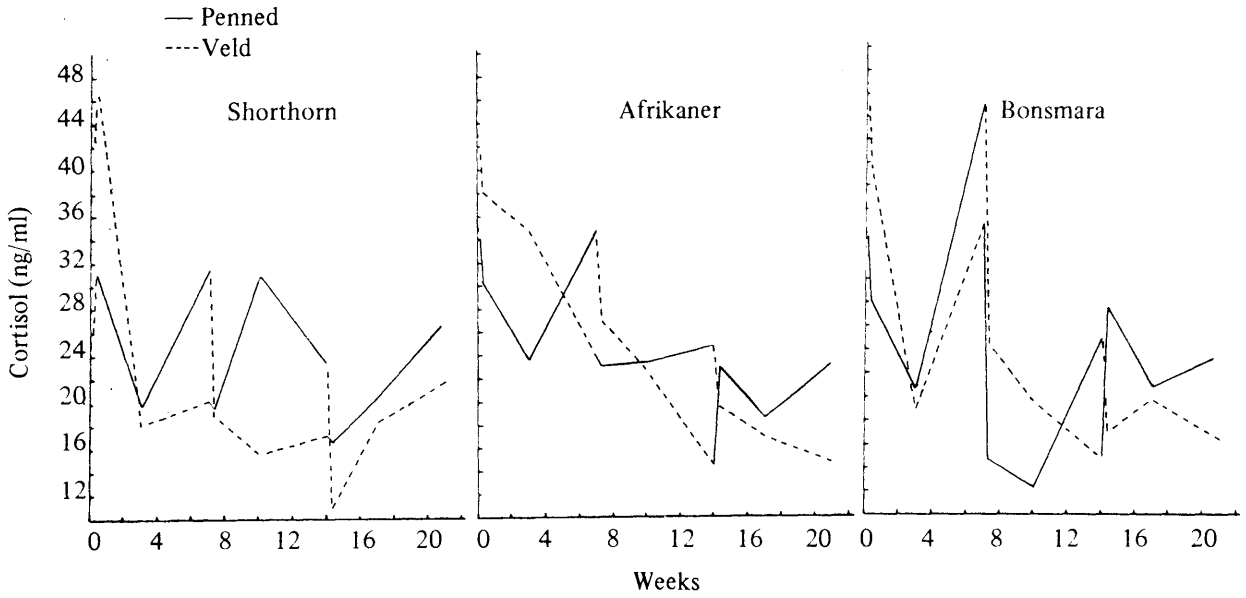

Fig. 2 *Cortisol secretions of Shorthorn, Afrikaner and Bonsmara heifers under penned and veld conditions.*

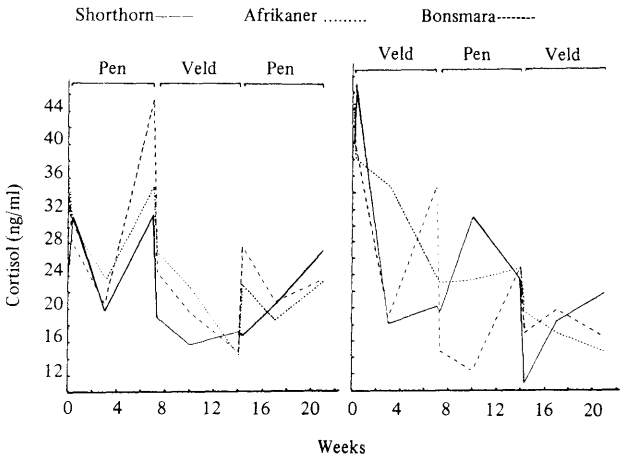

Fig. 3 *Plasma cortisol profiles of beef heifers under penned and veld conditions during the winter.*

During this season, penning again had no significant effect on the plasma cortisol concentrations of either of the breeds. Plasma cortisol concentration of Shorthorn heifers in confinement was 5,2 ng/ml higher than their counterparts on the veld. In contrast, cortisol values of the Afrikaner and Bonsmara heifers on the veld were, respectively, 10,8 and 2,3 ng/ml higher than those in the pens. Although penning increased plasma cortisol concentration significantly ($P < 0,05$) on 3 occasions, the effect of penning was variable and on one occasion had a significant reversed effect ($P < 0,01$) (Table 3). During the whole summer season, penning had a reduced influence on adrenal cortex activity of the 3 breeds (Fig. 4); the Shorthorn heifers showed the highest and the Bonsmaras the lowest activity (Fig. 5). These variations realised extreme values within breeds and to such an extent that reversed effects of penning occurred in individual heifers within the same breed (Fig. 6).

The effect of prolonged penning of the heifers is summarised in Fig. 7.

Discussion

Although not significant, cortisol levels of the Afrikaner and Bonsmara heifers were 13,3 and 13,9% higher than those of the Shorthorn heifers at the onset of the experiment. Van der Westhuysen (1973) found that plasma cortisol concentration of Afrikaner bulls was 11,9% higher than that of Simmentaler bulls, and that Aberdeen Angus steers had a significantly lower plasma cortisol level than Mashona steers. Thus, there is a tendency for *Bos indicus* types to show higher adrenal cortex activity than *Bos taurus* types. Judged from the cortisol levels of the Bonsmara heifers, this breed resembles the *Bos indicus* types.

The effect of penning tended to increase plasma cortisol concentrations of the heifers, but the variation within breeds overrode the significance of these effects. During the winter, penned conditions caused a greater increase of cortisol secretion in Afrikaner heifers than in the other two breeds. In addition, the Afrikaner heifers lost 8,5 kg per heifer during this season which may imply that these heifers were under slight stress. However, this condition was eliminated during the summer season, and the heifers adjusted to pen conditions.

Most of the studies on the effects of increased animal population density on stock production are fragmentary and evidence is based mainly on studies with laboratory animals. By using the mass of the adrenal gland as an indicator of stress, it was found that grouping of small animals led to an enlargement of the adrenal gland

Table 3

A comparison of cortisol levels between heifers in the pen and on the veld (ng/ml) – summer season

Breeds	No	Treatment	Period 1	Period 2	Period 3
Shorthorn	6	Kraal	23,867 ± 5,936	16,617 ± 2,842	19,050 ± 3,207
	6	Veld	15,317	21,867	11,917
		Significance	N.S.	N.S.	N.S.
Afrikaner	6	Kraal	19,283 ± 1,427	14,217 ± 1,783	16,817 ± 1,407
	6	Veld	14,550	23,0833	12,300
		Significance	P < 0,05	P< 0,01	P < 0,05
Bonsmara	6	Kraal	18,200 ± 1,640	13,067 ± 2,220	14,850 ± 1,915
	6	Veld	11,033	19,233	13,167
		Significance	P <0,05	N.S	N.S.

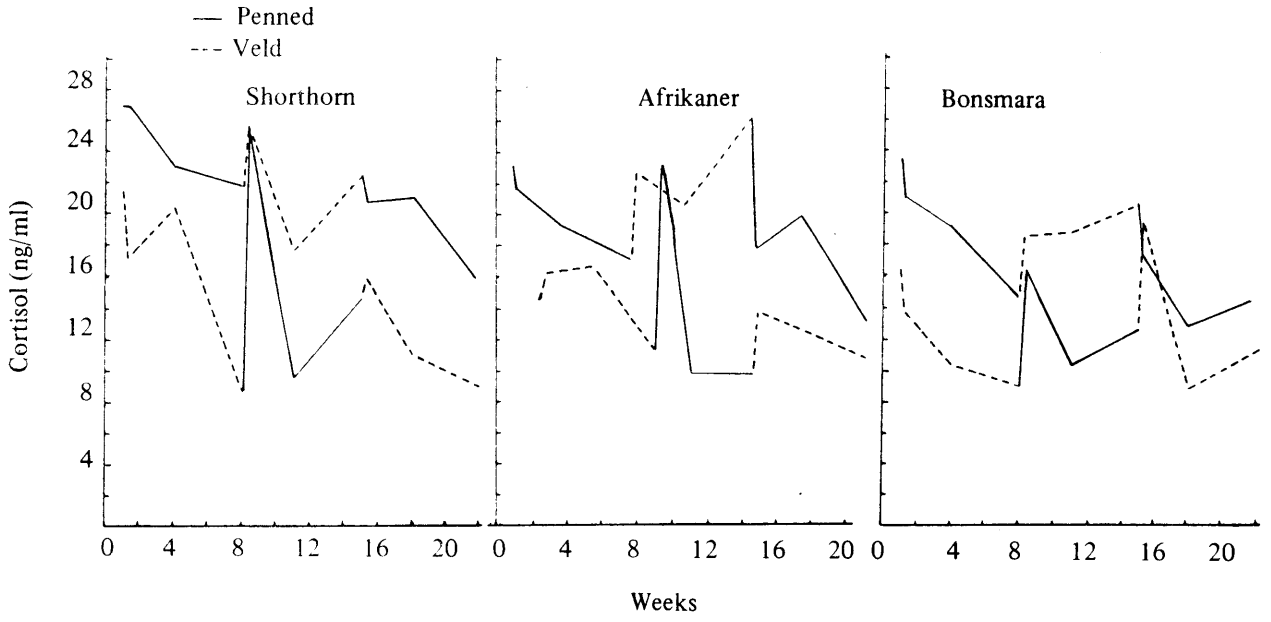

Fig. 4 *Plasma cortisol profiles of Shorthorn, Afrikaner and Bonsmara heifers under penned and veld conditions.*

(Christian & Davis, 1956; Louch, 1956; Christian, 1959). However, other authors found no difference in adrenal gland weight between high and low population densities of various mammals (Chitty, 1955, 1961; Southwick, 1958, 1964; Bendell 1959; McKeever, 1959; Clough, 1965). In fact, Thompson (1954) reported that adrenal glands were heavier in low concentrations of lemmus than in high population densities. More recently, results obtained with lactating Holstein cows showed increased glucocorticoid response with reduced stall numbers (Friend, Polan, Gwazdauskas & Heald, 1977; Friend, Gwazdauskas & Polan, 1979).

In spite of the foregoing contraditions, it can be expected that the effect of stress upon animals would

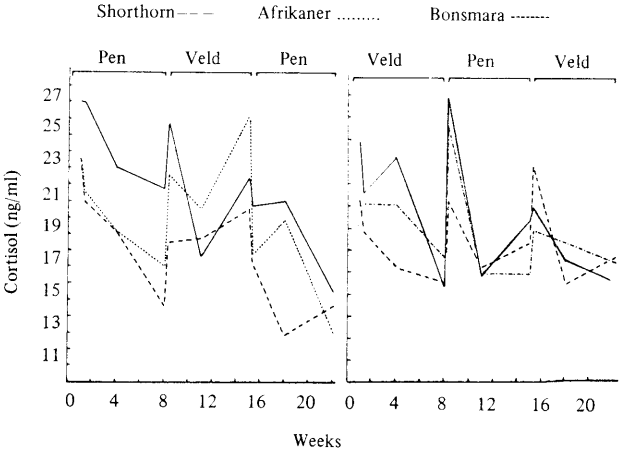

Fig. 5 *Plasma cortisol profiles of beef heifers under pen and veld conditions during the summer.*

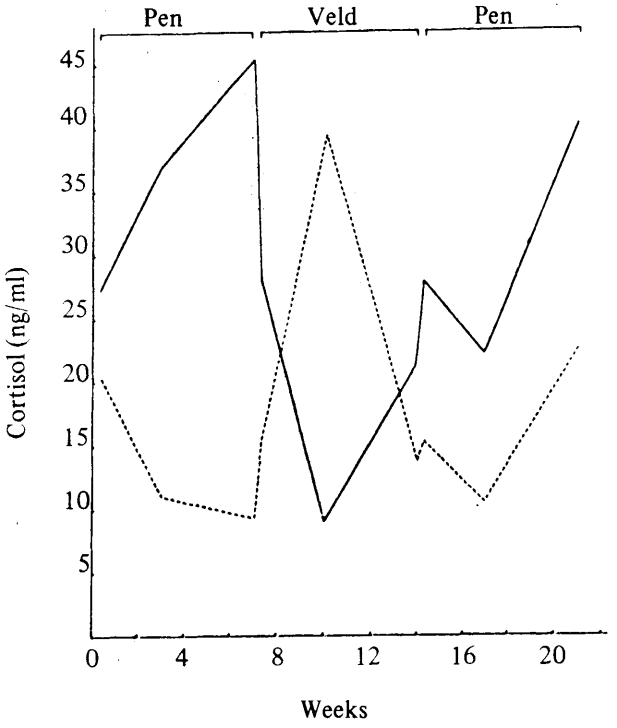

Fig. 6 *Variation in cortisol secretion in two Shorthorn heifers under identical conditions.*

probably be determined by the degree to which population density is increased. The present study indicated that availability of feed, as well as breed and/or temperament of the heifers, played an important part in determining minimum floor space. When animals are grouped, a social order is established. Should this group be enlarged while floor space is maintained, a situation is created where subordinate animals cannot easily avoid those of higher rank. Conflict thus increases, and stress is placed on the subordinate animals. In this study, the response of plasma cortisol concentration to penning is ascribed to this influence of dominance, especially at the feeding and water troughs. However, the non-significance of this response indicates that a floor space of 4,6 m^2 per heifer was sufficient to obviate large-scale dominance by higher ranking animals. It is apparent that the *Bos taurus* breed, having the lowest adrenal cortex activity and the highest mass gain over the period, was more suited to penning than the *Bos indicus* type. Although the cortisol concentration of the Bonsmara heifers generally resembled the *Bos inidcus* types, this breed was well adapted to both penned and free-grazing conditions, gaining only 2,1 and 1 kg per heifer less than Shorthorn heifers over the winter and summer seasons respectively. Wagner (1974) showed that movement of animals to a new environment may cause an increase in adrenal function. An increased urinary excretion of reducing corticoids in cattle for periods of 30 days after removal to a new environment was reported also by Holcombe (1957). In the present study, an increase in adrenal cortex activity was brought about during the winter only when heifers were moved from free-grazing to penned conditions (Fig. 2), thus underlining the influence of penning. During the summer season, increased cortisol concentration occurred either when heifers were penned, or moved to free-grazing conditions (Fig. 4).

The fact that all the heifers did not respond similarly to penned and veld conditions (Fig. 6), is in agreement with results obtained by Arave, Erb & Albright (1973). By reducing floor space from 9,3 to 2,3 m^2 per cow, they found marked corticoid increases in some, but not all cows following the change. Extending the penning period from 7 to 14 weeks had no additional influence on cortisol concentration of the Afrikaner and Bonsmara heifers. Cortisol levels of Shorthorn heifers under penned and veld conditions followed approximately the same tendency, except from the 10th week of confinement onwards. The latter indicates that stress may be exerted on such heifers after a prolonged period of penning.

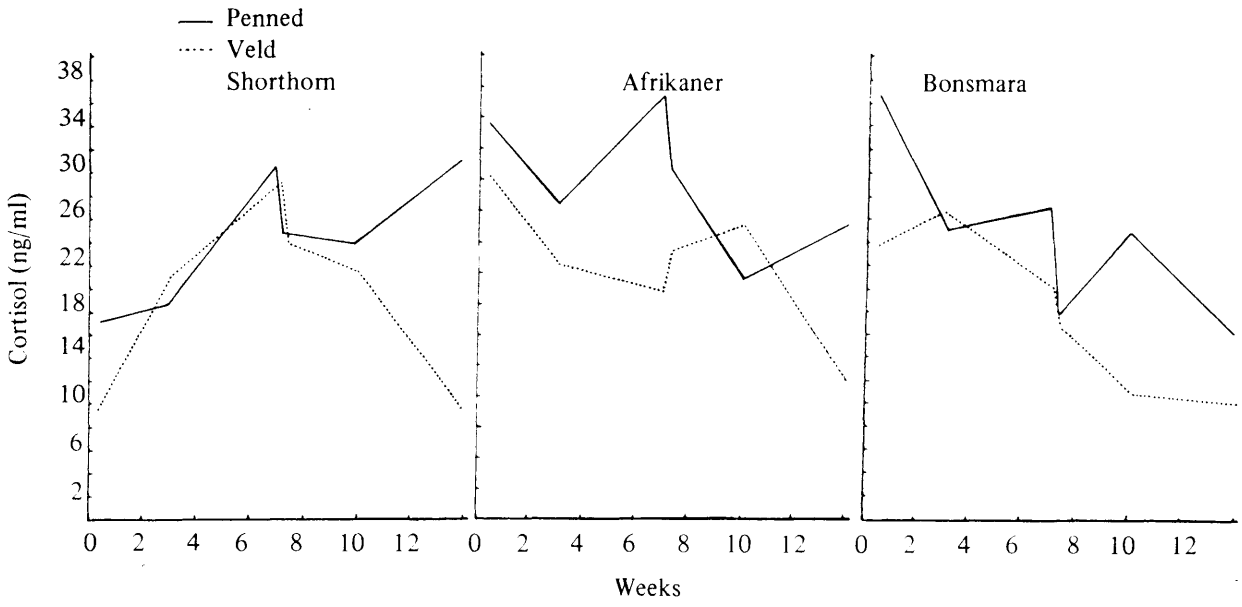

Fig. 7 *Cortisol secretions of Shorthorn, Afrikaner and Bonsmara heifers under penned and veld conditions for 14 weeks.*

Conclusions

Penning of growing beef heifers with a mass of approximately 270 kg at 4,6 m^2 per heifer caused a non-significant but definite rise in plasma cortisol concentrations of such heifers. The pronounced influence of penning on cortisol concentrations of *Bos indicus* heifers indicates that floor space should not be reduced beyond 4,6 m^2 per heifer. However, it is expected that factors such as availability of feed, breed and temperament would interact to determine optimum floor space.

The high variation of cortisol concentration between and within breeds, such as was found in this study, rendered this parameter less suitable as an exact indicator of stress or to use these values as physiological norms to express stress effects under pen conditions. It was also difficult to gauge at which level of cortisol production stress effects become operational either within or between breeds.

Acknowledgements

The authors wish to thank Mr J. Grobler for technical assistance, Mr D.W.W.Q. Smith for his assistance in statistical analysis, and Dr D. Wentzel (Grootfontein College of Agriculture) for providing facilities for cortisol determinations.

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