Growth response, sexual development, carcass and meat quality of zinc tannate treated bulls

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Effects of intratesticularly administered zinc tannate (ZT) on growth performance, sexual development, slaughter, carcass and meat quality characteristics of young bull calves (~225 kg, 7 months old) were investigated. Comparisons were made across a three (treatments: ZT animals, intact bulls and burdizzo-castrated steers) by two (slaughter masses: 350 and 440 kg) factorial arrangement. In a separate trial, sexual male behaviour of ZT animals was compared to that of bulls, surgically- and burdizzo-castrated animals. Bulls (B) and ZT animals gained mass faster ($P < 0.05$) and more efficiently ($P < 0.05$) and produced carcasses with less total fat ($P < 0.05$) and more muscle ($P < 0.05$) than steers (S). These differences coincided with higher plasma testosterone levels ($P < 0.05$) in the B and ZT animals in comparison with that of steers. However, higher relative mass and meat distribution in the forequarters, lower meat quality (tenderness) and persistent bull-like behaviour of ZT animals were detrimental. These characteristics could also be ascribed to retained testosterone production. ZT administration caused excessive swelling of the testes and necrosis of the testis parenchyma, especially in the direct vicinity of application. No live sperm could be detected 30 days after application of ZT. Sufficient Leydig cells were left intact, however, to maintain plasma testosterone levels comparable to that of bulls ($P > 0.05$). Signs of pain and discomfort were observed directly after treatment with ZT. The study of the behaviour of ZT animals in a feedlot, indicated that they persisted with bulling and mounting behaviour normally associated with intact animals. Although ZT offers positive growth response and therefore seems to be a promising alternative to surgical or burdizzo castration, the negative side-effects hamper its further development.

Die effek van sinktannaat (ZT) op die groeiprestasie, geslagsontwikkeling, slageienskappe, karkas- en vleiskwaliteits-eienskappe van jong bulle (~225 kg, 7 maande oud) wat intra-testikulêr met sinktannaat behandel is, is ondersoek. Vergelykings is by wyse van 'n drie (ZT-diere, bulle en burdizzo-gekastreerde osse) by twee (350 kg en 440 kg) faktoriaalontwerp getref. In 'n afsonderlike proef is die seksuele manlike gedrag van ZT-diere met dié van intakte bulle, chirurgies- en burdizzo-gekastreerde diere vergelyk. Bulle (B) en ZT-diere het vinniger ($P < 0.05$) en meer doeltreffend ($P < 0.05$) gegroei en karkasse met minder totale vet ($P < 0.05$) en meer spier ($P < 0.05$) as dié van osse (S) geproduseer. Die verskil tussen bulle en ZT-diere enersyds en osse andersyds, het gepaard gegaan met hoër plasma-testosteroonvlakke ($P < 0.05$) vir eersgenoemde twee groepe. Die relatief hoër verspreiding van karkasmassa en vleis in die voorkwart, laer vleiskwaliteit (sagtheid) en voortgesette seksuele manlike gedrag, was egter minder aanvaarbare eienskappe van die ZT-diere. Hierdie eienskappe kan ook aan die voortgesette produksie van testosteroon toegeskryf word. Die toediening van ZT het uitermatige swelling van die testis tot gevolg gehad en tot nekrose van die testisparenchiem aanleiding gegee, veral in die direkte omgewing van toediening. Geen lewende sperme kon 30 dae na behandeling met ZT gevind word nie. Die Leydigselle het egter tot so 'n mate behoue gebly dat die plasmatestosteroonvlakke met dié van bulle vergelyk het ($P > 0.05$). Direk na toediening van ZT is tekens van pyn en ongemak by behandelde diere waargeneem. Die studie in verband met seksuele manlike gedrag van ZT-diere het getoon dat die normale kopstamp en ryery, wat normaalweg by intakte bulle voorkom, ook by ZT-diere waargeneem is. Alhoewel ZT na 'n belowende plaasvervanger vir chirurgiese en burdizzo-kastrasie lyk, diskrediteer die negatiewe aspekte van die produk die verdere ontwikkeling daarvan.

Keywords: Carcass and meat quality, chemical castration, feed conversion, growth rate, libido, meat distribution, plasma testosterone, sexual behaviour, zinc tannate.

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Introduction

Advantages of using intact males for meat production, as a result of endogenous testosterone levels, are well documented: bulls growing faster and having a higher feed conversion efficiency than steers slaughtered at the same mass or fed over the same period period of time (Seideman *et al.*, 1982; Jones *et al.*, 1984). In addition, bull meat is leaner than that from steers of the same slaughter or carcass mass (Seideman *et al.*, 1982). Bulls can therefore be fed to higher optimum slaughter mass before attaining similar carcass fatness levels as steers. Related disadvantages of bull meat production are also well-known, in that although bulls have a higher muscle:bone ratio and their carcasses are leaner (common carcass mass) than those of steers, bull carcasses are characterized by a relatively smaller proportion of muscle in the more expensive hindquarter cuts compared to steer carcasses. This is due to relatively more

muscle development in the forequarter of bulls, compared with steers. Furthermore, bull meat is generally less tender than that of steers of the same physiological (equal carcass fatness) and chronological age (Crouse *et al.*, 1985; Burson *et al.*, 1986). This phenomenon has been ascribed to the higher content and lower solubility of collagen in the cooked muscles of bulls (Cross *et al.*, 1984). The solubility of collagen generally decreases with age, but this decrease occurs at a higher rate in bulls than in steers. In addition, bull meat is often darker and of coarser grain than steer meat, with a greater tendency to become dark, firm and dry (DFD) (Price & Tennessen, 1981). Bull carcasses may also be more bruised, because of temperament.

Advantages as well as disadvantages of producing meat with intact male animals are due to their production of testosterone (Seideman *et al.*, 982. Cross *et al.*, 1984). Removal of the source of testosterone through conventional castration (i.e. removal of the testes or burdizzo castration) alleviates the problems but also cancells the benefits. It can be argued that, on balance, advantages of intact males outweigh the disadvantages. Accordingly several researchers have attempted to sterilize animals (to prevent unwanted pregnancies) without completely destroying the Leydig cells; the latter being the primary source of testosterone. Several techniques have emerged. Short scrotum castration involves pushing the testicles back through the inguinal canal into the abdominal cavity. The elevated temperature of the cavity suppresses spermatogenesis (Weis *et al.*, 1975; Naudé *et al.*, 1983). The parenchyma may also be physically removed through an incision in the testes (Baiburtcjan, 1963).

Chemical suppression of spermatogenesis has been achieved by injecting solutions into the testes. Ethanol (Freeman, 1975) and calcium chloride (Bowman *et al.*, 1978) caused scar tissue to develop, which blocked the epididymis; cadmium chloride and calcium chloride selectively destroyed the germinal epithelium (Parizek, 1960; Kar & Das, 1962); a 6% tannic acid and zinc sulphate solution totally destroyed the germinal epithelium (Fahim, 1978, as cited by Moeller, 1980; Moeller, 1980), but most of the Leydig cells remained functional. Tannic acid and zinc sulphate treated bulls grew faster and more efficiently than did steers.

Although zinc tannate showed promising results regarding growth response, its effect on the animal's well-being (both during and after treatment) and on the physiology of the testes is not well documented. In addition, zinc tannate's effect on meat and carcass quality is not quantified. Consequently, a trial was conducted to assess these parameters in young bulls. This experiment investigates the effect of zinc tannate on the growth response, sexual behaviour and development, and carcass and meat quality of young bulls.

Materials and Methods

Sixty Drakensberger bulls, approximately 7 months of age and with a mean mass of 225 kg, were allocated to three treatments: they were either castrated with a burdizzo (S) (n = 20), injected intratesticularly with a 6% solution of zinc tannate (ZT) (n = 20) or left intact (B) (n = 20). Animals within each treatment group were slaughtered at one of two different target masses, viz. 350 kg and 440 kg. Animals were fed a high-energy diet (12.4 MJ ME/kg DM) *ad libitum* in individual pens. Individual feed intake (dry-matter basis) and live mass were recorded weekly. Average daily gain (ADG) and feed conversion ratios (FCR) were calculated on both a live- and carcass-mass basis for each treatment-slaughter mass group (Table 1)

Venous blood samples, collected from the jugular vein of each animal of the 440 kg slaughter group, were drawn on the first day of the trial and every 28 days thereafter for five months (animals' age: 12 months). Three samples, drawn 30 min apart, were mixed to obtain a representative sample. The blood was collected in heparinized 'vac-u-test' tubes,

Table 2 Mean values and standard deviations for plasma testosterone levels at different ages

Parameter	Age (months)	Treatment		
		Steer	ZT	Bull
Testosterone (ng/ml)	8	10 ± 130[a]	430 ± 130[b]	450 ± 130[b]
	9	10 ± 210[a]	420 ± 210[ab]	830 ± 210[b]
	10	20 ± 250[a]	650 ± 250[b]	890 ± 250[b]
	11	30 ± 290[a]	640 ± 290[a]	1470 ± 310[b]
	12	10 ± 340[a]	990 ± 390[b]	1260 ± 410[b]

[a,b] Values in the same row, with different superscripts differ significantly ($P < 0.05$).

Table 1 Mean values and standard deviations for growth characteristics of slaughter groups and treatments

Parameter	Slaughter group		SL[1]	Treatment		
	350 kg	440 kg		Steer	ZT	Bull
ADG (g/day)						
Live	1204 ± 36	1235 ± 39	NS	1100 ± 47[a]	1235 ± 44[b]	1312 ± 47[b]
Carcass	842 ± 26	771 ± 27	*	739 ± 34[a]	821 ± 31[ab]	860 ± 33[b]
FCR (MJ ME/kg)						
Live	69.22 ± 1.55	72.29 ± 1.66	NS	77.12 ± 2.00[a]	68.20 ± 1.90[b]	66.90 ± 2.00[b]
Carcass	99.14 ± 2.53	116.24 ± 2.68	***	116.32 ± 3.31[a]	103.50 ± 3.05[b]	102.78 ± 3.22[b]

[1] Significance level: * = $P < 0.05$; *** = $P < 0.001$; NS = Non-significant ($P > 0.05$).

[a,b] Values in the same row, within the treatment, with different superscripts differ significantly ($P < 0.05$).

centrifuged in a Heraeus Labofuge centrifuge for 15 min at 3500 rpm and the plasma fraction was frozen at –20 °C. Plasma testosterone levels were determined by radioimmunoassay (Table 2). Semen was also collected (electro-ejaculator) from the same group every 28 days. Sperm concentration, motility, percentage live sperm (at collection) and abnormalities were recorded.

All ZT-treated animals were observed continuously for signs of discomfort and the testes were palpated to detect swelling or any other abnormality. Physical measurement of scrotal circumference of the live animal (every 28 days and post-slaughter) helped to determine the effect of ZT on testis development and quantify the amount of swelling, if present (Figure 1). Scrotal circumference prior to injection of the ZT solution served to indicate the volume of ZT applied (Table 3; Moeller, 1980). Testes and secondary sex organs (seminal vesicles and prostate) were removed during the slaughter process, the epididymis was separated and all the genitalia were weighed. Length and circumference of testes were measured (*tunica vaginalis* was removed) (Table 4). A sample of the core of each testis was removed and fixated in formalin, for histological examination of the effect of ZT on the different cell types of the parenchyma. Sperm concentration in the epididymis was estimated according to the method of Dott & Skinner (1967).

Carcasses were electrically stimulated (2 min at 500 V) immediately after exsanguination. Dressing percentage was expressed on a pre-slaughter mass basis (Table 5). Carcasses were chilled for 18 h at 0–7 °C, weighed and split. The right

Table 3 Dosage schedule for zinc tannate 6% (Moeller, 1980)

Scrotum circumference (cm)	Volume zinc tannate (ml/testicle)
16–17	3
18–19	4
20–24	5
25–29	6
30–34	7
35–37	8
38–40	9
40–60	10

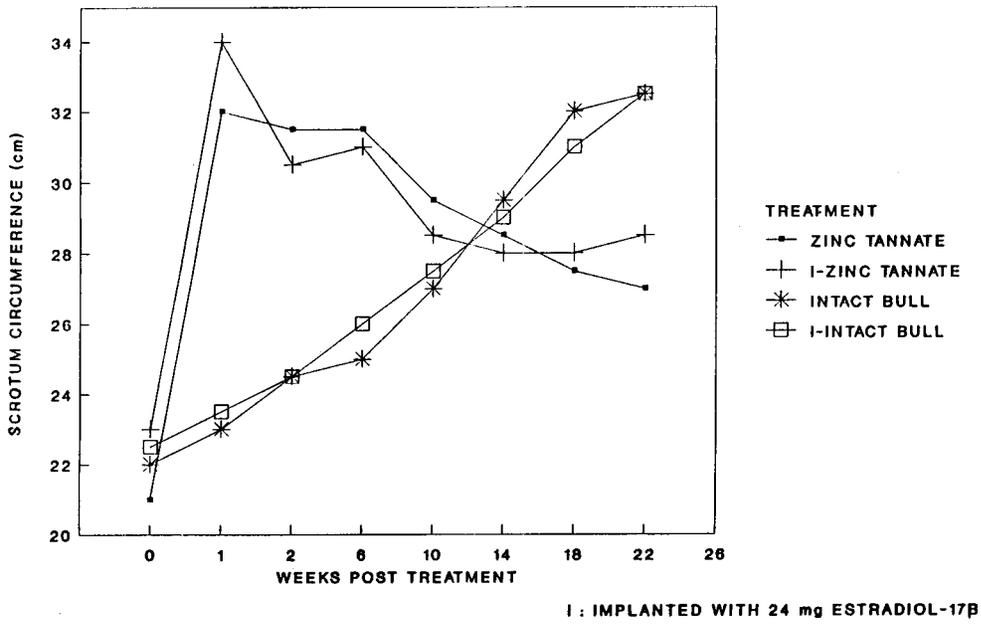

Figure 1 Change in the scrotum circumference of bulls and ZT animals.

Table 4 Mean values, *F* values and standard deviations for sex organ characteristics of the different slaughter and treatment groups

	Slaughter group			Treatment		
Parameter	350 kg	440 kg	SL[1]	ZT	Bull	SL[1]
Testis circumference (mm)	148 ± 4	153 ± 5	NS	130 ± 4	172 ± 5	***
Testis weight (g)	138.51 ± 9.26	141.39 ± 10.43	NS	76.84 ± 9.79	202.72 ± 9.79	***
Epididymis weight (g)	11.42 ± 0.87	13.37 ± 0.98	NS	9.54 ± 0.92	15.02 ± 0.92	***
Seminal vesicle weight (g)	16.57 ± 1.22	22.29 ± 1.38	**	18.31 ± 1.29	19.88 ± 1.29	NS
Prostate weight (g)	1.57 ± 0.11	2.22 ± 0.12	***	1.92 ± 0.12	1.79 ± 0.12	NS

[1] Significance level: ** = $P < 0.01$; *** = $P < 0.001$; NS = Non-significant ($P > 0.05$).

Table 5 Mean values standard deviations for slaughter animal and carcass quality characteristics of slaughter and treatment groups

	Slaughter group			Treatment		
Parameter	350 kg	440 kg	SL[1]	Steer	ZT	Bull
Dressing percentage						
Pre-slaughter mass	58.55 ± 0.23	58.52 ± 0.25	NS	58.99 ± 0.30[a]	58.37 ± 0.28[a]	58.28 ± 0.30[a]
Carcass composition (%)						
Dissection:						
Subcutaneous fat	4.38 ± 0.23	5.54 ± 0.24	**	5.37 ± 0.29[a]	5.23 ± 0.28[a]	4.10 ± 0.29[b]
Meat	80.27 ± 0.23	79.68 ± 0.25	NS	79.37 ± 0.30[a]	79.76 ± 0.29[a]	80.87 ± 0.31[b]
Bone	15.36 ± 0.19	14.93 ± 0.20	NS	15.26 ± 0.25	15.00 ± 0.23	15.22 ± 0.25
Calculated:[1]						
Total carcass fat	16.77 ± 0.63	20.74 ± 0.68	***	20.24 ± 0.82[a]	18.12 ± 0.77[ab]	17.53 ± 0.82[b]
Muscle	67.57 ± 0.64	64.26 ± 0.68	*	64.40 ± 0.82[a]	66.58 ± 0.78[ab]	67.06 ± 0.82[b]
Tissue distribution						
Hindquarter percentage	50.22 ± 0.22	49.65 ± 0.23	NS	50.58 ± 0.29[a]	49.75 ± 0.27[b]	49.58 ± 0.28[b]
Meat in more expensive cuts (%)[2]	43.53 ± 0.19	41.49 ± 0.21	***	42.71 ± 0.25	42.57 ± 0.23	42.47 ± 0.25
Meat in less expensive cuts (%)[3]	28.53 ± 0.89	30.22 ± 0.85	**	26.34 ± 1.09[a]	31.44 ± 0.95[b]	31.47 ± 1,06[b]

[1] Significance level: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; NS = Non-significant ($P > 0.05$).

[a,b] Values in the same row and same treatment with different superscripts differ significantly.

[1] According to Naudé (1972).

[2] More expensive cuts: prime rib, wingrib, loin, rump, topside, silverside, thick flank.

[3] Less expensive cuts: chuck, shoulder, neck.

sides were quartered, the quarters weighed and then cut into 15 wholesale cuts. The latter were deboned and subcutaneous fat was removed. The composition of each cut and the whole carcass side and the distribution of bone, meat and subcutaneous fat on the carcass side were determined from the mass of the various tissues (Table 5). The lean meat and subcutaneous fat of the prime rib cut were ground, mixed and proximately analysed for percentage protein, moisture, ash and fat (AOAC, 1985). As the prime rib cut is highly related to the carcass composition, the percentages muscle and total fat were calculated from the chemical (fat, ash, protein, moisture) and physical composition of this cut (Naudé, 1972).

The *M longissimus thoracis* (LT) of the prime rib and of the whole wingrib cut were removed from the left side, vacuum packed and aged for seven days at 0–7 °C. They were then frozen at –20 °C until analysed respectively for collagen content and solubility (Bergmann & Loxley, 1963; Hill, 1966; Weber, 1973; Heinze *et al.*, 1986) and sensory and physical parameters (Table 6).

Wing rib cuts were thawed at 7 °C and oven roasted (oven temperature = 160 °C) to an internal temperature of 70 °C. A ten-member trained taste panel evaluated small cubes of LT (1 × 1 × 1 cm) for tenderness and residue, according to a six point Lidart-type scale in which 6 indicates the highest

Table 6 Mean values and standard deviations for certain meat quality characteristics of slaughter group × treatment interactions

	Slaughter group					
	350 kg			440 kg		
Parameter	Steer	ZT	Bull	Steer	ZT	Bull
Physical						
Shear force resistance (N)	94.59 ± 4.30[ab]	104.87 ± 4.30[a]	92.43 ± 4.30[b]	99.42 ± 5.14[a]	94.9 ± 4.81[a]	88.56 ± 5.14[a]
Collagen content[1]	3.02 ± 0.09[a]	3.45 ± 0.09[b]	3.45 ± 0.09[b]	3.25 ± 0.11[a]	3.18 ± 0.09[a]	3.29 ± 0.11[a]
Collagen solubility (%)	22.88 ± 1.20[a]	24.68 ± 1.20[ab]	26.32 ± 1.20[b]	24.14 ± 1.34[a]	24.91 ± 1.20[a]	22.76 ± 1.34[a]
Sensory						
Tenderness	4.02 ± 0.12[a]	3.75 ± 0.12[a]	3.71 ± 0.12[a]	4.01 ± 0.14[a]	3.50 ± 0.13[b]	3.84 ± 0.14[ab]
Residue	3.49 ± 0.12[a]	3.17 ± 0.12[a]	3.30 ± 0.12[a]	3.66 ± 0.14[a]	3.09 ± 0.12[b]	3.40 ± 0.14[ab]

[a,b] Values in the same row same slaughter mass (350 kg and 440 kg) with different superscripts differ significantly ($P < 0.05$).

[1] Unit: (Hydroxyproline nitrogen/total nitrogen content of sample) × 1000.

positive score and 1 the lowest (Table 6). Shear force resistance of the oven-roasted meat was measured on an Instron Materials Testing Machine, equipped with a Warner-Bratzler shearing device. Shear force was expressed as the force needed (Newton) to shear the meat (2.54 cm diameter core) perpendicular to the fibres.

Secondary sexual behaviour of the ZT animals under feedlot conditions was compared to that of intact bulls and other conventionally castrated animals in a separate trial. For this purpose 28 animals were either castrated surgically (n = 7), with a burdizzo (n = 7), injected with ZT (n = 7) or left intact. Each group was kept in a pen and their behaviour (Figure 2: in terms of butting and mounting) was monitored for 60 min in the early morning and again in the afternoon, for 14 consecutive days after the respective treatments.

Data were statistically analysed by analysis of variance for a 3 (treatment) × 2 (slaughter mass) factorial design. The main effects were tested for significance. Means were separated by Student's t test (Snedecor & Cochran, 1980) when a significant treatment effect was observed.

Discussion

Growth response and carcass quality characteristics

Bulls and ZT animals grew significantly ($P < 0.05$) faster and more efficiently to the same target masses than did steers (Table 1). In terms of carcass gain, only bulls gained significantly ($P < 0.05$) faster than steers, although bulls and ZT animals had better FCRs (carcass) than steers ($P < 0.05$). Plasma testosterone levels (in animals between 8 and 12 months of age) were significantly ($P < 0.05$) higher for bulls and ZT animals (except for 9-month levels), compared to levels in steers (Table 2). Contrary to these results, Moeller (1980) reported that ZT animals had lower plasma testosterone levels and grew slower and less efficiently than bulls, whereas Fahim (1978, as cited by Moeller, 1980) and results of trials executed at the University of Missouri (1983, unpublished reports) indicated that ZT animals grew faster than bulls and steers.

Further support for the effect of the higher testosterone levels of bulls and ZT animals was evident from their significantly lower relative percentage of hindquarter (relatively more weight in the forequarters) compared to that of steers (Table 5). According to Forrest (1978) and Kocharkian & Tillotson (1957, as cited by Lawrie, 1979) C-19 steroids, such as testosterone, enhance protein retention in general, but also have specific receptors on certain muscles of the neck, shoulders, back, brisket, head and ribs. This causes the development of secondary sex characteristics in the forequarters of male animals. These results support this statement in that the relative meat yield of cuts in the neck and shoulder region of the bull and ZT groups (less expensive cuts) tended to be higher ($P > 0.05$) than that of the steer group, whilst yields of the back and hindleg did not differ significantly between the groups (Table 5). In addition, the total muscle yield of ZT animals did not differ from that of bulls or steers, but was associated more closely with that of bulls. The total carcass fat followed the same pattern, although in the opposing direction. Bulls and steers differed ($P < 0.05$) in total fat and muscle yield, since steers deposit fat (to the cost of muscle) at a higher rate and at an earlier stage than do bulls, owing to the lack of testosterone production by steers (Berg *et al.*, 1979). With regard to ZT animals, the current results are supported by Klastrup *et al.* (1984), with a similar pattern found by Naudé *et al.* (1983) for short scrotum bulls. Contrary to the pattern of total fat and muscle yield, the percentages subcutaneous fat and meat were respectively higher and lower ($P < 0.05$) in ZT animals and steers than in bulls.

Since the steer carcasses were fatter than those of the bull and ZT groups (common slaughter mass) one could have expected the dressing percentage to be in favour of the former, as reported by Hedrick *et al.* (1969). However, these findings are in accordance with those of Naudé *et al.* (1983) and Moeller (1980) who indicated no difference in dressing percentage between bulls, steers and short scrotum animals or between bulls and ZT animals (Table 5).

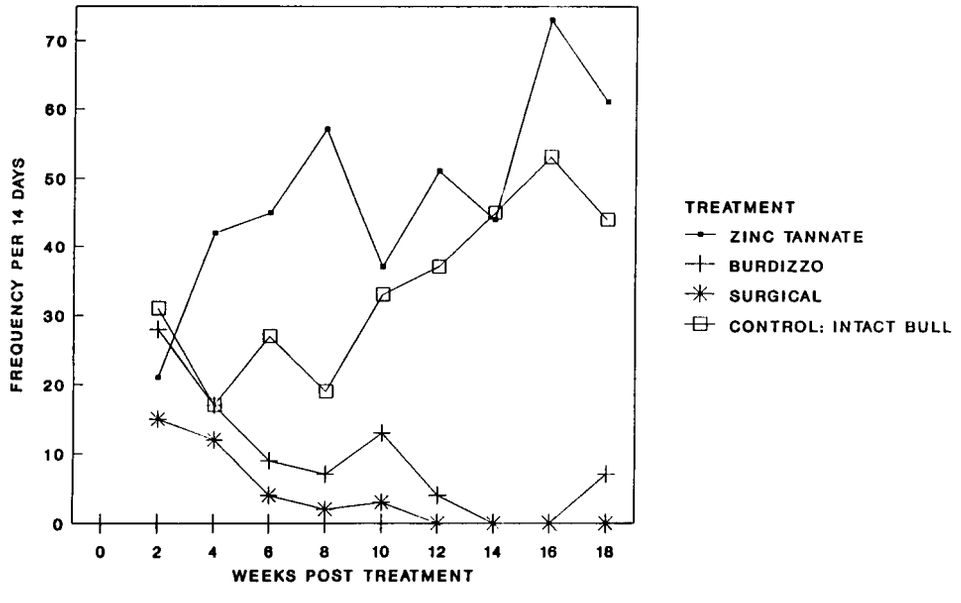

Figure 2 Comparison of the effect of different methods of castration on the frequency of mounting in feedlot cattle (Control group: intact bulls).

Meat quality characteristics

Meat quality is an important consideration if meat is produced from bulls. Although meat quality has a multi-dimensional nature, tenderness is probably the most important quality parameter affecting consumer acceptance of meat (Cross *et al*, 1986). Various methods of measuring meat tenderness exist and are interrelated, such as sensory evaluation, shear force resistance, and collagen content and solubility. Collagen solubility is correlated with the physical tenderness measurement (shear force resistance), while collagen content of meat is correlated with the sensory evaluation score for tenderness (Seideman, 1986). According to Cross *et al.* (1984) muscle collagen content and solubility, respectively, increase and decrease with age. The decrease in collagen solubility is related to the development of secondary sex characteristics in bulls, taking place at a higher rate in bulls than in steers as a result of higher plasma testosterone levels (Gerrard *et al.*, 1987). Bull meat, therefore, tends to become less tender at an earlier age than does steer meat.

In this study both bulls and ZT animals of the lower target mass group had higher testosterone levels and associated collagen content ($P < 0.05$) than did steers of the same group (Tables 2 & 6). However, in contrast to the findings of Seideman (1986), the sensory panel results indicated no significant difference in tenderness between the three groups. Shear force resistance values, on the other hand, indicated that the ZT meat was less tender than that of bulls ($P < 0.05$) and steers ($P > 0.05$) at 350 kg slaughter mass, although the collagen solubility of ZT animals ($P > 0.05$) and bulls ($P < 0.05$) was higher than that of steers.

At 440 kg slaughter mass there was no significant difference in collagen content or collagen solubility between the different groups, which suggests that the steers had reached a comparable stage of maturity to bulls. The sensory panel, however, scored ZT meat less tender ($P < 0.05$) than steer meat (bulls intermediate), whilst the shear force values did not differ significantly between treatment groups. No relationship between muscle collagen characteristics and meat tenderness has emerged from this study, as was found by Seideman (1986).

Sexual development

Zinc tannate contains tannic acid, a constringent which binds with the proteins albumin and globulin in the testis parenchyma (Lindholmer, 1974). Furthermore, soluble zinc salts are toxic to sperm, especially in the absence of albumin. ZT, therefore, will precipitate in the testis parenchyma and not spread any further, as was proven through macroscopic and microscopic examinations of testes in the current trial. Macroscopic examinations indicated that the ZT solution did not disseminate proportionally through the testis tissue, but instead coagulated with the cell contents in the direct vicinity of the application site and precipitated as crystals. These crystals caused abscesses, probably owing to the harsh action of a high concentration of ZT on a relatively small number of cells. The necrosis occupied 20 to 90% of tissue volume. Crystallization occurred as a result of the chemical characteristics of ZT. The latter is soluble at pH values below 3, but crystallizes quickly in the testis tissue at pH 7. In the area surrounding the sterile abscesses, which occurred in all but one of the treated animals, cell debris was observed through microscopic examinations of the tissue. Further removed from the abscess, the Sertoli and Leydig cells were less affected. No sperm production was observed. In strong contrast with macroscopic and microscopic examinations of ZT-injected testes of this trial, pathological reports from studies by Moeller (1980) and the University of Missouri (1983; unpublished reports) only mention a few cases of slight necrosis of the seminiferous tubules and necrotic cell nuclei.

Viable sperms were first detected in bulls at 11 months of age. Initially only dead sperms were found in the ZT animals' ejaculate, but no sperm could be found at 13 months of age (6 months post-treatment). Moeller (1980) reported sperm counts of 6000/ml ejaculate 14 days after injection with ZT, but none were viable. It seems that, in the current trial, sperm production was effectively eliminated by ZT, as was found by Fahim *et al.* (1984) and Migally & Fahim (1984). According to these researchers, ZT selectively coagulates with certain cells such as spermatozoa, spermatides, spermatogonia, Sertoli cells and the basal lamina of the seminiferous tubules. The testosterone-producing Leydig cells are less susceptible to heavy metals and are, therefore, largely retained. This seemed to be the case in the current study as the plasma testosterone levels of ZT animals were only significantly ($P < 0.05$) lower than those of bulls at 11 month of age (Table 2). Feher *et al.* (1985) reported that the plasma testosterone levels of intact animals did not change significantly between seven and nine months of age, while levels in surgically-castrated steers decreased from 16.7 nmol/l to 3.0 nmol/l within 24 h of castration. However, in ZT animals plasma testosterone levels declined gradually from 17.2 nmoles/l to 2.6 nmoles/l over a nine-month period. Three months after the injection of ZT, plasma testosterone levels were lower ($P < 0.05$) than those of intact bulls, which is in contrast with findings of the current study. According to Moeller (1980), however, the injection of ZT did not affect testosterone production of the animals, provided the correct dosage was used.

Scrotum circumference of the intact bulls in the current study increased gradually over time, whereas that of the ZT animals increased by 50% during the 7 days following treatment (Figure 1). This was due to oedema caused by the ZT solution. According to Mason *et al.* (1964) the testis has a unique vascular system, viz. a semistagnant pulseless flow of blood, which allows heavy metals (such as zinc) to increase capillary permeability. Besides the toxic effect of metals on the sperm, higher permeability leads to oedema and the resulting increased pressure to anoxia. Following the initial swelling, the scrotum circumference of the ZT animals declined gradually over the next seven days, probably owing to subsidence of the oedema and the onset of atrophy of the testis parenchyma. The epididymis weight, testis weight and testis circumference of the ZT animals were correspondingly significantly ($P < 0.001$) lower than those of intact animals, yet development of the secondary sex glands was not affected by ZT (Table 4). These results are supported by Moeller (1980), but reports of a study at the University of Missouri (1983, unpublished reports) state that testes development of ZT animals was similar to that of intact bulls.

Regarding the effect of ZT on animal behaviour and well-being, treated animals constantly kicked at or lay flat on their

sides, and were restless when compared to the burdizzo castrated animals. These symptoms appeared approximately 40 min post-treatment and disappeared after two days. Swollen testes remained as the only sign of treatment. The ZT solution, being acidic, possibly crystallized out very soon after being injected. The presence of a high concentration of this corrosive substance in a relatively small tissue volume could have caused pain. The reports of the Missouri trial (1983) did not indicate any specific symptoms of discomfort or pain, but mentioned scrotal swelling, a stiff gait and a slightly depressed appetite, which returned to normal after four days.

Moreover, the report maintains that adult bulls treated with ZT appeared very docile four weeks after treatment (compared to their untreated counterparts), even though testosterone production continued as normal. The researchers ascribed the docility to the absence of sperm production. In the current study the surgically and burdizzo castrated animals appeared very docile, whereas the ZT animals were just as active as the intact animals, as far as butting and mounting were concerned (Figure 2). Blockey & Galloway (1978) confirmed these findings by stating that sexual behaviour occurred in bulls even when plasma testosterone levels were 7 ng/ml, compared to the normal 6–22 ng/ml. Plasma testosterone levels for ZT animals in the current study were only significantly ($P < 0.05$) lower than those of bulls at 7 and 11 months of age.

Conclusion

The intratesticular injection of a solution of ZT effectively sterilized bulls within approximately 30 days of injection. The retained growth performance and higher muscle yield, characteristic of bulls, could be due to sufficient testosterone-producing Leydig cells remaining intact. Less beneficial is the higher relative mass and meat distribution in the forequarter, lower meat quality in terms of tenderness, and persistent bull-like behaviour in treated animals. Furthermore, ZT caused excessive swelling of the testes a few days after treatment, owing to a change in the capillary blood flow and permeability of the testes. The necrotic action of ZT, especially in the direct vicinity of injection, caused total degeneration of testicular tissue into sterile abscesses. Symptoms of pain and discomfort appeared directly after treatment, possibly due to the harsh corrosive action of ZT. In the light of the increased awareness of animal welfare and the fact that the production and product traits of the ZT animals were similar to those of intact bulls, sterilizing animals with ZT will most probably not be preferred to conventional methods of castration.

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