**CSIRO** PUBLISHING

# Australian Journal of Experimental Agriculture

Volume 37, 1997


*… a journal publishing papers (in the soil, plant and animal sciences) at the cutting edge of applied agricultural research*

**www.publish.csiro.au/journals/ajea**

All enquiries and manuscripts should be directed to
*Australian Journal of Experimental Agriculture*
**CSIRO** PUBLISHING
PO Box 1139 (150 Oxford St)
Collingwood
Vic. 3066
Australia

Telephone: 61 3 9662 7614
Facsimile: 61 3 9662 7611
Email: chris.anderson@publish.csiro.au
lalina.muir@publish.csiro.au

Published by
**CSIRO** PUBLISHING
in co-operation with the
**Standing Committee on Agriculture and Resource Management (SCARM)**

*Australian Journal of Experimental Agriculture*, 1997, **37**, 719–26 

# Liveweight gains, and carcass and meat characteristics of entire, surgically spayed or immunologically spayed beef heifers

*M. Jeffery*[A], *I. Loxton*[B], *S. Van der Mark*[B], *T. James*[C], *R. Shorthose*[D], *K. Bell*[E] *and M. D'Occhio*[F]

[A] Queensland Department of Primary Industries, Brigalow Research Station, MS 1855, Theodore, Qld 4719, Australia.
[B] Queensland Department of Primary Industries, Tropical Beef Centre, PO Box 5545, Rockhampton, Qld 4702, Australia.
[C] Queensland Department of Primary Industries, Charters Towers, Qld 4820, Australia.
[D] CSIRO Meat Research Laboratory, PO Box 12, Cannon Hill, Qld 4170, Australia.
[E] Queensland Department of Primary Industries, PO Box 102, Toowoomba, Qld 4350, Australia.
[F] CSIRO Tropical Agriculture, Tropical Beef Centre, PO Box 5545, Rockhampton, Qld 4702, Australia.

**Summary.** Growth, carcass and meat characteristics, market suitability and economic return were compared in surgically spayed (SS), immunologically spayed (IS) and entire (E) heifers. Spaying had no effect on daily weight gains of heifers up to 8 weeks following spaying. Between spaying at 15 months of age, and slaughter at 30 months of age, growth was greater for E heifers (0.36 kg/day) than for SS heifers (0.32 kg/day) ($P$<0.01) and for IS heifers (0.33 kg/day) ($P$<0.05). There was no difference in growth between SS and IS heifers. Carcass weights at slaughter were: E, 246 kg; SS, 239 kg; IS 240 kg ($P$>0.05). Other carcass attributes (meat and fat colour, texture and marbling) were similar for the 3 treatments.

Subcutaneous rump fat depth (P8 site) was similar for the 3 groups (E, 20 mm; SS, 21 mm; IS, 19 mm) and the percentages of carcasses that had rump fat depths between 6 and 22 mm were: E, 72%; SS, 66%; IS, 83% ($P$>0.05). All other carcasses had fat depths greater than 22 mm.

Warner-Bratzler initial yield and peak force values of striploin (*Longissimus dorsi)* samples were lower ($P$<0.05) in the SS treatment than both E and IS treatments, whereas Instron compression values from the E striploin were lower ($P$<0.05) than for both the SS and IS treatments. There were no differences between treatments in any meat attributes measured from the eye round (*Semitendinosus)*.

Entire heifers ($A522) realised a higher ($P$<0.05) carcass value than SS heifers ($495) whilst IS heifers ($503) did not differ ($P$>0.05) from E and SS heifers. Direct costs of the spaying treatments (SS, $2.50 per head; IS, 4 vaccinations at $5.50 each) increased the difference relative to E heifers to $29.50 (SS) and $41 (IS) per head.

## Introduction

The implementation of early weaning programs and improvements in the management of beef cattle breeding herds in northern Australia has increased the numbers of heifers not required as breeder replacements, and therefore potentially available for meat production (Burns *et al.* 1990; Holmes 1990). Under current marketing systems, most heifers are sold between 6 and 24 months of age, with most to low priced markets. With the development of the Australian domestic beef market, Korean and Japanese export markets, and live cattle export markets, there is an opportunity for Australian cattle producers to direct heifers into these markets.

Heifers, especially those which are heavily pregnant, receive lower prices at sale than steers of comparable age and carcass weight (Todd and Cowell 1981). If these pregnant heifers are calved out, they may need to be retained for up to an additional year to recover lost body condition, making them too old for some markets. There is an industry perception that spayed heifers have greater liveweight gains and increased subcutaneous fat than entire (non-spayed) heifers grown under similar conditions. This perception, however, has not been supported by results in North America (Crouse *et al.* 1987; Garber *et al.* 1990) or southern Australia (Bouton *et al.* 1982; Saul *et al.* 1982). There is no published information from northern Australia on the growth and carcass characteristics of spayed and entire heifers, or the effects of spaying on meat quality.

Traditionally, surgical spaying or isolation of heifers from bulls has been used to prevent unwanted pregnancies (Rudder and Corlis 1974). The development

10.1071/EA97074

of a spaying vaccine, Vaxstrate, which induces heifers to produce antibodies to luteinising hormone releasing hormone, leading to anoestrus in heifers (Hoskinson *et al*. 1990) provided a third option to control unwanted pregnancies. The aim in this study was to investigate the short- and long-term growth of heifers left entire, surgically spayed or immunologically spayed 16–18 months before slaughter. The effects on carcass characteristics, meat quality, market suitability and economic return were also investigated.

## Materials and methods

The study was conducted at the Queensland Department of Primary Industries' Brigalow Research Station (240º50'S, 149º48'E), Theodore, Queensland, between January 1993 and May 1994. Seasonal rainfall and long-term average rainfall is shown in Table 1.

Below-average rainfall in summer and autumn 1993 and late spring rain in 1993 resulted in drought conditions and low heifer growth during this period. All heifers grazed together on green panic (*Panicum maximum* var. *trichoglume*), buffel (*Cenchrus ciliaris*) and Rhodes (*Chloris gayana*) grass pastures growing on cracking clays and duplex soils of the Highworth land system (Speck *et al*. 1968). Stocking rates were about 1 adult equivalent (400 kg liveweight) per 3 ha. Heifers were purchased from a commercial property at Julia Creek, North Queensland, in June 1992, transported to Brigalow Research Station and grazed as a single group. The heifers were 1/2–3/4 *Bos indicus* content and 6–9 months of age at purchase. Heifers were allocated on the basis of unfasted liveweight to 1 of 3 treatments in July 1992 then run as a single group until treatments began in February 1993. Treatments and unfasted liveweights in February were: entire (E, $n$ = 30, 333 kg); surgically spayed (SS, $n$ = 30, 334 kg); or immunologically spayed (IS, $n$ = 30, 334 kg).

### *Spaying and vaccination*

The spaying was carried out when the heifers were about 15 months old. The IS heifers were given a primary Vaxstrate vaccination in January 1993 and a secondary vaccination 4 weeks later (Hoskinson *et al*. 1990). Booster vaccinations were given in September 1993 and February 1994. All Vaxstrate vaccinations were given subcutaneously in the upper neck area of the heifers on alternative sides of the neck at each vaccination time. At the same time as the IS heifers received their secondary vaccination, the SS group were surgically (flank) spayed through the left paralumbar fossa (Heinze 1970) by an experienced contract spayer. The flank area was disinfected before incision and treated with fly-strike powder after the ovaries were removed and the incision stitched. Heifers were returned to their paddock within 30 min of the final heifer being spayed. All were monitored daily for a 2-week period for post-operation morbidity and complications.

### *Weighing and reproductive studies*

All heifers were weighed 1, 2 and 4 weeks after the start of treatments and every 4 weeks thereafter. Cyclic ovarian activity in E and IS heifers was determined by measuring plasma concentration of progesterone (D'Occhio *et al*. 1988). Commencing in March 1993, about every 2 months E and IS heifers were bled twice 11 days apart. Plasma progesterone concentrations of ≥2 ng/mL were taken as indicative of the presence in the ovary of an active corpus luteum.

### *Slaughter and carcass measurements*

During the experiment, 1 heifer from each treatment group was removed and the data reported are for the remaining 29 heifers in each treatment. Of the 3 heifers removed, one was found to be pregnant at spaying, one calved during the experiment and the third heifer died due to unknown causes during the drought. Heifers were turned off for slaughter when carcass weights were estimated to be suitable for the heavy domestic/light Korean beef markets. There was no attempt to market animals on the basis of individual weight or fat depth. Heifers were consigned for slaughter on the basis of their initial liveweight blocking over a 3-week period in May 1994. Heifers were serial slaughtered to alleviate problems of data collection from all 87 animals as 1 group. Ten heifers from each treatment were slaughtered in each of the first and second weeks, with the remaining 9 heifers from each treatment slaughtered in the third week. At turnoff, heifers were mustered and weighed unfasted, trucked 250 km the following morning to an abattoir, given access to water overnight and slaughtered the next morning. A blood sample was

**Table 1. Seasonal rainfall (mm) at Brigalow Research Station during the experimental period and mean annual rainfall (± s.d.) over the period 1960–94**

| Year | Dec.–Feb. | Mar.–May | June–Aug. | Sept.–Nov. | Annual |
|---|---|---|---|---|---|
| 1992–93 | 172.7 | 10.2 | 47.1 | 170.8 | 400.8 |
| 1993–94 | 179.4 | 217.8 | n.a. | n.a. | n.a. |
| 1960–94 | 309 ± 117 | 135 ± 112 | 95 ± 62 | 191 ± 94 | 731 ± 145 |

n.a., not applicable.

collected for measurement of progesterone concentration from E and IS heifers within 5 min of slaughter and each body was electrically stimulated using an ultra-low voltage anal/nasal stimulator for 45 s at 32 rms within 10 min of slaughter. Each body was assessed for dentition, and each carcass measured for skeletal length and depth (Anon. 1984) and subcutaneous fat depth at the P8 site. Carcasses from the IS treatment had lesions trimmed from the vaccination sites and the trimmings weighed. All carcass sides were placed in a chiller at 4ºC within 1 h of slaughter.

After about 20 h in the chiller, the left side of each carcass was quartered between the 12th and 13th ribs. After allowing at least 20 min for the meat to attain full colour (bloom), subjective meat colour of the *Longissimus dorsi* (*L. dorsi*) was assessed using the AUS-MEAT (1990) 11 point scale of 1A, 1B, 1C, 2–9, where 1A is bright and 9 is dark. Intermuscular fat colour of the *L. dorsi* was subjectively assessed using the AUS-MEAT 13 point standard of 0–12 with 0, white fat and 12, yellow fat. Marbling scores of the *L. dorsi* were assessed using a subjective rating of intramuscular fat content on an AUS-MEAT 12 point scale with 1, nil and 12, excessive marbling. Eye muscle area was measured using a standard 1 $cm^2$ grid (AUS-MEAT 1990).

During boning a 1 kg sample from the anterior end of the striploin section of the *L. dorsi* and the entire *Semitendinosus* (eye round) were collected. These respective meat samples were wrapped in plastic and stored in a blast freezer at –28ºC for a minimum of 4 days then relocated to a storage freezer at –20ºC 3 weeks before objective meat quality measurements. The striploin represents the superficial muscles of the carcass and can be affected by cold shortening, while the eye round is not affected by cold shortening and represents the deep skeletal muscles of the carcass.

*Meat quality measurements*

Meat samples were thawed for 48 h at 5ºC. A number of subsamples (about 250 g each) were removed from the anterior end of the striploin sample and the distal third of the *Semitendinosus* for cooking. These subsamples were individually wrapped in polyethylene bags and cooked by total immersion in a water bath at 80ºC (± 0.5ºC) for 60 min. After cooking, each sample was cooled in cold running water (20ºC) for a minimum of 30 min and dried with paper towel before being placed in polyethylene bags and stored overnight at 0–1ºC.

Laboratory determination of sarcomere length, ultimate pH, shear force (initial yield and peak force) and compression of the *L. dorsi* as well as adhesion on the *Semitendinosus* samples was carried out using methods previously described by Bouton and Harris (1972), and Shorthose and Harris (1990). Ultimate pH values <5.6 are considered ideal, 5.6–5.7 acceptable and >5.7 unacceptable. Sarcomere lengths <1.9 µm indicated muscle shortening while Instron compression values <2 kg indicated acceptable levels of connective tissue toughness. Warner-Bratzler initial yield values <4 kg indicated tender meat, 4–8 kg acceptable tenderness, and >8 kg tough meat (Baxter *et al.* 1972; Harris 1976).

Objective meat and fat colour was measured using a Minolta CR-200 chromometer. Meat lightness (‘L’ values) of both the *L. dorsi* and *Semitendinosus* were calculated as the mean of 3 measurements taken from a freshly cut surface perpendicular to the grain of the meat, which had been allowed to bloom at 0ºC for 60 min. Higher ‘L’ values for meat colour indicate brighter (lighter) meat. Colour of subcutaneous fat was measured only on the fat covering the *L. dorsi*. Fat was removed, cut and 3 measurements taken immediately to give an average fat colour. Lower ‘b’ values for fat colour indicate whiter fat. Total fat content and dry matter percentage of the denuded *L. dorsi* samples were determined using the methods described by the Association of Official Analytical Chemists (1980).

*Carcass price and value*

The carcass price (cents/kg) was determined by the meatworks on the basis of a price grid based on hot standard carcass weight, dentition and P8 fat depth. Overall carcass values used in the economic analysis are those received from the meatworks.

*Statistical analyses*

The data were analysed by analysis of variance, using a randomised block design, where blocks were based on initial weight of individual animals. The l.s.d. was used to test for differences amongst group means. A logistic regression was used to test for significance in the proportion of animals within different categories. Parameters analysed using log-linear regression were dentition, subjective meat and fat colour, subjective marbling, P8 rump fat depth and levels of cyclicity of the E and IS heifers. Turnoff times were used as blocking. In all parameters analysed, the number of heifers in each treatment was the same ($n$ = 29).

## Results

No individual SS heifers had severe weight loss, showed signs of post-operative trauma or infection, or died following the surgical spaying.

*Liveweight and liveweight gain*

*Weight changes after spaying.* There was no effect of spaying on daily gains up to 8 weeks post-spaying. In the first week following spaying, SS heifers maintained liveweight, while E heifers gained 6 kg and IS heifers gained 4 kg during the same period. By the end of week 4 after spaying, the weight gains for the E, SS and IS groups were 17, 12 and 15 kg, respectively, and gains by week 8 were 18, 15 and 16 kg, respectively ($P$>0.05).

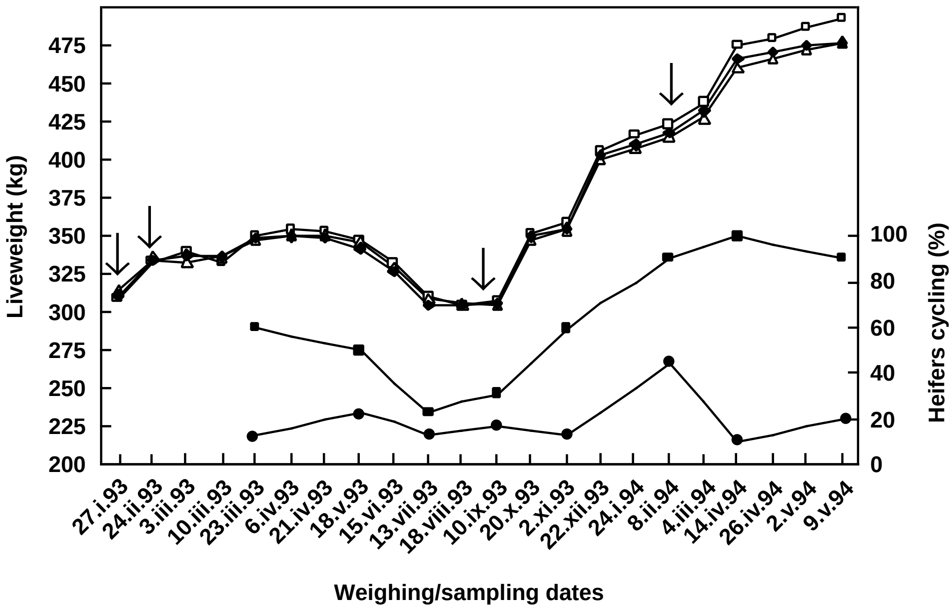


**Figure 1.** Liveweights of heifers left entire (□), immunologically spayed heifers (◆) and surgically spayed heifers (△), percentage of entire heifers (■) and immunologically spayed heifers (●) cycling, and vaccination times (↓) during the experiment.

At the end of the experiment in May 1994 when the heifers were about 30 months of age, the E heifers (491 kg) were heavier ($P$<0.05) than the SS (473 kg) heifers. Liveweight of IS heifers (478 kg) did not differ from SS or E heifers. Liveweights during the experiment are shown in Figure 1.

*Daily weight gains.* Overall weight gain was greater for E heifers (0.36 kg/day) than SS heifers (0.32 kg/day) ($P$<0.01) and IS heifers (0.33 kg/day) ($P$<0.05), but there was no significant ($P$>0.05) difference between SS and IS treatments.

*Cyclic ovarian activity*

The percentage of E and IS heifers that showed cyclic ovarian activity during the study are shown in Figure 1.

Except for July and September 1993, there were significantly ($P$<0.05) fewer IS heifers cycling at all observations than E heifers. The percentage of IS heifers cycling varied between 10 and 20%, except in February 1994 when the percentage was 40%. The percentage of E heifers cycling at any one time varied between 25% in July 1993 to 100% in March 1994.

Of the E heifers, 21% were found to be cycling at every observation during the study. There were no E heifers which failed to cycle during the experiment, and only 7% were acyclic at 2 or more of the 8 sampling periods. Within the IS heifers, 76% were acyclic on at least 6 of the 8 sampling dates, with 45% acyclic for the full period. No IS heifers cycled for the full experimental period.

*Carcass characteristics*

There were no significant ($P$<0.05) differences between the treatments for any carcass attribute (Table 2).

P8 rump fat depths were similar between the 3 treatments with no carcasses with rump fat depths below 7 mm. Thirty-four percent of the SS heifers had

**Table 2. Carcass attributes of heifers either left entire (E), surgically spayed (SS) or immunospayed (IS)**

| Treatment | Carcass wt (kg) | Dressing (%) | Rump fat depth (mm) | Carcass length (mm) | Carcass depth (mm) | Eye muscle area ($cm^2$) |
|---|---|---|---|---|---|---|
| E | 246 | 50.0 | 20 | 1059 | 569 | 63.9 |
| SS | 238 | 50.3 | 21 | 1051 | 567 | 61.8 |
| IS | 239 | 50.0 | 19 | 1043 | 566 | 61.7 |
| l.s.d. ($P$ = 0.05) | 7.4 | 0.7 | 3.0 | 17.0 | 10.1 | 3.3 |

**Table 3. Marbling score, objective meat colour score, objective and subjective fat colour scores, fat content, and dry matter percentage of striploin (*Longissimus dorsi*) samples of heifers either left entire (E), surgically spayed (SS) or immunospayed (IS)**

Values within columns followed by the same letter are not significantly different at $P$ = 0.05

| Treatment | Marbling score | Objective meat colour score | Subjective fat colour score | Objective fat colour score | Fat content (%) | Dry matter (%) |
|---|---|---|---|---|---|---|
| E | 1.3 | 33.4a | 1.7 | 15.4a | 2.60 | 26.9 |
| SS | 1.5 | 35.0b | 2.1 | 16.9b | 2.99 | 27.2 |
| IS | 1.3 | 34.5b | 1.9 | 16.7b | 2.68 | 26.9 |
| l.s.d. ($P$ = 0.05) | n.s. | 1.0 | n.s. | 1.2 | 0.47 | 0.44 |

rump fat depths greater than the market preferred maximum of 22 mm compared with 28% of E heifers and 17% of IS heifers ($P$>0.05), while 11% of E heifers had rump fat depths above 30 mm, compared with 3% in both the IS and SS treatments ($P$>0.05). The E heifers tended to have heavier, longer and deeper carcasses with greater eye muscle areas than SS and IS heifers ($P$>0.05) (Table 2). Site reactions to the Vaxstrate vaccinations resulted in 86% of IS heifers requiring trimming of tissue from the vaccination sites (0.9 kg/head).

*Meat and fat attributes*

There was no difference in marbling score of the 3 treatments, with the E, IS and SS treatments having mean scores of 1.3, 1.3 and 1.5 respectively (Table 3). In all groups, 90% of carcasses had marbling scores ≤2.

Subjective meat colour (AUS-MEAT) scores of all carcasses were similar between treatments and ideal by industry standards, ranging from scores of 1A to 1C. The SS (35.0) and IS (34.5) treatments had lower objective meat colour measurements (lighter meat) than the E (33.4) treatment ($P$<0.05).

The subjective fat (AUS-MEAT) colour scores of all carcasses were 5 or below with 80% of carcasses scoring 2 or less. Mean subjective fat colour scores for the E, SS and IS treatments were 1.7, 2.1 and 1.9 respectively ($P$>0.05). The objective subcutaneous fat colour measurements showed the E heifers had whiter fat (15.4) than both the SS (16.9) and IS (16.7) heifers ($P$<0.05). Treatment did not influence either ($P$>0.05) dry matter percentage or fat content of the *L. dorsi* samples.

*Meat attributes*

Objective meat attribute measurements are shown in Table 4.

There were no significant differences in ultimate pH or sarcomere length of the *L. dorsi* between treatments (Table 4). Ultimate pH levels, sarcomere lengths and meat colour of all samples were ideal. The SS treatment had lower ($P$<0.05) initial yield and peak force values than both the IS and E treatments while the Instron compression values for the E treatment were higher ($P$<0.05) than both the IS and SS treatments, which did not differ. There were no significant differences (Table 4) between any of the treatments in any of the *Semitendinosus* meat attributes.

*Economic returns*

The economic analysis is based on costs and returns from the experiment. Direct treatment costs were the

**Table 4. Meat attributes of the striploin (*Longissimus dorsi*) and eye round (*Semitendinosus*) samples of heifers either left entire (E), surgically spayed (SS) or immunospayed (IS)**

Values within columns followed by the same letter are not significantly different at $P$ = 0.05

| Treatment | Ultimate pH | Sarcomere length (µm) | Initial yield (kg) | Peak force (kg) | Instron compression (kg) | Adhesion (kg) |
|---|---|---|---|---|---|---|
| | | | *Longissimus dorsi* | | | |
| E | 5.49 | 1.82 | 5.09b | 6.01b | 2.16a | 26.9 |
| SS | 5.49 | 1.81 | 4.42a | 5.21a | 2.01b | 27.2 |
| IS | 5.51 | 1.81 | 5.00b | 5.83b | 2.03b | 26.9 |
| l.s.d. ($P$ = 0.05) | 0.06 | 0.05 | 0.58 | 0.59 | 0.12 | 0.44 |
| | | | *Semitendinosus* | | | |
| E | 5.52 | 2.16 | 4.55 | 6.17 | 2.53 | 84.1 |
| SS | 5.52 | 2.20 | 4.46 | 5.92 | 2.58 | 80.9 |
| IS | 5.53 | 2.18 | 4.50 | 6.07 | 2.61 | 94.3 |
| l.s.d. ($P$ = 0.05) | 0.04 | 0.04 | 0.27 | 0.36 | 0.16 | 23.38 |

**Table 5. Values and gross returns from heifers left entire (E), surgically spayed (SS) or immunospayed (IS)**

| Treatment | Carcass value (cents/kg) | Gross return ($A/head) | Cost of treatment ($A/head) | Advantage to E after costs ($A/head) |
|---|---|---|---|---|
| E | 211 | 522a | — | — |
| SS | 208 | 495b | 2.50 | 30 |
| IS | 210 | 503ab | 22.00 | 41 |
| l.s.d. ($P$ = 0.05) | 4 | 22 | | |

surgical spaying costs at $A2.50 per head and the cost of Vaxstrate vaccinations at $5.50 per dose ($22 total). There was no difference between treatments in carcass value (cents/kg) ($P$>0.05; Table 5).

Gross returns per head were higher ($P$<0.05) for the E heifers than the SS heifers, with no difference between the IS and E heifers or IS and SS heifers. The gross returns from the E heifers were $A27 and $19 greater than the SS and IS heifers respectively. After accounting for direct treatment costs, these differences increased to $30 and $41 per head for the SS and IS heifers respectively.

## Discussion

The findings of the present study indicate that surgical or immunological spaying tended to reduce weight gains and economic returns but did not affect carcass or overall meat attributes in heifers. In this study, although spaying improved some meat quality (tenderness) attributes it is unlikely the differences would be detected by consumers or members of a taste panel or be commercially important. Costs of spaying and lighter carcass weights of spayed heifers slaughtered at the same age as E heifers reduced returns to spayed heifers. Surgical spaying was the only method of ensuring animals were non-pregnant at slaughter unless entire heifers were removed from the herd, with the Vaxstrate vaccination failing to provide protection against pregnancy in 55% of heifers for the duration of the study.

The growth rate trends in this study were similar to those from other studies from North America and southern Australia. In all reported studies, E heifers recorded higher growth rates than SS or IS heifers. Crouse *et al.* (1987), Garber *et al*. (1990), and Klindt and Crouse (1990), using heifers lot-fed for up to 140 days, found SS heifers grew slower than IS heifers, which grew slower than E heifers, although the differences were not significant. Adams and Adams (1990), and Adams *et al.* (1990) also found lot-fed, E heifers grew faster than IS heifers, whilst the latter grew slower than ovarectomised heifers. Saul *et al*. (1982) in a study of 4 pasture-based experiments in southern Australia found no differences in growth rates of flank spayed or E heifers.

The lack of major differences in carcass composition between E heifers and spayed heifers observed in this study agreed with results obtained in feedlot-based studies (Zinn *et al.* 1970; Crouse *et al*. 1987; Adams *et al*. 1990; Klindt and Crouse 1990) and pasture-based studies (Bouton *et al.* 1982; Saul 1983).

There were no treatment effects on rump fat depth. Immunospaying tended to increase the proportion of heifers with rump fat depths within market requirements at the time of study, while surgical spaying increased the proportion of heifers with excessive subcutaneous fat. The relatively large number of heifers from each treatment with fat depths above 22 mm may be important when trying to maximise returns from these heifers, as these heifers may be penalised when sold due to being over-fat. The loss of value of those carcasses with fat depths above the market-preferred level may be reduced through selling heifers on an individual basis, however, this would require more mustering and hence increase the costs of managing the heifers. Selling the heifers into a lighter weight market may reduce this problem.

The lack of major differences in meat quality attributes between E, SS and IS heifers is in agreement with previous studies from both pasture and feedlots. Bouton *et al.* (1982) found no differences in meat colour, ultimate pH or sarcomere length between E and SS heifers that were pasture-fed. Likewise, there were no differences in these characteristics between E and SS heifers that were lot-fed (Horstman *et al.* 1982).

The small advantage of the E heifers over the SS and IS heifers in carcass weight resulted in a higher return ($P$<0.05) from these animals at slaughter. Each of the spaying treatments incurred other costs including treatment and mustering costs, which further reduced the returns from the heifers in these treatments. Balanced against these extra costs associated with the spaying treatments is the risk of E heifers becoming pregnant before reaching market weights through failure of keeping bulls away from the heifers. A major advantage to surgical spaying is that the heifers can be run with the main herd without the risk of becoming pregnant, reducing the need for extra infrastructure and management. Surgical 'passage' spaying could be used to overcome the reluctance of some markets to purchase sides of carcasses from heifers which have been flank spayed and have an operation scar. This can reduce market options or lead to price reductions at sale.

Whilst the use of multiple vaccinations of Vaxstrate to control heifer cyclicity was encouraging, with fewer IS heifers than E heifers cycling at any time, practical application of this method is limited. The failure of the vaccine to prevent the same individual heifers from cycling resulted in 55% of the IS heifers cycling at some stage of the study. These heifers could potentially have become pregnant if exposed to bulls, negating the value of the vaccination. The costs of the vaccine and the need to muster the heifers at least once every 4 or 5 months to administer booster vaccinations further reduces the practical application of Vaxstrate in its present form. The immunospaying technology needs to be further developed so that all heifers respond to vaccination and a sustained immunospayed response is induced by a single vaccine.

The reasons for the apparent reduced effectiveness of the Vaxstrate between the third (September 1993) and fourth (February 1994) vaccinations are not clear. During this period, 66% of the IS heifers which cycled only once during the study were found to be cycling. The rapid improvements in pasture conditions and liveweight change of the heifers may have caused this breakdown of the vaccination, but this is not supported by liveweight changes of cyclic and acyclic heifers at this time as each had similar weight changes. Other possible causes may be an overall reduction in heifer sensitivity to successive vaccinations or individual animal sensitivity to the vaccine, neither of which can be supported by the current study.

Returns to cattle producers from surplus heifers can be maximised if heifers can be maintained as entire and non-pregnant until turnoff. However, whilst surgical spaying did not increase growth rates or modify carcass composition, it remains the most reliable method of ensuring heifers are not pregnant at slaughter in areas where cattle control can be difficult. Possible reduced growth performance due to morbidity resulting from complications, mortalities and reduced market acceptance must be considered when flank spaying.

## Acknowledgments

The authors thank the manager and staff of Brigalow Research Station for their assistance in conducting this experiment. Financial support, in part, was provided by the Meat Research Corporation and Dr Tim E. Trigg (Peptech Animal Health Pty Ltd). The technical support of Mr T. Whyte (CSIRO Tropical Agriculture) and staff of CQME abattoirs, Rockhampton, is also greatly appreciated.

## References

Adams, T. E., and Adams, B. M. (1990). Reproductive function and feedlot performance of beef heifers actively immunised against GnRH. *Journal of Animal Science* **68**, 2793–802.

Adams, T. E., Dunbar, J. R., Berry, S. L., Garret, W. N., Famula, T. R., and Lee, Y. B. (1990). Feedlot performance of beef heifers implanted with Synovex-H: effect of Melengestrol acetate, ovariectomy or active immunisation against GnRH. *Journal of Animal Science* **68**, 3079–85.

Anon. (1984). 'Australian Beef Carcase Appraisal Method.' (Australian Meat and Livestock Corporation: Woolloongabba, Qld.)

Association of Official Analytical Chemists (1980). 'Official Methods of Analysis of the AOAC.' 13 Edn. (Washington DC.)

AUS-MEAT (1990). 'Chiller Assessment. A Pictorial Guide.' (Australian Meat and Livestock Corporation: Woolloongabba, Qld.)

Baxter, R. I., Bouton, P. E., Fisher, A. L., and Harris, P. V. (1972). Evaluation of hanging methods for improving the tenderness of beef and mutton. CSIRO Meat Research Report No. 2/72, Brisbane.

Bouton, P. E., and Harris, P. V. (1972). A comparison of some objective methods used to assess meat tenderness. *Journal of Food Science* **37**, 218.

Bouton, P. E., Harris, P. V., and Shorthose, W. R. (1982). A comparison of the meat properties of pasture-fed steers, heifers, pregnant heifers and spayed heifers. *Meat Science* **6**, 301–8.

Burns, B. M., Sullivan, M. T., and Holmes, W. E. (1990). Sensitivity of beef cattle turnoff strategies to prices and branding rates of north-west Queensland Mitchell grass pastures. *Proceeding of the Australian Society of Animal Production* **18**, 156–9.

Crouse, J. D., Schanbacher, B. D., Cross, H. R., Seideman, S. C., and Smith, S. B. (1987). Growth and carcass traits of heifers as affected by hormonal treatment. *Journal of Animal Science* **64**,1434–40.

D'Occhio, M. J., Gifford, D. R., Hoskinson, R. M., Weatherly, T., and Setchell, B. P. (1988). Gonadotrophin secretion and ovarian responses in prepubertal heifers actively immunized against androstenedione and oestradiol-17. *Journal of Reproduction and Fertility* **83**, 159–68.

Garber, M. J., Roeder, R. A., Combs, J. J., Eldridge, L., Miller, J. C., Hinman, D. D., and Ney, J. J. (1990). Efficacy of vaginal spaying and anabolic implants on growth and carcass characteristics in beef heifers. *Journal of Animal Science* **68**, 1469–75.

Harris, P. V. (1976). Structural and other aspects of meat tenderness. *Journal of Texture Studies* **7**, 49–63.

Heinze, C. D. (1970). Abdominal surgery. *In* 'Bovine Medicine and Surgery'. (Eds W. J. Gibbons and E. J. Carcott.) pp. 806–11. (American Veterinary Publications: Illinois, USA.)

Holmes, W. E. (1990). Phosphorus and beef production in northern Australia. II. A case study approach to the economic assessment of phosphorus supplementation. *Tropical Grasslands* **24**, 250–5.

Horstman, L. A., Callahan, C. J., Morter, R. L., and Amstutz, H. E. (1982). Ovariectomy as a means of abortion and control of oestrus in feedlot heifers. *Theriogenology* **17**, 273.

Hoskinson, R. M., Rigby, R. D. G., Mattner, P. E., Huynh, V. L., D'Occhio, M., Neish, A., Trigg, T. E., Moss, B. A., Lindsey, M. J., Coleman, G. D., and Schwartzkoff, C. L. (1990). Vaxstrate: an anti-reproductive vaccine for cattle. *Australian Journal of Biotechnology* **4**, 166–76.

Klindt, J., and Crouse, J. D. (1990). Effect of ovariectomy and ovariectomy with ovarian autotransplantation on feedlot performance and carcass characteristics of heifers. *Journal of Animal Science* **68**, 2381–7.

Rudder, T. H., and Corlis, P. L. (1974). Spaying permits planned sales. *Queensland Agricultural Journal* **100**, 619.

Saul, R. G. (1983). The composition, fat distribution and yield of carcass beef from steers and heifers when entire, spayed, pregnant or fitted with an intravaginal device. *Australian Journal of Experimental Agriculture and Animal Husbandry* **23**, 354–60.

Saul, R. G., Baud, S. R., McDonald, J. W., McRae, C., and Clark, A. J. (1982). A comparison of the growth rate and carcass characteristics of steers and heifers when entire, spayed, pregnant or fitted with an intravaginal device. *Australian Journal of Experimental Agriculture and Animal Husbandry* **22**, 258–63.

Shorthose, W. R., and Harris, P. V. (1990). Effect of animal age on the tenderness of selected beef muscles. *Journal of Food Science* **55**, 1–8, 14.

Speck, N. H., Wright, R. L., Sweeney, F. C., Nix, H. A., and Perry, R. A. (1968). Land systems of the Dawson Fitzroy Area, Part 3. CSIRO Division of Land Research, Land Research Series No. 21, Melbourne.

Todd, M. G., and Cowell, M. D. (1981). Within sale price variation of cattle and carcase auctions. *Australian Journal of Agricultural Economy* **25**, 30–47.

Zinn, D. W., Durham, R. M., and Hedrick, H. B. (1970). Feedlot and carcass grade characteristics of steers and heifers as influenced by days on feed. *Journal of Animal Science* **31**, 302–5.

Received 8 July 1997, accepted 12 September 1997