S. Afr. J. Anim. Sci. 3, 33–37 (1973)

THE EFFECT OF CASTRATION AND PLANE OF NUTRITION ON GROWTH AND CARCASS COMPOSITION OF MALE RATS

D.H. Hale

Department of Anatomy, University of Rhodesia, Salisbury

OPSOMMING DIE INVLOED VAN KASTRASIE EN VOEDINGSPEIL OP DIE GROEI EN KARKASSAMESTELLING VAN MANLIKE ROTTE

Veertig rotte is gebruik om die invloed van kastrasie en voedingspeil op die groeiproses te ondersoek. Die diere het 8, 12, 16 of 20 g per rot per dag van 'n kommersiële kleindierrantsoen ontvang. Kastrasie het 'n onderdrukkende invloed op voerinname, groeisnelheid, doeltreffendheid van voerverbruik, karkasmassa en proteïeninhoud gehad. Die invloed van kastrasie het toegeneem met 'n toename in voedingspeil. Die resultate het aangedui dat die invloed van kastrasie op die groei van rotte byna uitsluitlik aan die invloed van aptyt toegeskryf kan word.

SUMMARY

Forty rats were used to examine the effect of plane of nutrition on the growth response of rate to castration. Rats were offered 8, 12, 16 or 20 g/rat/day of a commercial small animal feed. Castration depressed feed consumption, growth rate, efficiency of feed utilization and carcass mass and protein content. The influence of castration increased as plane of nutrition improved. The results indicated that the effect of castration on growth of rats may be attributable almost entirely to an effect on appetite.

Studies with beef cattle have demonstrated that castration reduces rate of increase in bodymass and efficiency of feed conversion and causes animals to produce a fatter carcass with less bone and protein than that of intact animals (Prescott & Lamming, 1964, and Hale & Oliver, 1972b). However, it has been shown that this effect of castration of bulls is obtained only if the plane of nutrition is adequate, i.e. sufficient to support rates of increase in bodymass of bulls of at least 0,5 kg/day (Hale & Oliver, 1972a, b). Large numbers of animals are required to examine in further detail the effects of plane of nutrition on the response to castration.

Use of large animals for studies of this type is expensive, time-consuming and gives rise to difficulties in controlling precisely the conditions of the experiments because of the long duration of these trials. Small laboratory animals of inbred strains are more convenient experimental animals, are easily housed and handled, and are available in large numbers at low cost. Further, they respond to exogenous stimuli in a less variable manner than do, for example, farm animals, because conditions of trials with small animals can be standardized more precisely and there is less genetic variation between animals.

The anabolic effects of androgens involve fundamental physiological processes. Although the results of studies using rats cannot be applied directly to problems of beef production, information from rat studies should be of great use in guiding future experimentation with farm animals.

The effects of castration of rats on parameters such as increase in bodymass and carcass composition have been studied in few instances. Although Kochakian, Tillotson & Endahl (1956) and Commins (1932) have reported that castration of male rats leads to a reduction in growth, other workers, e.g. Engel (1941) could find no effect of castration on bodymass of mice. This difference in results could be attributable either to a species difference or to the use of older animals by Engel (1941). No information is available on the effects of plane of nutrition on the gross body response of male rats to castration.

Consequently, a trial was established to examine the effects of castration on growth and body composition of male rats which were fed on one of several planes of nutrition.

Procedure

Forty male rats of the Sprague Dawley strain were used. Animals were aged $4^1/2$ (range ± 0,5) weeks and their mass ranged between 85,0 and 107,5 g at the start of the trial. Animals were allocated at random to experimental groups. When the trial started, mean mass of rats did not differ significantly between groups.

The experimental design was factorial (2 x 4 with 5 replicates), there being two castration treatments and four nutritional treatments. Twenty animals were castrated surgically on the day before the start of the trial and the remaining twenty animals remained intact. Five castrated and five intact rats were allotted to each of the nutritional treatment groups. Animals in the four nutritional groups were offered respectively 8, 12, 16 or 20 g/rat/day of a small animal feed (Mouse Comproids, National Milling Company, Lusaka) for thirty-eight days. Routine analysis revealed that the ration was approximately 21% protein, its energy content was 13,24 kj/g. Animals were caged and fed individually and consumption of feed was recorded daily. Water was freely available. Animals were weighed (± 0,5 g) at intervals of four days throughout the feeding period.

At the end of the feeding period, animals were weighed and then killed by cervical dislocation. Animals were skinned by blunt dissection and the skin was weighed.

The head, feet, tail, testes (of intact animals), pluck (heart, liver, lungs, diaphragm and trachea) and gut (including stomach and contents) were removed and weighed and the remaining carcass was weighed. Carcasses were placed individually in water tight containers and frozen (−20°C). After two days, carcasses were chopped into small pieces and refrozen as quickly as possible. Complete carcasses were then passed rapidly through a mincing machine three times in an attempt to ensure homogeneity of, and to minimize loss of moisture from, the resulting mince, which was stored frozen in watertight containers until analysis could be undertaken.

Water content of carcasses was determined by drying of duplicate samples to constant mass in an oven at 100°C. Protein and ether extract (fat) concentrations of duplicate samples of the mince were estimated by the standard Kjeldahl procedure and extraction by petroleum spirit in a Soxhlet apparatus respectively. Fat-free residues were placed in a muffle furnace at 600°C for four hours and the residual ash weighed.

Data were subjected to statistical analysis according to the procedure of Snedecor (1953) for factorial experimental designs with treatment groups of unequal numbers.

Regressions of rate of increase in bodymass on feed consumption were derived and values of "b" calculated for intact and castrated rats irrespective of nutritional treatments.

Results

Four animals (two intact and two castrated) died between the 10th and 23rd days of the experimental period.

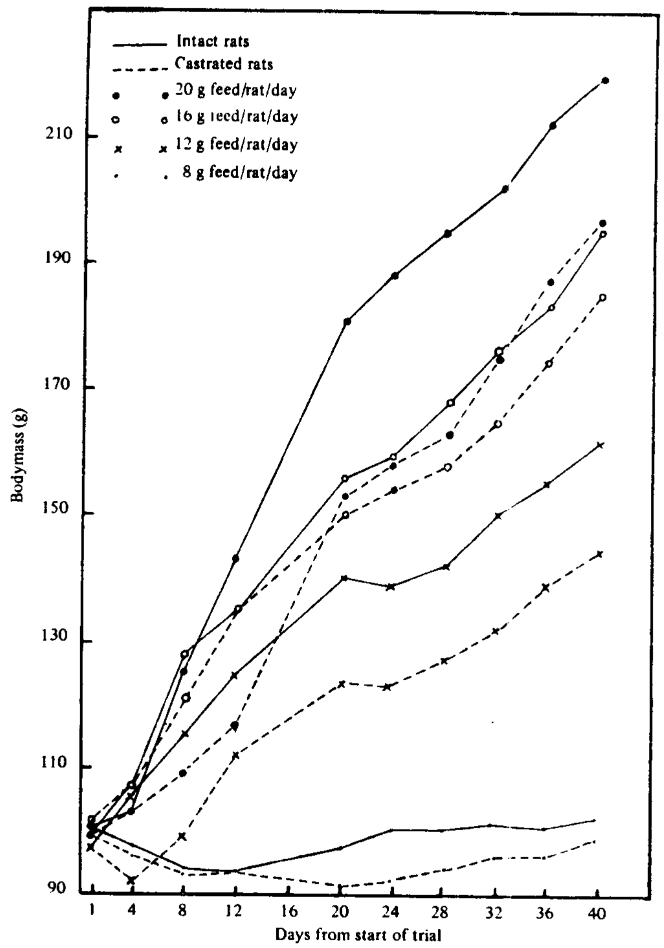

Fig. 1. – *The effect of castration and of plane of nutrition on bodymass of male rats*

Table 1

The effect of plane of nutrition on feed consumption, rate of increase in bodymass and efficiency of feed conversion by castrated and intact male rats

Feed offered g/day	8		12		16		20		Overall standard error
Treatment	Castr.	Intact	Castr.	Intact	Castr.	Intact	Castr.	Intact	
No. of animals	3	3	5	5	5	5	5	5	
Feed consumed (g/day)	7,99	7,98	11,69	11,98	15,54	15,87	16,75	18,69	1,59
Rate of increase in bodymass (g/day)	0,07	0,13	1,23	1,69	2,19	2,50	2,51	3,16	0,03
Efficiency of feed conversion (g food consumed/g increase in bodymass)	160,28	63,33	9,78	7,12	7,13	6,35	6,73	5,92	0,14
Final bodymass (g)	98,5	101,7	143,9	161,5	184,8	195,3	194,8	219,2	1,10

All fatalities were in the groups offered only 8 g food daily. Deaths were not preceded by any marked decline in bodymass or feed consumption. It is possible that the prolonged period of undernutrition rendered these animals susceptible to stresses such as diurnal fluctuations in ambient temperature.

Rates of increase in bodymass varied between a mean of 0,07 to 2,51 g/day for castrated animals and a mean of 0,13 to 3,16 g/day for intact animals (Table 1). Intact animals grew more rapidly ($P < 0,001$) and consumed more feed ($P < 0,001$) than did castrated animals, even on the lowest plane of nutrition (Fig. 1). These differences tended to increase as plane of nutrition improved and interactions between the effects of castration and of

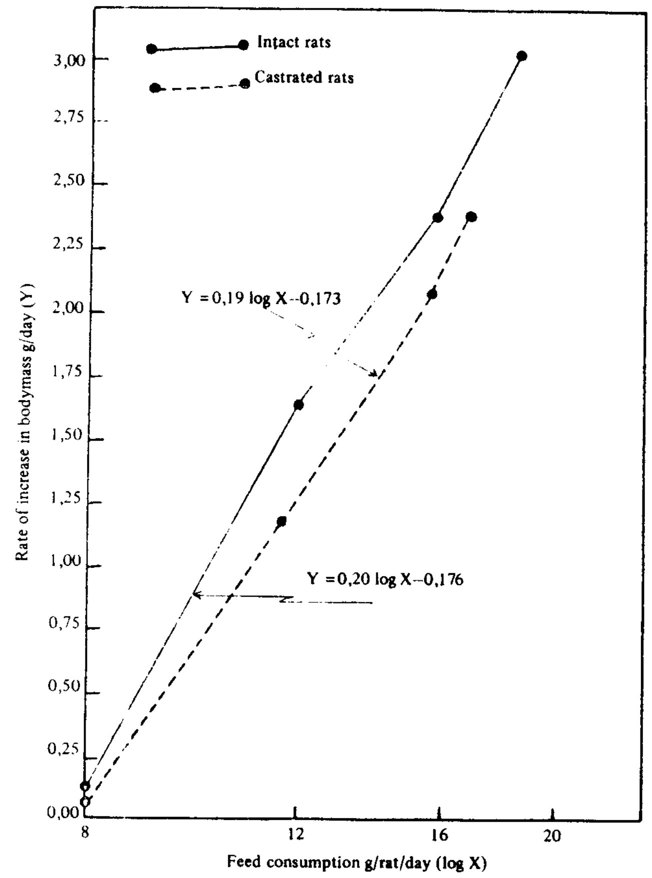

Fig. 2 — *The influence of castration and feed consumption (log scale) on rate of increase in bodymass of male rats.*

When data from rats in this lowest nutritional group were excluded from the statistical analysis, efficiency of feed conversion of intact animals was found to be significantly ($P < 0{,}001$) greater than that of castrated animals in the remaining nutritional groups.

Rate of increase in bodymass increased with amount of feed consumed and regressions were highly significant in both intact ($P < 0{,}001$) and castrated ($P < 0{,}001$) rats (fig. 2). Regressions were defined by the following equations:

$Y = 8{,}00 \log x - 7{,}03$ for intact animals and

$Y = 7{,}67 \log x - 6{,}91$ for castrates, where x is feed consumed (g/day) and Y is increase in bodymass (g). Neither slopes nor Y intercepts differed significantly between the two formulae and data were combined to give the equation $Y = 7{,}97 \log x - 7{,}13$.

Heads ($P = 0{,}001$), skins ($P = 0{,}05$) and tails ($P < 0{,}001$) of intact animals weighed more than those of castrated rats (Table 2). Feet of intact rats also tended to be heavier than those of castrates, but this difference was not significant statistically. The effect of castration on mass of head and tail ended to increase with plane of nutrition ($P < 0{,}05$).

When expressed as a proportion (%) of final bodymass, carcass mass was not affected by castration. Thus, because intact animals were heavier at slaughter than were castrates, absolute mass of carcass was greater in intact animals than in castrates on all planes of nutrition ($P < 0{,}001$). Further, the differences between carcass mass of intact rats and that of castrates increased with plane of nutrition. This interaction of the effects of nutrition and of castration was significant statistically ($P < 0{,}05$).

Mass of testes was influenced strongly by plane of nutrition ($P < 0{,}001$).

TABLE 2

The influence of plane of nutrition on mass (g) of various organs of intact and castrated male rats.

Food offered (g/day)	8		12		16		20		Overall standard error
Treatment	Castr.	Intact	Castr.	Intact	Castr.	Intact	Castr.	Intact	
No. of animals	3	3	5	5	5	5	5	5	
Mass of carcass	48,9	51,6	74,1	83,5	92,1	100,8	101,9	112,4	0,66
Mass of head	12,8	13,6	14,9	16,4	17,5	18,6	18,0	18,5	0,37
Mass of feet	4,0	5,0	4,7	5,0	5,9	5,7	6,5	7,1	0,14
Mass of skin	10,2	9,9	20,5	20,3	26,7	27,9	26,5	33,8	0,50
Mass of pluck	5,4	5,0	7,6	8,3	10,4	11,4	11,1	11,3	0,20
Mass of gut	10,1	9,5	14,0	14,9	17,2	16,5	18,5	18,7	0,26
Mass of tail	3,1	3,4	3,5	3,5	4,6	6,1	4,9	5,8	0,08
Mass of testes	–	1,0	–	2,0	–	2,5	–	2,9	0,05

nutrition were significant ($P < 0{,}05$ and P 0,001) respectively). Efficiency of feed conversion was extremely variable when animals were offered only 8 g feed/day and statistically significant differences in this parameter were not detectable between intact and castrated animals.

Differences between intact and castrated rats in percentage carcass composition (i.e. of protein, fat, water and ash) were not statistically significant (Table 3). However, intact animals tended to have a higher percentage

Table 3

The effect of castration and plane of nutrition on carcass composition of male rats

Feed offered (g/day)	8		12		16		20		Overall standard error
Treatment	Castr.	Intact	Castr.	Intact	Castr.	Intact	Castr.	Intact	
No. of animals	3	3	5	5	5	5	5	5	
Water (%)	71,2	69,5	69,0	69,8	65,1	68,0	65,0	64,0	0,30
Crude protein (%)	21,0	21,6	20,7	19,8	19,3	20,4	18,5	19,4	0,32
Fat (%)	2,5	2,3	4,1	3,0	7,6	6,5	10,6	10,7	0,25
Ash (%)	4,8	4,9	4,3	5,1	5,4	4,4	4,3	4,5	0,16
Mass (g) fat-free carcass	47,68	50,41	71,05	80,93	85,10	94,25	91,10	100,37	0,64
Total mass (g) of protein in carcass	10,28	11,17	15,34	16,59	17,78	20,56	18,85	21,81	0,27
Total mass (g) of fat in carcass	1,22	1,18	3,07	2,55	6,99	6,55	10,80	12,02	0,27

of protein in the carcass than did castrates on three of the four planes of nutrition. Thus, because they were heavier, carcasses of intact animals contained more protein than those of castrates ($P < 0{,}01$). The interaction between the effects of nutrition and of castration on total yield of protein was significant ($P < 0{,}05$) and the difference between intact and castrated rats increased as plane of nutrition improved. On the other hand, castration did not affect total yield of fat in the carcass, even on the highest plane of nutrition.

Discussion

Results of this trial show that castration depresses markedly growth rate, feed consumption, efficiency of utilization of feed and carcass mass and protein content of male rats. These findings confirm and extend previous knowledge obtained from experiments with beef cattle (Hale & Oliver, 1972b). Thus, in the present trial, interactions between plane of nutrition and castration were notable. As plane of nutrition increased, so the superiority of intact rats over castrates increased. This result provides evidence in support of the postulate of Palsson (1955) that an adequate plane of nutrition is essential for the manifestation of potential sexual differences in performance.

Differences between the bodymasses of intact and castrated rats tended to increase throughout the duration of the trial. Consequently, the possibility may be discounted that the effect of castration on growth and carcass composition was attributable simply to the trauma associated with excision of the testes.

Unfortunately, little comparable information is available about the effect of castration of rats and its interrelationships with plane of nutrition on the parameters studied in the present trial. Kochakian, Tillotson & Endahl (1957) and Commins (1932) have reported that castration depresses growth of male rats. A considerable amount of work has been conducted on the effect of castration on the perineal skeletal musculature of rats (e.g. Dorfman & Dorfman, 1963; and Wainman & Shipounoff. 1941), but use of this measurement as an index of total body response to anabolic stimuli has been criticised (e.g. Rowe, 1968). In mice, however, Rowe (1967) has shown that sexual differences exist in fibre diameter of muscles which are not normally considered as being under the direct influence of testosterone and that castration depresses growth of muscle fibres (Rowe, 1968). Breuer & Florini (1965) showed that castration of immature male rats decreased by 50% the incorporation of H^3-leucine into protein by ribosomes in skeletal muscle.

The lack of difference between the regressions of increase in bodymass on feed consumption between intact and castrated rats provides useful information about the mechanisms by which castration influences growth. This finding indicates that the superior performance of the intact animal relative to the castrate is almost entirely attributable to the ability of the former to consume more feed. Thus, if feed consumption of intact rats had been restricted exactly to that of castrated rats, it is likely that no difference in performance would have resulted. In the present trial, restriction of amount of feed offered to the animals did not result in equal consumption of feed by intact and castrated rats (Table 1), because the latter tended to clear up their feed less completely than did intact rats, even when animals were offered as little as 12 g of food/rat/day. As plane of nutrition improved, so feed consumption was governed progressively less by amount of feed offered to the animals and progressively more by appetite of the rats. Consequently, the greater appetite of intact rats relative to castrates was more and more apparent as amount of feed offered to the animals increased. On the high plane of nutrition, intact rats were able to eat considerably more feed than castrates and so they grew faster and used their feed with greater efficiency to produce a heavier carcass containing more protein than did castrates.

The effect of the presence of a functional testis on appetite of rats could result from a direct effect of testicular secretions on the appetite centres in the hypothalamus. These have been reviewed by Brodish (1968). However, this effect could also arise from a generally greater rate of metabolism in intact rats in relation to castrates resulting from a stimulatory effect of testicular secretions on protein synthesis at the cellular level (Wilson, 1962; Breuer & Florini, 1965) or from a synergistic action of androgens with growth hormone (Simpson, Marx, Becks & Evans, 1944). The effects of androgens on liver (Wicks & Kenney, 1965) and on kidney (Failoni & Scarpelli, 1965) might also contribute to a general effect on metabolism and thus on appetite.

In the present trial, parameters which reflect bone development (mass of head, tail and feet) were greater for intact animals than for castrates. This effect too might be attributable to synergism between the actions of testosterone and of growth hormone (Simpson *et al.*, 1944).

Mass of testes of intact animals increased with increasing plane of nutrition (Table 2). Rate of testicular secretion is difficult to measure in rats because of the technical difficulties arising from the small size of blood vessels, but Setchell, Waites & Lindner (1965) have shown that testicular androgen production of rams was depressed when animals were underfed. An effect of plane of nutrition of testicular function in the present trial may have contributed to the influence of nutritive status on the response to castration. However, since testicular mass may not necessarily be a good index of testicular steroid production, this postulate is tenuous. Further study is required to examine the influence of plane of nutrition on the responsiveness of somatic tissues to androgens.

References

BREUER, C.B. & FLORINI, J.R., 1965. Effects of hormones on rat muscle protein synthesis in *vitro. Fed. Proc. 24* 2(1), 600.

BRODISH, A., 1968. Neuroendocrinology. *Yale J. biol. Med. 41*, 143.

COMMINS, W.D., 1932. The effect of castration at various ages upon the adult weight of male albino mice. *J. exp. Zool. 63*, 573.

DORFMAN, R.I. & DORFMAN, R.S., 1963. The assay of subcutaneously injected androgens in the castrated rat. *Acta endocr., Copenh. 42*, 245.

ENGEL, P., 1941. Body and muscle growth in normal and castrate albino mice. *Endrocrinology, 29*, 852.

FAILONI, D. & SCARPELLI, D.G., 1965. Alterations of renal ultrastructure in the mouse induced by castration and testosterone propionate. *Fed. Proc. 24* 2(1), 428.

HALE, D.H. & OLIVER, J. 1972a. The effect of castration and vasectomy on male Zebus which grazed veld under two systems of management. *S. Afr. J. Anim. Sci. 2*, 27.

HALE. D.H. & OLIVER, J., 1972b. The effect of castration and plane of nutrition on growth of male Zebus. *S. Afr. J. Anim. Sci. 2*, 33.

KOCHAKIAN, C.D., TILLOTSON, L. & ENDAHL, G.L., 1956. Castration and the growth of muscles in the rat. *Endocrinology, 58*, 226.

PASSON, H., 1955. Conformation and body composition. In *Progress in the Physiology of Farm Animals*, Vol. 2, p. 430, ed. J. Hammond. London: Butterworths.

PRESCOTT, J.H.D. & LAMMING, G.E., 1964. The effects of castration on meat production in cattle, sheep and pigs. *J. agric. Sci. Camb. 63*, 341.

ROWE, R.W.D., 1967. Effect of low nutrition on size of striated muscle fibres in the mouse. *J. exp. Zool. 167*, 353.

ROWE, R.W.D., 1968. Effect of castration on muscle growth in the mouse. *J. exp. Zool. 169*, 59.

SETCHELL, B.P., WAITES, G.M.H. & LINDNER, H.R., 1965. Effect of undernutrition on testicular blood flow and metabolism and the output of testosterone in the ram. *J. Reprod. Fert. 9*, 149.

SNEDECOR, G.W., 1953. *Statistical Methods* p. 379 Iowa: Iowa State Univ. Press.

SIMPSON, M.G., MARX, W., BECKS, H. & EVANS, H.M., 1941. Effect of testosterone propionate on the bodyweight and skeletal system of hypophysectomized rats. Synergism with pituitary growth hormone. *Endocrinology, 35*, 309.

WAINMAN, P. & SHIPOUNOFF, G.C., 1941. The effect of castration and testosterone propionate on the striated perineal musculature in the rat. *Endocrinology, 29*, 975.

WICKS, W.D. & KENNEY, F.T., 1965. Stimulation of transfer RNA synthesis by steroid hormones. *Fed. Proc. 24*, (2), 600.

WILSON, J.D., 1962. Regulation of protein synthesis by androgens and estrogens. *Ciba Foundation Symposium on Protein Metabolism*, ed. F. Gross. Basle: Springer-Verlag.