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SUMMARY

Between-breed variation in body weight, food intake, carcass composition, milk yield, efficiency of food conversion during growth and maintenance efficiency in adult cattle was examined in a multibreed experiment at the AFRC Animal Breeding Research Organisation. Females from 11 beef, 8 dual-purpose and 6 dairy breeds were fed a complete pelleted diet (AA6) ad libitum from weaning at 12 weeks of age until the birth of their third calf. Females were mated by AI to produce both purebred and crossbred progeny which were reared under the same conditions and slaughtered at either 24, 48 or 72 weeks of age. In addition, non-pregnant, non-lactating mature females from two beef breeds, two dairy breeds and one dual purpose breed were fed for prolonged periods on fixed levels of the same AA6 diet until an equilibrium body weight had been attained. There was significant variation among breeds for body weight, cumulated intake and cumulated food efficiency over the age range of 12 to 72 weeks. At 72 weeks of age the between-breed variation as a proportion of the total ($t^2$) was 0.71 for body weight, 0.62 for cumulated intake and 0.15 for cumulated food efficiency. Breed and sex had significant effects on carcass composition at all three age of 24, 48 and 72 weeks. Heterosis in carcass composition although significant at 24 weeks declined at subsequent ages. Beef breeds when compared with dairy breeds had on average daily lactation yields that were half as high, total lactation yields that were 1/3 as high and lactation lengths that were 2/3 as long. Maintenance efficiency in mature cattle varied with potential milk yield, beef breeds being about 20% more efficient than dairy breeds.

INTRODUCTION

Mason's (1969) Dictionary of livestock breeds lists some 1000 different cattle breeds around the world. Many are specialist breeds devoted to either beef or dairy production, whilst others are used in a dual purpose role for meat and milk. In some countries where population density is high and agriculture systems are intensive, beef and dairy enterprises are closely linked and much of the beef produced derives from the dairy breeds and their crosses. In the UK it is estimated that 70% of the beef produced derives from dairy breeds. It is therefore appropriate to consider all three breed types when assessing their role for beef production. The purpose of this paper is to report estimates of some of the biological parameters for variation among beef, dairy and dual purpose breeds for growth, food intake, carcass composition, milk yield, efficiency of growth and efficiency of maintenance in mature adults.

## MATERIALS AND METHODS

A multibreed cattle experiment was established in 1970 at the AFRC Animal Breeding Research Organisation's farm at Blythbank in Scotland. Twenty five British breeds were included which represented a wide range in mature size and potential milk yield. The breeds could be broadly classified according to Mason (1969) as beef, dual purpose and dairy. The beef breeds were Aberdeen Angus, Belted Galloway, Beef Shorthorn, British Charolais, Devon, Galloway, Hereford, Highland, Longhorn, Luing and Sussex ; the dual purpose breeds were British White, Dairy Shorthorn, Dexter, Lincoln Red, Red Poll, South Devon, Shetland and Welsh Black; the dairy breeds were Ayrshire, British Friesian, Guernsey, Jersey, Kerry and Red and White Friesian.

Each breed was represented by about 12 females from 6 sires. Calves were purchased at a few weeks of age over a ten year period. They were housed throughout the experimental period. Young calves were fed whole milk in proportion to body weight up till weaning at 12 weeks of age. They were then fed ad libitum on a complete pelleted diet (AA6) which had a digestibility of 660g/kg, a metabolisable energy of 10.0 MJ/kg and a crude protein of 137g/kg in the dry matter. The dry matter was 860g/kg. Animals were fed through a system of Calan-Broadbent electronic gates so that individual food intake could be measured. Body weight and food intake were recorded at two-weekly intervals. Females were mated by AI and each purebred foundation female was scheduled to produce four calves, one purebred and three crossbred. The breeding programme was a partial 3x3x3 factorial diallel design where each breed was allocated to one of three levels for body weight, growth rate and milk yield. A description of the crossing design has been given by Taylor (1976). At a later stage the number of crossbred types scheduled from breeds of intermediate growth rate categories were reduced and eventually 56 different crossbred types, with 48 reciprocal crosses and 25 purebreds were produced. The Charolais breed as a later addition was included only as a purebred. The progeny were reared under the same experimental system up to a specified slaughter age of 24, 48 or 72 weeks. After slaughter one side of each carcass was dissected into its component tissues of muscle, fat and bone. The number of animals in each slaughter group is given in Table 1. All females regardless of breed type were machine milked through a herringbone parlour and milk yield and composition were estimated weekly. A full description of the experiment is given by Thiessen, Hnizdo, Maxwell, Gibson and Taylor (1984).

An ancillary study on efficiency of maintenance was carried out with two beef breeds (Hereford and Angus), two dairy breeds (Friesian and Jersey) and one dual purpose breed (Dexter). Each breed was represented by four unrelated adult animals that were non-pregnant and non-lactating. One animal from each breed was assigned to a specified feeding level of AA6 diet so as to reach specified equilibrium body weights that were 0.7, 0.9, 1.1 and 1.3 times a standard adult body weight (A). Standard body weight was taken as being the mature weight of an animal containing an estimated 20% lipid in the body. The specified equilibrium body weights were associated with target condition scores of 0.5, 2.0, 3.5 and 5.0 as given by Lowman, Scott and Somerville (1976).

To attain equilibrium body weights, animals were brought to their target weights and then fed at constant levels from 6 months to a year to ensure that animals had reached a true equilibrium. The feeding levels for maintenance ($f_m$) were initially based on Taylor and Young's (1968) genetically size-scaled formula of

$$f_m = E_m^{-1} W_T A^{-0.27}$$

where the maintenance requirement, $E_m^{-1}$, the reciprocal of maintenance efficiency, was taken to be 0.70 MJ per unit body weight ($W_T$) scaled by adult weight A to the power - 0.27. When it became apparent that this relationship did not lead to equilibrium body weights across all breeds, a dairy-beef gradient was introduced to allow for a differential maintenance requirement between beef and dairy breeds. The study on maintenance efficiency has been described in more detail by Taylor, Thiessen and Murray (1986).

TABLE 1

Number of purebred and crossbred animals slaughtered at each age.

| | Age (weeks) | | | |
|---|---|---|---|---|
| Type | 24 | 48 | 72 | Total |
| Purebreds | 40 | 45 | 57 | 142 |
| Crossbreds | 72 | 89 | 94 | 255 |
| Total | 112 | 134 | 151 | 397 |

## RESULTS AND DISCUSSION

### Growth, food intake and food efficiency

Data were analysed over the rapid growth phase from 12 to 72 weeks (similar in age range to an 18-month beef production system). The overall mean body weight curve was slightly sigmoid in form with growth rate reaching its maximum between 6 and 9 months of age. Daily food intake increased rapidly up to about 30 weeks of age but thereafter at a progressively slower rate. Food efficiency declined continuously with increasing age and weight.

Breed mean curves for body weight and cumulated intake were remarkably regular and ranked in approximately the same order. The between-breed inter-age correlations of body weight with body weight, cumulated intake with cumulated intake and body weight with cumulated intake were all very high (Thiessen, 1985) so that breed rankings could be readily predicted at later ages from measurements taken at young ages.

Variation among breeds as a proportion of the total variation was estimated as the intraclass correlation ($t^2$) and is given in Table 2 for body weight, cumulated intake and cumulated efficiency. For both body weight and cumulated intake most of the variation was among breeds and the proportion increased with age up to about one year, but thereafter gradually plateaued. Genetic changes in body weight and food intake would therefore be most readily made by breed substitution and this would be best assessed by comparisons beyond one year of age.

TABLE 2

The intraclass correlation ($t^2$)+ estimating between-breed variation as a proportion of the total variation for body weight, cumulated intake and cumulated efficiency from 12 to 72 weeks of age.

| Age (weeks) | Body weight | Cumulated intake | Cumulated efficiency |
|---|---|---|---|
| 12 | 0.44 | | |
| 24 | 0.47 | 0.25 | 0.10 |
| 36 | 0.59 | 0.44 | 0.11 |
| 48 | 0.68 | 0.54 | 0.22 |
| 60 | 0.70 | 0.58 | 0.22 |
| 72 | 0.71 | 0.62 | 0.15 |

+ Standard errors were about 0.07

The proportion of variation among breeds for food efficiency was considerably less, being at most about 20%. However, breed differences in food efficiency were signifcant and as genetic variation among breeds is more accessible than genetic variation within breeds, between-breed selection would be of value prior to within-breed selection as discussed by Thiessen, Taylor and Murray (1985). When breeds were grouped by type into dairy, dual purpose and beef there were no significant differences in these sample groupings for body weight or cumulated intake over successive intervals from 12 to 72 weeks of age (Table 3). For cumulated efficiency there were significant differences among breed type from 12 to 60 weeks of age but not over other intervals. The trend of the least squares means for cumulated food efficiency (Table 3) suggests that beef breeds may be more efficient for live weight gain than dairy or dual purpose breeds.

TABLE 3

Least squares means+ of dairy, dual purpose and beef breeds for body weight, cumulated intake and cumulated efficiency over the age range of 12 to 72 weeks.

| | Age (weeks) | | | | | |
|---|---|---|---|---|---|---|
| | 12 | 24 | 36 | 48 | 60 | 72 |
| **Body weight (kg)** | | | | | | |
| Dairy | 75 | 130 | 206 | 273 | 330 | 387 |
| Dual Purpose | 81 | 138 | 215 | 282 | 341 | 399 |
| Beef | 79 | 131 | 206 | 277 | 340 | 395 |
| **Cumulated intake (kg)** | | | | | | |
| Dairy | | 302 | 857 | 1523 | 2233 | 2969 |
| Dual purpose | | 313 | 870 | 1534 | 2267 | 3008 |
| Beef | | 298 | 831 | 1476 | 2189 | 2939 |
| **Cumulated efficiency (%)** | | | | | | |
| Dairy | | 18.3 | 15.2 | 13.0 | 11.4 | 10.4 |
| Dual purpose | | 18.3 | 15.5 | 13.2 | 11.5 | 10.5 |
| Beef | | 17.5 | 15.4 | 13.5 | 12.0 | 10.8 |

+ Standard errors were approximately 5.6%, 4.6% and 1.8% of the means for body weight, cumulated intake and cumulated efficiency respectively

Other studies comparing breeds for food efficiency have mainly been from crossbred progeny from a number of sire breeds crossed to one or two dam breeds. Southgate, Cook and Kempster (1982 a and b) reported sire breed differences in food conversion efficiency when compared at a constant level of subcutaneous fat in the carcass. Smith, Laster, Cundiff and Gregory (1976) and Cundiff, Koch, Gregory and Smith (1981) compared a number of sire breeds crossed to Hereford and Angus dams. Their comparisons of food efficiency in the progeny were made over a constant weight gain interval, at a constant age, and at a constant level of fatness in the carcass. There were sire breed differences at all three end points, but the minimum variation was at a constant age, the criterion used in this study, when the number of days maintenance was equivalent for all animals.

Carcass composition

An analysis of variance of the partial factorial diallel design showed highly significant breed and sex effects on the proportion of muscle, fat and bone at all three ages of 24, 48 and 72 weeks (Table 4). There was also a significant heterosis effect on the proportion of muscle and bone at 24 weeks of age and on the proportion of bone at 48 weeks of age. Parity showed a significant effect on composition at 24 and 48 weeks but this may have been due in part to some confounding with breed effects. The interaction terms in heterosis and in reciprocal differences were not significant and have not been included in the ANOVA table of mean squares.

TABLE 4

ANOVA mean squares and degrees of freedom for carcass traits at three ages.

| | Sex | Parity | Breed | Heterosis | Residual |
|---|---|---|---|---|---|
| df | 1 | 3 | 24 | 1 | 23+ |
| Age 24 weeks | | | | | |
| Muscle (%) | 97*** | 17.8* | 16.5*** | 40.0** | 4.6 |
| Fat (%) | 208*** | 6.8 | 14.3** | 1.1 | 4.5 |
| Bone (%) | 22* | 3.0 | 5.4 | 26.0** | 2.9 |
| Age 48 weeks | | | | | |
| Muscle (%) | 1500*** | 8.2 | 19.3** | 8.6 | 7.3 |
| Fat (%) | 2277*** | 30.8** | 29.4*** | 31.9 | 8.7 |
| Bone (%) | 76*** | 6.8** | 4.0*** | 7.7* | 1.4 |
| Age 72 weeks | | | | | |
| Muscle (%) | 2869*** | 1.5 | 50.2*** | 6.3 | 12.0 |
| Fat (%) | 4393*** | 1.9 | 77.7*** | 27.9 | 16.9 |
| Bone (%) | 158*** | 0.8 | 6.6*** | 7.2 | 1.9 |

+ Residual df were 29 at age 48 weeks and 42 at 72 weeks.

The overall least squares means adjusted to a male Hereford first parity carcass are given for carcass composition traits at three ages in Table 5. Muscle and bone as a proportion of the carcass declined with increasing age and weight, while the proportion of fat increased correspondingly. Males had significantly more muscle and bone and less fat than females and these sex differences increased with age.

There was considerable variation amongst the estimated breed means. At 72 weeks of age the range was from 67% to 52% muscle with a corresponding range of 16% to 13% bone and 17% to 36% fat. The variation was also considerable within each of the three yield types which had similar overall means. There was a trend for the muscle to bone ratio to be higher in beef and dual purpose breeds than in dairy breeds.

TABLE 5

Least squares means for sex and heterosis effects on carcass traits at 24, 48 and 72 weeks of age.

| | Overall+ mean | se | Sex M-F | se | Heterosis | se |
|---|---|---|---|---|---|---|
| Age 24 weeks | | | | | | |
| Muscle (%) | 61.6 | 1.7 | 2.4 | 0.5 | 1.5 | 0.6 |
| Fat (%) | 15.2 | 1.7 | -3.0 | 0.5 | -0.2 | 0.5 |
| Bone (%) | 22.4 | 1.4 | 0.6 | 0.4 | -1.2 | 0.4 |
| Age 48 weeks | | | | | | |
| Muscle (%) | 61.4 | 1.6 | 6.4 | 0.5 | -0.6 | 0.6 |
| Fat (%) | 21.0 | 1.9 | -8.1 | 0.6 | 1.2 | 0.7 |
| Bone (%) | 17.2 | 0.7 | 1.6 | 0.2 | -0.6 | 0.3 |
| Age 72 weeks | | | | | | |
| Muscle (%) | 57.9 | 2.0 | 8.8 | 0.5 | -0.5 | 0.5 |
| Fat (%) | 27.6 | 2.5 | -10.8 | 0.7 | 1.0 | 0.7 |
| Bone (%) | 14.7 | 0.9 | 2.0 | 0.2 | -0.5 | 0.3 |

+ Adjusted to first parity Hereford male.

## Lactation traits

Dairy, dual purpose and beef breeds were compared over one to three lactations for lactation length and measures of yield and milk composition. Only lactations over 100 days were included and data for lactations longer than 301 days were truncated at that length. Least squares means for the three yield types are given in Table 6. Dairy breeds on average lactated for 50% longer than beef breeds. They had yields three times as high with average daily yields and peak yields about twice as high. Dual purpose breeds were intermediate between beef and dairy types for these traits. Peak yields for all three types were about 60% higher than average daily yield. Dairy breeds reached their maximum yield at about 7.5 weeks, two weeks later than dual purpose or beef breeds. All three yield types were on average similar in percentage protein but dairy breeds tended to have a higher percentage of fat.

TABLE 6

Least squares means for lactation traits in dairy, dual purpose and beef breeds.

| | Breed type | | | | | |
|---|---|---|---|---|---|---|
| | Dairy | se | Dual Purpose | se | Beef | se |
| Length (weeks) | 39 | 1.6 | 32 | 1.4 | 26 | 1.5 |
| Yield (kg) | 3248 | 280 | 1963 | 251 | 1035 | 258 |
| Yield/day (kg) | 11.7 | 0.9 | 8.2 | 0.8 | 5.6 | 0.8 |
| Peak yield/day (kg) | 18.1 | 1.3 | 13.0 | 1.1 | 9.2 | 1.2 |
| Time of peak yield (weeks) | 7.5 | 0.5 | 5.5 | 0.5 | 5.5 | 0.5 |
| Fat (%) | 4.4 | 0.1 | 4.1 | 0.1 | 4.2 | 0.1 |
| Protein (%) | 3.4 | 0.1 | 3.4 | 0.1 | 3.5 | 0.1 |

+ Lactations less than 14 weeks were excluded and those greater than 43 weeks truncated.

Maintenance efficiency in mature cattle

A least squares analysis of maintenace efficiency for the five breeds and four feeding levels showed highly significant breed effects but only marginal significance for feeding level. The two beef breeds, Hereford and Angus had a higher maintenance efficiency than the Dexter which was more efficient than the two dairy breeds, Friesian and Jersey (Table 7). The breed differences were consistent across feeding levels. The feeding level differences did not show a clear trend and it appeared that the longer the animals were at eqilibrium weights and food intakes the lower were the deviations due to feeding level.

Maintenance efficiency was then examined in relation to the genetic potential of a breed for milk yield taken as Y/A, where Y is the lactation yield of energy corrected milk and A the standard mature weight of the breed. The respective estimates of Y/A for the Hereford, Aberdeen Angus, Dexter, British Friesian and Jersey were 1.2, 1.6, 6.5, 7.8 and 8.5. The regression of breed maintenance efficiency, $E_m$, on the genetic potential of a breed for milk yield, Y/A was highly significant. The regression equation was

$$E_m = 1.78 - 0.043\ Y/A$$

where the standard error of the regression coefficient was ±0.007 and the proportion of variation explained by breed differences in Y/A was 0.71.

The corresponding regression equation of maintenance requirement on Y/A was

$$E_m^{-1} = 0.561 + 0.017Y/A$$

Thus it appears that the maintenance requirement of any breed can be predicted from estimates of its mature size and potential milk yield.

TABLE 7

Overall mean and breed deviations in equilibrium maintenance efficiency (kg body weight maintained per MJ of ME per metabolic day) of mature cattle.

| Overall Mean | Hereford | Aberdeen Angus | Dexter | British Friesian | Jersey |
|---|---|---|---|---|---|
| 1.56±0.05 | 0.15±.04 | 0.14±0.05 | 0.03±0.05 | -0.18±0.04 | -0.15±0.05 |

A review of the literature by Taylor, Thiessen and Murray (1986) yielded a wide scatter of estimates of maintenance efficiency (or maintenance requirement). When these were examined more closely and comparisons made among mature animals within the same type of feeding experiment, it was found that estimates among dairy breeds were similar to each other but were different from those for beef breeds, while dairy x beef crossbreds were intermediate. Comparisons of estimates of maintenance efficiency in growing cattle were also seen to follow a similar pattern. The overall estimate from the literature was in very good agreement with the present estimate. Beef cattle would therefore appear to maintain themselves about 20% more efficiently than dairy cattle. Further analysis of published estimates suggested that most of the variation was due not to genetic differences in fasting metabolism but to genetic differences in the efficiency ($k_m$) with which breeds utilized their food for maintenance.

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