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THE SUBPOPULATIONS OF THE BONSMARA CATTLE BREED- THEIR PHYLOGENETIC RELATIONSHIPS AND THEIR CHARACTERIZATION IN TERMS OF GROWTH, CARCASS AND MEAT ATTRIBUTES

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SUMMARY

Ninety bull calves of five Bonsmara strains, viz. Edelheer (E), T-49 (T), Wesselsvlei (W), Roodebos (R) and Belmont Red (BR) were fattened under intensive feeding conditions and serially slaughtered at four different slaughter weights. The phylogenetic relationships between the five strains were determined by means of blood typing. Growth performance, carcass characteristics and meat quality characteristics were compared between the subpopulations. The genetic distances between the animals confirmed the existence of five genetic subpopulations. Means for production and product characteristics were adjusted for mean overall subcutaneous fatness level (%) by means of analysis of covariance. T gained weight faster and more efficiently on a live and carcass weight basis than the other Bonsmara groups. Regarding carcass composition, T had proportionally more meat in the high-priced cuts of the carcass than W. Muscle of the W line had a significantly higher ageing potential (measured as myofibrillar fragmentation; MFI) than T, resulting in higher tenderness scores for W.

Keywords: Phylogenetic, subpopulation, meat, Bonsmara cattle

INTRODUCTION

The Bonsmara is an indigenous composite cattle breed which originated in the early 1940 s from a 5/8: 3/8 combination of the Afrikaner (indigenous Sanga or *Bos taurus africanus*) and Shorthorn/Hereford (*Bos taurus taurus*) through an initiative of the Department of Agriculture of South Africa (Bonsma, 1980). By 1970, it was detected that the genetic structure of the breed had narrowed considerably due to over-exploitation of the Edelheer strain, which was the dominant breeding line in most Government stud herds. Consequently, it was decided to develop other subpopulations within the Government herds and certain private herds to re-establish genetic variation within the breed (Bosman, 1988). The Edelheer (E) breeding line (progenitor, the bull Edelheer) is still regarded as the main strain of the breed, since it dominated the artificial insemination industry of the Bonsmara prior to the introduction of the other subpopulations. The Wesselsvlei (W) strain, originated from the bull Spanner, a 5/8 Afrikaner x 3/8 Red Poll bull, instead of the normal Afrikaner/Hereford/Shorthorn combination, while the Roodebos (R) strain was developed from an unrelated group of animals in a specific Government herd. T-49 (T) is not a formal strain, but was regarded in this study as an independent strain due to the large number of animals within the E strain that were related to a certain bull, T-49. This bull achieved exceptional growth performance indices in the National Performance Testing Scheme (Bosman, D.J., 1996 - personal communication). The Belmont Red (BR) is an independent breed, developed in Australia from 1/2 Afrikaner, 1/4 Shorthorn and 1/4 Hereford. It was imported into South Africa and was further developed as an unrelated subpopulation within the Bonsmara breed.

In this study the phylogenetic relationships among the five Bonsmara strains were determined. Also, the strains were compared in terms of production and product characteristics. Such a data basis can serve as a marketing tool for producers. The Bonsmara, a popular local and now exported breed, is well known for its adaptability to harsh, extensive conditions combined with the anticipated favourable meat tenderness.

MATERIAL AND METHODS

Ninety Bonsmara weaner bulls (±7 months) were selected from various herds over the country representing five different strains, viz. E (n=18), T (n=18), R (n=18), W (n=18), BR (n=18)(n

replicates per treatment). Animals were stratified into four groups according to live weight and slaughtered at the commencement of the trial (S0), slaughter weights of 75% (S1), 90% (S2) and 105%(S3). The animals were kept in single pens and fed a commercial pelleted diet (10,70 MJ ME/kg energy, 13.20% protein, 0.80% calcium, 0.47% phosphorus and 12.80% fibre) including *Eragrostis tef* hay at 1 kg per day. Feed conversion ratio (FCR) and average daily gain (ADG) for carcass and meat at all slaughter points were determined by using the carcass weights and carcass composition of S0 as the starting point.

Phylogenetic relationships

Blood samples were collected from each animal at the commencement of the trial. Phylogenetic relationships between the subpopulations were studied using the gene frequency values obtained from the electrophoretic analysis of eight structural gene loci that code for blood-soluble proteins, together with 23 blood group loci. In addition, the genetic differentiation within the subpopulations was studied. Values of the genetic distances between subpopulations, the phenograms and cladograms, as well as the goodness-of-fit statistics of those dendrograms were computed using the BIOSYS-1 program (Swofford and Selander, 1981).

Carcass measurement

Carcass and buttock length were determined to calculate the carcass compactness. The right sides were quartered between the 9th and 10th thoracic vertebrae where the eye muscle area was measured as the length x width of the M. longissimus thoracis (LT). The two quarters of the right sides were processed into 15 wholesale cuts according to the London and Home Counties cutting techniques (Gerrard and Mallion, 1977) and Bisschop (1946, as described by Naudé, 1974), which were dissected into meat (muscle + intermuscular fat), subcutaneous fat (SCF) and bone. The composition of each cut and the whole carcass side, as well as the distribution of bone, meat and subcutaneous fat in the carcass side were determined from the weights of the various tissues. The meat and subcutaneous fat of the prime rib cut (8th to10th rib; Figure 1) were ground, mixed and proximate analyses were determined for percentage protein, moisture, ash and fat (A.O.A.C., 1985). The percentage yield of muscle and total fat was calculated from the chemical (fat, ash, protein, moisture) and physical composition of this cut (Naudé, 1972). The LT of the wing rib cut (11th to 13th rib) of the right side was retained after separating bone, fat and lean to determine the degree of intra-muscular fat (marbling)(A.O.A.C., 1985).

Muscle biochemistry and histology and meat quality measurements

The LT of the prime rib and the whole wing rib cut were analysed respectively for collagen content and solubility (Bergman and Loxley, 1963; Hill, 1966 and Weber, 1973), and sensory and physical parameters. Three samples (approx. 50g each) of the M. longissimus lumborum (LL; 1st lumbar vertebrae) of the right side were retained, vacuum-packed and aged between 3°C±3°C for 1, 7 and 14 days, respectively, for the determination of the myofibrillar fragmentation index (MFI) according to the method of Culler *et al.* (1978), as adapted by Heinzé and Bruggemann (1994).

For the histochemical demonstration of succine dehydrogenase the nitro-blue tetrazolium technique of Malaty and Bourne (1953) was used. Fibres were classified by means of a video image analysis (VIA: Kontron Germany) into red, intermediate and white according to the intensity of the staining reaction. Fibre cross-sectional areas were also determined by VIA. The sarcomere length was also determined by means of VIA (Kontron Germany).

Wing rib cuts were used for sensory analysis and sampled directly after cooking, while the other half was designated for shear force measurement. Aroma intensity, juiciness, overall tenderness, residual amount of connective tissue and overall flavour intensity were evaluated on an 8-point scale. The samples were also analysed for shear force using a Warner Bratzler shear device mounted on an Universal Instron apparatus (Instron Corporation, 1990). The reported value in Newton represented the average peak force measurement.

Statistical analysis

Sources of variation were investigated by analysis of variance (ANOVA) or analysis of covariance (ANCOVA). ANCOVAs were performed using the general linear model facility of the Genstat 5 statistical programme (Genstat 5 Committee, 1993). Means separation was achieved by application of the Bonferroni Multiple Comparison Method at the 5% test level. Pairwise correlations were determined within breed to describe the linear relationships between any two characteristics.

RESULTS AND DISCUSSION

Phylogenetic relationships

The phylogenetic study revealed heterozygosity levels varying between 31% and 43% for the Bonsmara. The lowest level was observed in T, which is in accordance with the development of this strain, being the most inbred. The highest heterozygosity levels were observed in E and R, which represent the largest section of the Bonsmara population. The formation of two clusters was observed, one by W and another formed by the rest of the population, except the BR which separated from the hypothetical trunk very early. Within the second cluster, E and T showed a higher relationship, differentiating from R. E and R were more related than E and W. The cladogram was topologically similar to the phenogram (dendrogram), which corroborates the stability of the classification. The rate of inbreeding relative to the other strains in the breed, F_{is}, confirmed that T had the highest level (25.0%), followed by BR, W, E and R with F_{is} values of 22.7%, 21.0%, 16.2% and 15.4% respectively. The relatively high F_{is} values for BR and W were also expected since these strains are fairly low in animal numbers and therefore more prone to inbreeding. The genetic distances among the subpopulations confirm the existence of five genetic subpopulations.

Growth and carcass characteristics

The W strain of the Bonsmara gained live weight significantly less efficiently and at a slower rate (non-significant) than the other strains but in particular T and R. Similar trends were found for carcass and meat gain, showing differences between T, R and W of more than 30% for carcass and meat growth rate and 20% for efficiency of carcass and meat gain. T and R also showed a tendency for higher total carcass fat yield and subsequent lower muscle yield compared to W (adjusted for carcass SCF), while T and E tended to yield more total carcass weight (2.3%) and meat (1.9%) in the high-priced cuts, compared to W and BR. BR, the most unrelated strain, had a significantly lower hindquarter compactness (conformation) than E and also tended to have the smallest eye muscle area of all the strains. In support of the differences in growth and carcass characteristics, Korver *et al.* (1987) reported carcass composition differences between animals, even after adjusting for maturity, while Kempster *et al.* (1982) found differences in muscle to bone ratios for Charolais and Devon breeds of similar maturity types.

Meat quality characteristics

Sensory panel scores and shear force values, showed a 17% advantage in meat tenderness and MFI for W compared to T for muscle aged for 7 days. MFI was used to measure the degree of fragmentation of the myofibrils caused by proteolyses (Olson and Parish, 1997). Although Olsson and Tornberg (1992) regarded fragmentation of myofibrils not as a crucial factor determining muscle tenderness, Culler *et al.* (1978) reported that MFI accounted for 50% of the variation in loin steak tenderness and regarded myofibril fragmentation as a more important effector of tenderness than sarcomere length or collagen solubility (similar age). In addition, Crouse *et al.* (1991) and Seideman *et al.* (1987) reported correlation coefficients of 0.53 and 0.60 between MFI and sensory tenderness for muscle aged over a period of one to seven days compared to 0.40 ($P<0.001$) in the current study.

Muscle fibre type differences in size and ratio occurred among the Bonsmara groups. Intermediate muscle fibre area of E and white muscle fibre area of E and R were respectively 25% and 34% larger than that of BR, while the percentage white fibre of E tended to be higher than that of W. These differences did not seem to have any direct effect on the differences in muscle tenderness despite a correlation of -0.45 ($P<0.001$) between white muscle fibre percentage and sensory tenderness. Calkins *et al.* (1981), who found a negative relationship between white fibre area and tenderness, but a positive relationship between red fibre area and tenderness, illustrated the effect of variation in muscle fibre characteristics. Calkins *et al.* (1981) and Dreyer *et al.* (1977) also reported that an increased percentage of white fibres could be associated with a decrease in sensory tenderness. The lack of fibre type related differences in muscle tenderness in the current trial could probably be attributed to the fact that a whole pattern of events takes place when muscle changes to meat. These events are influenced by a variety of physiological and physical interventions that have a major bearing on the ultimate meat quality (Devine and Chrystall, 1992). In this study it appeared as if the fragmentation of muscle independently had the largest effect in this process and probably masked the effect of other factors on meat tenderness. The significant negative correlations between MFI and white fibre percentage confirm the negative effect of white fibres on tenderness. With regard to MFI, Seideman *et al.* (1987), reported that myofibrillar fragmentation on its own explained more of the variation in tenderness than

any fibre type characteristic (size or ratio), while Crouse *et al.* (1991) showed that the effect of fibre type ratio and size on the variation in tenderness was limited to three days of ageing, whereupon the effect diminished and fragmentation of fibres took place independent of fibre type variation. Meat in the present study was aged for seven days.

Regarding the stromal protein properties (connective tissue), one aspect could not be satisfactorily clarified. E had a significantly higher collagen solubility than the other strains, while R was superior to T, W and BR. A significant interaction between strain and slaughter group was found, which indicated that the collagen solubility of E was very high at S1, but then declined sharply to levels closer to the other strains at S3. In contrast, W, BR and T did not show any variation in collagen solubility between slaughter groups, while R was intermediate to E and the other groups. T and W, being the most unlike strains with regard to sensory tenderness, were the most similar in collagen solubility. According to Crosley *et al.* (1994), such collagen solubility differences are expected among animals with large physiological age differences. However, the animals in this trial were all between nine and 12 months of age. Furthermore, Naudé and Boccard (1973) reported much less variation in collagen solubility among a number of breed crosses slaughtered within the same age class as the animals in the current trial. Their data showed values for collagen solubility ranging between 32% and 34%, which are much higher than the average value in the current trial.

No significant correlation between shear force measurement or sensory tenderness and collagen solubility was found in the current study, which is in contrast to the findings of Crouse *et al.* (1985). Once again, it can be assumed that other muscle properties had a greater influence on sensory tenderness than collagen alone. In support of this statement, Seideman *et al.* (1987) reported that MFI, as well as the percentage red muscle fibre, contributed significantly towards differences in sensory tenderness and shear force, while collagen content and solubility and sarcomere length had relatively insignificant effects on tenderness.

Relationships between growth performance and muscle characteristics

In the light of the differences found between T and W, and N and NB for growth performance and certain muscle/meat quality traits, relationships between production and product characteristics were investigated by means of simple correlation. In addition to the significant correlations between MFI and muscle tenderness, MFI for meat aged for 7 days, also had a negative relationship with average daily gain (Bo: $r=-0.44$) and a positive relationship with feed conversion ratio (Bo: $r=0.46$) measured on a carcass basis. The relationship between growth performance and sensory tenderness followed the same pattern, although the correlations were much lower for the Bonsmara, viz. $r=-0.23$ for ADG (carcass; $P>0.05$) and $r=0.25$ for FCR (carcass; $P<0.05$). Calkins *et al.* (1987) speculated that, if an increase in the concentration of catheptic enzymes occurs during rapid rates of growth due to increased protein turnover, enhanced muscle tenderness should result due to an increased stromal (connective tissue such as collagen) and contractile protein degradation. However, their study did not show any increase in enzyme or palatability traits as a result of higher growth rates, although it may be argued that higher growth rates were artificially induced by the feeding regime and were not due to the intrinsic genetic ability of the animals. On the other hand, an animal genetically superior in growth performance is expected to have a higher rate of protein synthesis, or a lower rate of protein breakdown, or both. These processes are controlled by various muscle enzyme systems, such as the calpain system (calpain enzymes and their inhibitor, calpastatin), which also plays a major role in meat tenderisation *post mortem* (Koohmaraie, 1992). Although overemphasised, the action of growth promoting agents, such as b-agonists, is an example of the effect of this enzyme system. They are known for their enhancing effect on growth performance and detrimental effect on muscle tenderness, mainly through the retardation of myofibrillar protein breakdown by the proteolytic enzyme system, regulated by calpastatin (Koohmaraie, 1992). It is, therefore, possible that such a system of net-protein gain in genetically fast-growing more efficient animals is coupled to a retardation in the protein breakdown process *post mortem* in these animals, resulting in less tender meat. However, although relatively high correlations were found between MFI and growth performance on the one hand and growth, muscle tenderness and MFI on the other, the direct relationship between tenderness and growth performance was relatively low. This could probably be attributed to the fact that sensory tenderness is a culmination of a number of aspects, besides MFI, that might have influenced the judgement of the sensory panellist, such as marbling, sarcomere length, connective tissue properties, muscle fibre traits, etc.

ADG was negatively correlated with red fibre percentage ($r = -0.52$; $P<0.01$) and positively correlated with white fibre percentage ($r=0.39$; $P<0.05$). These relationships, to a certain extent, support the hypothesis that less tender meat may be associated with fast growers.

CONCLUSIONS

Despite very definite phylogenetic differentiation between the strains of the Bonsmara, the only consistent differences relating to production (growth performance), as well as product quality characteristics (carcass and meat quality) were found between T and W. The superior growth performance, higher IMF to SCF ratio and higher distribution of meat to the early developing high-priced cuts, could suggest that T should be later in carcass maturity than W. The differences that occurred between the strains, especially T and W, although slight, are simply the result of the intentions of the breeder society to broaden genetic diversity, and may be coupled to the specific origins of the different strains (Bosman, 1988). T, although not a formal strain, has T-49 as the dominant sire, which was favoured by many breeders as a result of its growth performance and was, therefore, expected to perform in that regard. On the other hand, the progenitor of W, the bull Spanner, introduced the characteristics of Red Poll, instead of Hereford/Shorthorn into the breed, probably with the resulting growth performance and meat quality as discussed. Therefore, the variation within the breed is probably higher than in other straight-bred groups of animals, with emphasis on the fact that this variation is to a certain extent captured within strains. This enables the breeder to utilise the variation efficiently through well-maintained breeding records which is standard procedure in the breed.

The contrast found between growth performance and meat quality for T and W may suggest that selection for fast growing, more efficient animals in a breed, which, in effect, is a selection for increased net-protein gain, may be confounded with a retardation in the protein breakdown process in the muscle *post mortem*, resulting in conflicting production and product quality. Further investigation, probably by means of the determination of proteolytic system activities in the muscle, is needed to verify these findings, since there is no direct relationship between tenderness and growth performance.

REFERENCES

A.O.A.C., 1985. Official Methods of Analysis. Ed. 14. Association of Official Analytical Chemists, Washington, DC.

Bergman, I. and Loxley, R., 1963. Two improved and simplified methods for the spectrophotometric determination of hydroxyproline. Analytical Chemistry 35.

Bonsma, J., 1980. Livestock production. A global approach. Tafelberg Publishers Ltd., Cape Town.

Bosman, D. J., 1988. Die verskillende lyne van die Bonsmara-beesras. Bonsmara J. August, 7.

Calkins, C. R., Seideman, S. C. and Crouse, J. D., 1987. Relationships between rate of growth, catheptic enzymes and meat palatability in young bulls. J. Anim. Sci. 64, 1448.

Crosley, R. I., heinzé, P. H. and Naudé, R. T., 1994. The relationship between beef tenderness and age classification in the South African Beef carcass classification system. Proceedings of the 40th International Conference of Meat Science and Technology The Hague, Netherlands S-III.15, 34.

Crouse, J. D., Cross, H. R. and Seideman, S. C., 1985. Effects of sex condition, genotype, diet and carcass electrical stimulation on the collagen content and palatability of two bovine muscles. J. Anim. Sci., 60 , 1228.

Crouse, J. D., Koohmaraie, M. and Seideman, S. D., 1991. The relationship of muscle fibre size to tenderness of beef. Meat Sci. 30, 295.

Culler, R. D., Parrish, F. C., JR., Smith, G. C. and Cross, H. R., 1978. Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine longissimus muscle. J. Food Sci. 43, 1177.

Devine, C. E. and ChrystalL, B. B., 1992. In: Encyclopaedia of Meat Science and Technology, ed. Y.H. Hui, p.1708.

Dreyer, J. H., NaudÉ, R. T., Henning, J. W. N. and Rossouw, E., 1977. The influence of breed, castration and age on muscle fibre type and diameter in Friesland and Afrikaner cattle. S. Afr. J. Anim. Sci. 7, 171.

Genstat 5,, 1993.. Committee of the Statistics Department. Rothamsted Experimental Station. Claredon Press, Oxford.

Gerrard, F. and Mallion, F.J., 1977. The complete book of meat. Virtue, London, UK.
Heinzé, P. H. and Bruggemann, D., 1994. Ageing of beef: Influence of two ageing methods on sensory properties and myofibrillar proteins. Sciences Des Aliments 14, 387.
Hill, F., 1966. The solubility of intramuscular collagen on meat animals of various age. J. Food Sci. 31, 161.
Instron, 1990. Series IX Automated Materials Testing System: Operating Instruction Manual. Instron Corporation Issue B November.
Kempster, A. J., Cook, J. L. and Southgate, J. R., 1982. A comparison of different breeds and crosses from the suckler herd 2. Carcass characteristics. Anim. Prod. 35, 99.
Kempster, A. J., Cook, J. L. and Southgate, J. R., 1988. Evaluation of British Friesians, Canadian Holstein and Beef breed X British Friesian steers slaughtered over a commercial range of fatness from 16-month and 24-month production systems. Anim. Prod. 46, 365.
Koohmaraie, M., 1992. The role of Ca 2+ dependent proteases (calpains) in post mortem proteolyses and meat tenderness. Biochimie. 74, 239.
Korver, S., Tess, M. W., Johnson, T. and Andersen, B. B., 1987. Size-scaled lean and fat growth patterns of serially slaughtered beef animals. J. Anim. Sci. 64, 1292.
Malaty, M. A. and Bourne, G. H., 1953. Histochemistry of succinic dehydronase. Nature 171.
Naudé, R. T., 1972. Die bepaling van spier, vet en been in karkasse van jong osse. The determination of muscle, fat and bone in the carcasses of young steers. S. Afr. J. Anim. Sci. 2, 35.
Naudé, R. T. and Boccard, R., 1973. Carcass and meat quality of Afrikaner and Jersey crossbred steers. S. Afr. J. Anim. Sci. 3, 95.
Naudé, R.T., 1974. Intensiewe vleisbeesproduksie uit melkrasbeeste. D.Sc.-thesis, University of Pretoria, Pretoria, South Africa.
Olson, D. G. and Parish, F. C., 1997. Relationship of myofibril fragmentation index to measures of beefsteak tenderness. J. Food Sci. 42, 506.
Olsson, U. and Tornberg, E., 1992. The interrelationship between myofibril fragmentation and tenderness for beef meat. Proceedings of the 38th International Congress of Meat Science and Technology, 399.
Seideman, S. C. and Crouse, J. D., 1986. The effect of sex condition, genotype and diet on bovine muscle fibre characteristics. Meat Sci. 17, 55.
Seideman, S. C., Koohmaraie, M. and Crouse, J. D., 1987. Factors associated with tenderness in young beef. Meat Sci. 20, 281.
Swofford, D. L. and Selander, R. B., 1981. Biosys-1: a Fortran program for the comprehensive analysis of electrophoretic data in population genetics and systematics. J. Heredity 72, 281.
Weber, R., 1973. The determination of hydroxyproline and chloride in meat and meat products: Simultaneous operation with nitrogen and phosphorus determinations. Technicon International Division S A , Technical Report 7.