MEAT QUALITY IN THE DOUBLE-MUSCLED BELGIAN BLUE BEEF BREED

Vleeskwaliteitkenmerken van het Belgisch Witblauw dikbilras

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ABSTRACT

The double-muscled Belgian Blue Beef breed (DM-BBB), being homozygous for the muscular hypertrophy (mh) allele, has meat quality attributes that differ from 'normal' beef cattle. These differences are due to this mutation in the myostatin locus. One of these differences is more tender meat, although this characteristic is in fact not observed in all individual animals. Most animals with this mutation have more tender meat, but some DM-BBB animals, especially those with an extremely muscular conformation, seem to have less tender meat. This is perhaps due to minor genes that influence muscular conformation and are at a higher frequency in these extremely muscular animals. Other genes or mutations also influence meat quality properties. Some are definitely present in DM-BBB; the presence of others is as yet unknown. Meat quality can be improved not only genetically, but also by improving feeding, handling and transportation. In current DM-BBB selection, meat quality is not taken into account. If it is to be considered, then selection should focus on the control of extreme meat quality disorders. Environmental factors may have a greater impact on the overall acceptance of DM-BBB meat.

SAMENVATTING

Het Belgisch Witblauw dikbilras (DM-BWB) heeft vleeskwaliteiteigenschappen die verschillen van die van conventionele vleesrassen. Deze verschillen zijn toe te schrijven aan de aanwezigheid van het allel voor musculaire hypertrofie. In de meeste gevallen, maar niet in alle, is het vlees malser. De dieren met extreme bevleesdheid vertonen soms minder mals tot taai vlees. Een mogelijke reden hiervoor is de aanwezigheid van "minor genes", die de oorzaak zijn van de extreme bevleesdheid. Andere genen en mutaties beïnvloeden eveneens de vleeskwaliteit. Sommige van deze genen en mutaties zijn beschreven bij het DM-BWB, andere niet. Het verbeteren van de vleeskwaliteit kan via genetische ingrepen maar ook door de voeding aan te passen en voorzichtig om te springen met de dieren tijdens het laden en lossen en tijdens het transport. In de DM-BWB-fokkerij wordt met vleeskwaliteit weinig tot geen rekening gehouden. Indien de vleeskwaliteit een streefdoel zou zijn binnen een selectieprogramma kan men het best extreme kwaliteitsproblemen genetisch proberen te voorkomen. Via milieu-ingrepen, die mogelijk een grotere invloed hebben dan genetische ingrepen, kan de vleeskwaliteit verhoogd worden tot op een aanvaardbaar niveau.

INTRODUCTION

The muscular hypertrophy (mh) allele of the myostatin (GDF8) locus, being present in different cattle breeds, affects muscular conformation (Grobet *et al.*, 1997; Kambadur *et al.*, 1997). The double-muscled Belgian Blue Beef (DM-BBB) breed, being homozygous for this mutation, produces high meat-yielding carcasses (Hanset *et al.*, 1987). Besides its influence on the carcass quality, this allele also affects the meat quality. For many people, this effect means an improvement in meat quality, a fact which has led to in-

creasing consumer demand (Sonnet, 1980; Hanset, 1994). People from Great Britain and the United States, who are used to consuming meat with a lot of intramuscular fat, do not like this type of meat (Keele and Fahrenkrug, 2001).

In this review, the meat quality attributes of animals that are homozygous for the mutation (mh/mh) are described. In particular, the double-muscled (mh/mh) Belgian Blue beef animals are considered. Genetic and environmental components that influence the quality of beef were sought out. In the discussion, ways in which meat quality in DM-BBB can be controlled and/or even improved are explained.

MEAT QUALITY ATTRIBUTES

Tenderness

According to Sonnet (1980) and Hanset (1994), the meat of the DM animals is lean, tender and pale. The percentage of cuts of premium quality (e.g. steaks) in the fore quarter is increased from 25.9 % tot 40.1 %, and in the hind quarter from 50.6 % to 63.9% (Hanset, 1994). The improved tenderness results from a relatively low content of hydroxyprolin (an indicator of the collagen tissue content) in the muscles, which implies a lower background toughness (Bailey *et al.* 1980; Hanset, 1981; Bouton *et al.*, 1982). There is a lower content in all the muscles, but this seems to have more of an impact in muscles that normally have a higher hydroxyprolin content (Hanset *et al.*, 1980).

Although these early reports, which have been confirmed in commercial butchery practice, indicate that double-muscled animals do indeed yield more tender meat, recent research indicates that this is not the whole picture. The tenderness of meat is not only a result of the hydroxyprolin content. Postmortal tenderization, being mainly the result of the calpain calcium-dependent proteolytic system (Koohmaraie, 1996) and cathepsins (Uytterhaegen *et al.,* 1994), is equally important. The proteolytic activity of calpain is inhibited by calpastatin. The higher the levels of calpastatin (absolute or relative), the less tender the meat (Whipple *et al.*, 1990).

The 'improved' tenderness of the meat of DM cattle is definitely not due to an improved meat tenderization rate. Although the post-mortem proteolytic tenderization process probably proceeds more rapidly than in 'normal' animals, it is shorter and reduced (Campo *et al.,* 1999). The results, presented by Uytterhaegen *et al.* (1994), suggest that this changed deficient proteolytic tenderization is due to reduced levels of proteolytic enzymes (calpains and cathepsins) in living DM animals. These authors (1994) state that, especially in the extremely muscular DM-BBB, the lower background toughness is compensated by reduced post-mortem proteolytic tenderization and therefore the meat of these animals may not be more tender, but rather even tougher than that of conventional animals. According to Clinquart *et al.* (1997), increased meat protein content correlates with tougher meat. Fiems *et al.* (2000) did not find clear shear force value differences between a non-DM and a DM group of BBB animals, probably because of the misclassification of both types. Shear force values of heated meat (to 75° C) between DM and non-DM animals do not differ, but there is a difference in raw meat (De Smet *et al.* 1998). Studies also revealed a different relationship between the tenderness of different muscles within 'normal' animals and within DM animals. In 'normal' animals, *longissimus thoracis* is more tender than top sirloin, top round and bottom round cuts. Its tenderness is representative of the tenderness of the other parts (Wheeler *et al.,* 2000). On the other hand, it was shown that the mh allele makes the *semi-tendinosus* and *semi-membranosus* more tender (Bouton *et al.*, 1982; Homer *et al.*, 1997), but not the *longissimus dorsi*. The *longissimus* does not seem to benefit from the overall lower hydroxyprolin content in DM cattle (Uytterhaegen *et al.* 1994). Therefore, the conclusions based on the shear force values for *longissimus* meat in 'normal' cattle differ from those of DM cattle. Moreover, the conclusion that the meat of DM animals is always more tender than the meat of conventional animals should be drawn with more nuance and care.

Fat properties

Intra-muscular fat concentration has declined by between 30% and 50% in DM cattle compared to 'normal' cattle, with the fat in DM cattle having a higher iodine value (= less saturated) (Ménissier, 1980; Hanset, 1981). Raes *et al.* (2001) concluded that intramuscular fat in DM cattle has a higher proportion of polyunsaturated fatty acids (PUFA) than polysaturated fatty acids (PSFA), and a similar proportion of conjugated linoleic acids (CLA) in total fatty acid content compared to 'normal' beef animals. Seen from the point of view of human health interest, this is a good property. The more PUFA over SFA, the better (De Smet *et al.*, 2000). CLA itself is related to desired biological effects such as the inhibition of carcinogenesis and atherosclerosis (Enser *et al.*, 1999).

Color

Meat from both DM and DM-BBB cattle is often paler and brighter, with a lower myoglobin (up to 10 %) concentration (mg myoglobin/g meat) than meat from 'normal' animals (Bouton *et al.*, 1982; Batjoens *et al.* 1990). This paler meat has a higher frequency of type IIB fibers, a lower amount of type IIA and type I fibres, and a higher total muscle fibre number (Wegner *et al.*, 2000). The scantiness of the covering fat favors a rapid oxidation of the pigments, which influences taste and visual acceptability (Sonnet, 1980). As for dark-cutting (dry, firm and dark; DFD) meat, there were fifteen DM animals in which Bouton *et al.* (1982) did not find DFD meat or high ultimate pH samples, although Holmes *et al.* (1973) suggested a reputation for producing dark-cutting meat. Fiems *et al.* (1997) saw that, after slaughter, DM–BBB cattle show a faster decline in pH than 'normal' BBB, thereby increasing the risk of pale, soft and exudative (PSE) meat. The chance of having PSE is much higher when the faster decline of Ph occurs when the carcass is still hot (Brewer *et al.*, 1999).

Water-holding capacities

Drip losses, which are defined as the percentage of weight loss over time, and cooking losses, which are defined as the percentage of weight loss after cooking in an open plastic bag in a water-bath for 60 min at 75° C and cooling under running tap water to room temperature, are significantly higher in DM-BBB compared to losses in conventional Belgian Blue Beef cattle (Uytterhaegen *et al.*, 1994). Clinquart *et al.* (1997) showed that drip and cooking losses increase with increasing protein content. A lower fat content was related to higher cooking losses, but not to higher drip losses. These results indicate that DM-BBB meat has a lower water holding capacity.

Taste

Bailey *et al.* (1980) found no differences in flavor or juiciness between DM meat and meat from conventional cattle.

GENETIC CONTRIBUTION TO MEAT QUALITY ATTRIBUTES

There is no doubt that the mh allele affects meat quality. Even animals carrying only one allele, and which are therefore heterozygous, showed increased tenderness and lower fat content (Bouton *et al.*, 1978). Carroll *et al.* (1978) found similar results, but saw different effects between sexes. The effect on meat flavor and overall acceptance was minor.

In DM-BBB, muscularity is still increasing, most likely because of selection in minor genes. Selection in the mh allele is no longer necessary, because homozygosity within the breed for this major gene has been achieved (Hanset, 1996). Increased muscularity in a double-muscled breed seems to affect tenderness in a negative way (Uytterhaegen *et al.*, 1994; Clinquart *et al.* 1997), and therefore it looks as though selection in minor genes affecting the degree of muscularity is not worthwhile from a meat quality point of view.

Nardone *et al.* (1999) are convinced that a major contribution to satisfying customer desires, such as good organoleptic quality of meat, particular concerning taste and tenderness, will come from genetics, because of the strong effect genotypes have on cattle meat quality. Vatansever *et al.* (2000) showed a clear genetic effect on fatty acid composition. The search for genes, or so-called quantitative trait loci (QTL), that directly influence meat quality can therefore be a worthwhile endeavor. It has been reported that in a DM-BBB-related family, a suggestive QTL was found for marbling on chromosomes 17 and 27 (Casas *et al.*, 2000). QTLs influencing meat tenderness were found on chromosome 15 (Keele *et al.*, 1999) and on chromosome 29 (Casas *et al.*, 2000). One potential candidate for these QTLs is the gene for calcium-activated neural protease (CAPN1) (Smith *et al.*, 2000). Other QTLs that are assumed to influence the meat quality attributes in beef cattle are located on chromosome 5 (fat depth) and chromosome 29 (shear force value at 3 and 14 days post-mortem); these QTLs are segregating in Piedmontese-related cattle (Casas *et al.*, 2000). Whether these QTLs segregate in the DM-BBB as well is not clear, but these findings shows that loci other than the mh allele influence meat quality.

Rehfeldt *et al.* (2000) are convinced that lean meat content and meat quality can be improved by selecting for greater numbers and for moderate size of muscle fibers. Both have a high heritability and show genetic variability.

When production traits such as growth and feed efficiency are selected for, the meat quality is affected. Selecting in the DM-BBB in this way, Clinquart (1997) found a low ultimate pH, tougher meat, lower myoglobin and lipid content and, therefore, a decrease in meat quality in terms of color and flavor.

ENVIRONMENTAL CONTRIBUTION TO MEAT QUALITY ATTRIBUTES

Selection for increased frequencies of QTLs that positively influence meat quality can lead to disappointing results. Environmental interference makes the selection for specific QTLs less progressive, as would be expected from a genetic point of view (Keele *et al.*, 1999). Barkhouse *et al.* (1996) are not really encouraging on this point either. They found a very low heritability (h^2) of 0.02 for shear value. If this figure is confirmed, it will mean that selection based on estimates of shear force in young bulls is not an effective means of improving shear force in market progeny. This is why, in some cases, changing the environment of slaughter animals and improving slaughter methods may produce a greater effect on meat quality properties.

There are many descriptions of non-genetic interventions for the purpose of improving meat quality or for preventing meat quality disorders in all kinds of beef breeds. Some of these interventions affect both types of cattle, but there are also cases where they affect only "normal" cattle or only double-muscled cattle. The reason is not always clear. Certain specific events have an effect on specific meat quality attributes, while others improve the overall meat quality.

Toughness in meat can be caused by low fat content (when bulls are not fattened professionally) and insufficient tenderization (too short a treatment period after slaughter) (Dransfield, 1994). The use of growth promoters, which are needed to lower feeding costs, will consistently reduce meat tenderness (Geay and Enright, 1998). Meat tenderness decreases with the length of the fattening period (Van Eenaeme *et al.*, 1997). Other indications of meat quality attributes that are influenced by feeding intensity and the finishing method are given by Vestergaard *et al.* (2000). Low voltage electrical stimulation, the chilling rate after slaughter, and freezing/thawing during aging each improve the tenderness of meat from young 'normal' bulls. No additional effect was seen when different treatments were combined (Hildrum *et al.* 1999). Electrical stimulation accelerates proteolysis, thus making the meat of conventional cattle more tender (Ferguson *et al.*, 2000; Roeber *et al.*, 2000). Boleman *et al.* (1996) found that differences in tenderness between stimulated and non-stimulated carcasses are most pronounced on the day of slaughter. On subsequent days the differences are lower because non-stimulated carcasses show a faster decline of shear force values. In DM-BBB, electrical stimulation does not seem to affect tenderness. Got *et al.* (1999) tried to influence the meat quality traits of old 'normal' cows (5-9 years old) by high-intensity, high-frequency ultrasound on day 0 (pH = 6.2) and on day 1 (pH = 5.4). No significant effect was found on the aging rate, the ultrastructure or any physico-chemical characteristics, and therefore no improvement in meat tenderness is to be expected.

Carcass fat cover score, carcass fat content and intramuscular fat content were slightly but significantly higher in the animals on a high energy (8.03 MJ ME/kg DM) versus a low energy (7.83 MJ ME/kg DM) diet. All the animals were fed this diet for 230 days. Improving the ratio of polyunsaturated (PUFA) to saturated fatty acids (SFA), as is recommended in nutritional guidelines, can best be achieved by maintaining low carcass and muscle fat content (De Smet *et al.*, 2000). A low energy diet can be of help in achieving this goal but genetic selection for leaner meat is as important. The meat composition can be changed by extending the duration of fattening. Mono-unsaturated fatty acids (MUFA) and cholesterol decrease over time and poly-unsaturated fatty acids (PUFA) increase over time (Van Eenaeme *et al.* 1997).

The ultimate recorded pH values in DM animals are the result of treatment during growth, pre- slaughter handling, duration of pre–slaughter starvation, prevailing weather conditions on the day prior to and the day of slaughter, and the interactions of all these factors (Bouton *et al.*, 1982). Bulls fed a high-energy diet a few weeks prior to transportation for slaughter are better protected against a possible glycogen depletion due to the transport and high temperatures, compared to bulls fed a low-energy diet (Immonen *et al.*, 2000). Awareness of the fact that DM bulls are highly sensitive to heat stress (Halipré, 1973) might be of great importance to meat quality of double-muscled animals. The effect of the diet was reflected in the ultimate pH values (pH = 5.69 with a standard error of $\pm$ 0.03 when the animal was fed a high-energy diet, and pH = 5.93 with a standard error of $\pm$ 0.03 when it was fed a low-energy diet) and residual glycogen content ($p < 0.0001$). Adjusting the diet before slaughter can therefore be helpful in preventing dark-cutting in beef (Immonen *et al.*, 2000).

Meat brightness is positively correlated with both the growth rate and the duration of fattening (Van Eenaeme *et al.*, 1997).

The analysis of the data of Toscas *et al.* (1999) revealed that hot boning (either 1 or 4 hours after slaughter) has little effect on meat quality, but vacuum–pack

aging may have a significant effect on acceptability. In fresh meat stored at modified atmospheric conditions of between 55% and 80%, O_2 is likely to maintain a good meat color. Nevertheless, temperature and time were found to be the most important factors for maintaining meat color and minimizing lipid oxidation. Both parameters should be as low (T = 2°C) as possible (Jakobsen and Bertelsen, 2000). On a farm where rapid growth in 75% Piedmontese (mh-allele) finishing bulls was promoted by adjusted feed supplementation, it was found that the consumer preferred this type of meat (Hoving-Bolink *et al.*, 1999). Vitamin C has no effect on the decrease in post-mortem pH, ultimate pH, water-holding capacity, tenderness, meat color or chemical composition of the meat in DM cattle (Fiems *et al.*, 1997). Vitamin D_3 supplementation 9 days before slaughter improved the meat tenderness in continental cross-bred steers (Montgomery *et al.*, 2000). A concentration of as little as 20 mg copper per kg diet for at least 100 days, which is within the physiological range, reduces back fat and serum cholesterol, and increases muscle polyunsaturated fatty acids in cross-bred continental steers fed high-concentrate diets (Engle *et al.*, 2000). Vitamin E supplementation of the finishing diet of young bulls (mh/+) initially improved color stability and decreased lipid oxidation. In other studies, the color stability over time due to vitamin E supplementation was less variable. In the *psoas major*, muscle drip loss was increased, but not in *longissimus thoracis* (Eikelenboom *et al.*, 2000). Vitamin E supplementation improves the shelf-life of meat (Zerby *et al.*, 1999). Schwarz *et al.* (1998) found that the duration of vitamin E supplementation has a more definite effect on meat color and the oxidative stability of bull beef than the level of supplementation.

DISCUSSION

In double-muscled animals and in the DM-BBB, meat has a lower fat content, is paler and has a lower water-holding capacity than meat from 'normal' beef cattle. Flavor and juiciness do not differ. The muscular hypertrophy allele is known to cause these differences. The tenderness is also better, although not in all cases. Extremely muscular DM-BBB can even have tougher meat than conventional animals. This can be explained by the influence of minor genes that improve muscular conformation and reduce post-mortem proteolytic tenderization and therefore oppose the lower background toughness caused by the mh allele. Selection towards even higher meat-yielding carcasses, as is done in DM-BBB (Hanset *et al.*, 2001), could eventually cause the meat to be too tough, which consumers regard as undesirable.

Other genes and/or mutations, such as tenderness and marbling, which are present in DM-BBB or other beef breeds, seem to have a positive affect on meat quality attributes. Emphasizing these in selection can help to prevent poor meat quality.

Although genetics can help to improve meat quality, changes in the environment of slaughter animals and improvements in slaughter methods may have a greater effect on meat quality properties. Especially for the DM-BBB, which is sensitive to heat stress, particular attention should be paid to handling and transportation before slaughter. Some growth promoters (e.g. ß-agonists) are known to deteriorate meat quality. Feeding the animals properly prior to slaughter is very important. Sufficient feed to stimulate growth improves tenderness. Especially animals that have a high genetic growth potential must be provided with sufficient energy and nutrients to support maximal growth. Feed composition also affects meat quality. It is known that some additives improve meat quality parameters in the DM-BBB. With copper and vitamin D_3, which positively influence the meat quality of 'normal' beef breeds, the effects in DM cattle and DM-BBB are still to be confirmed. This is very important because the effects of feed supplements may differ when used in different production systems and countries, as is mentioned by Eikelenboom *et al.* (2000), and probably also when used in different types of beef cattle.

In current DM-BBB, selection does not focus on meat quality at all, which can be explained by the lack of operational criteria for estimating meat quality and the lack of economic incentives (Hanset, 1994). Perhaps it is only necessary to prevent extreme meat quality disorders by selection and to improve the environment and treatment of potential slaughter animals on farms and in abattoirs in order to produce moderately to highly acceptable DM-BBB meat. In order to prevent extreme meat quality disorders, meat quality assessments should be organized on a regular basis. Meat quality control could be incorporated into the progeny tests of bulls for artificial insemination (AI), thus gathering data for progeny testing not only on the farms (Leroy and Michaux, 1999), but also in the abattoir.

CONCLUSION

It can be concluded that some meat quality attributes of double-muscled animals differ significantly from 'normal' beef breeds. Within DM breeds, there is some evidence that the rate of tenderness differs, especially between the extremely and the less conformed DM animals. When aiming to control and to improve meat quality in the DM-BBB, one should only consider scientifically based results obtained within the breed itself.

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