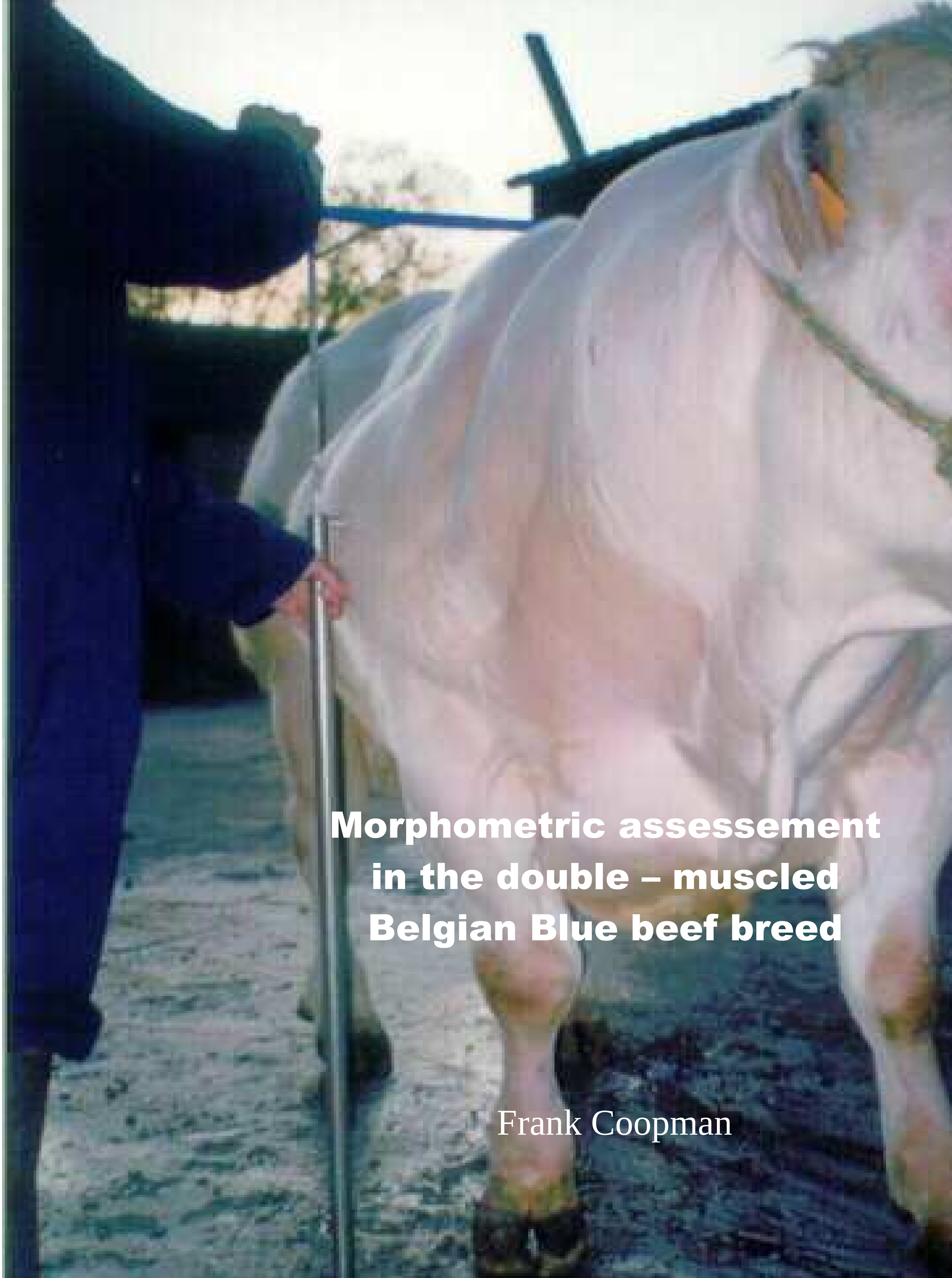

Morphometric assessement in the double – muscled Belgian Blue beef breed

Frank Coopman

Morphometric assessments in the double-muscled Belgian Blue beef breed

Proefschrift ter verkrijging van de graad van
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A reliable measurement is far more interesting than the opinion of one thousand experts.

First we take measurements, than we take measures.

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List of abbreviations

ADG: average daily weight gain
ADG B-3: average daily weight gain between birth and 3 months of age
ADG 3-7: average daily weight gain between 3 and 7 months of age
ADG 7-13: average daily weight gain between 7 and 13 months of age
ADG 13-20: average daily weight gain between 13 and 20 months of age
AI: artificial insemination
BBB: Belgian Blue beef
BBG: Belgian Blue group
BcW: width of the hindquarters
BLUP: best linear unbiased prediction
BL: body length
BT: body trait = body conformation measurement
BW: birth weight
BWB: Belgisch witblauw
CAR: congenital articular rigidity
CCW: cold carcass weight
CMD: congenital muscular dystony
CS: caesarian section
CTS: crooked tail syndrome
CV: coefficient of variation
CW: carcass weight
DM: double-muscled
DM-BBB: double-muscled Belgian Blue beef
DNA: desoxynucleic acid
E: plain muscular hypertrophy
EBV: estimated breeding value
FLB: front long bone
GDF8: growth differentiation factor 8
h^2: heritability
HD: heart depth
HG: heart girth
ID: identification
INEC: index économique – economic index
Isscr: length between ischium and sacrum cranialis
Issca: length between ischium and sacrum caudalis
kg: kilogram
LB: length of the back
ln: natural logarithm
LW: live weight
LW7: live weight at 7 months of age
LW13: live weight at 13 months of age
LW20: live weight at 20 months of age
MC: muscular conformation
MCT: muscular conformation trait
mh: muscular hypertrophy
MGF: mast cell growth factor
MSTN: myostatin locus
N: number of animals

NA: not available
P: price paid per kg cold carcass weight
PA: pelvic area
PH: pelvic height
Pusca: length between pubis and sacrum caudalis
Puscra: length between pubis and sacrum cranialis
PW: pelvic width
QTL: quantitative trait locus
r: correlation
R: silver factor
R^2: reliability
REMLF90: restricted maximum likelihood estimators FORTRAN 90
r_g: genetic correlation
RLB: rear long bone
S: extreme muscular hypertrophy
Sac: length of the sacrum
SAS: statistical analysis system
SD: standard deviation
SE: standard error of the estimate
SMA: spinal muscular atrophy
SPSS: statistical package for the social sciences
SW: shoulder width
Sym: length of the symfysis
TcTc: external distance between the most lateral points of the tuber coxae
TcTi: the external distance between the tuber coxae and tuber ischii
TGF-β: transforming growth factor-β
TiTi: the internal distance between the tuber ischii
TS: thickness of the skin
TT: thickness of the tail
TVL: total value of the live animal
TVS: total value of the slaughtered animal
TWA; tested, waiting and approved sire system
WCW: warm carcass weight
WH: withers height
WHD: white heifer disease

Chapter 1

General introduction

Parts of this review have been published in:

1. Coopman F., Peelman L. , Van Zeveren A. (2000). Spastic paresis, normal and abnormal hocks in the double-muscled Belgian Blue beef breed: inheritance, correlation and control. *Vlaams Diergeneeskundig Tijdschrift 69*, 249-257.
2. Coopman F., Van Zeveren A., Peelman L. (2001). The contribution of genetics in the history and the development of the double-muscled Belgian Blue beef breed. *Vlaams Diergeneeskundig Tijdschrift 70*, 88-103.

1. The Belgian Blue beef breed and its importance in Belgium and abroad

The double-muscled (DM) Belgian Blue beef (BBB) breed is an interesting breed in two ways. It is used as a pure beef breed and as a terminal breed in crossbreeding with dairy cattle or other specific breeds (Hanset, 2004). Because of the large demand for high quality carcasses, the DM-BBB breed is by far the most successful beef breed in Belgium (Hanset, 1984a). Figures of the Flemish agricultural information organization reveal that the number of beef cattle increases in Belgium, while the number of dairy cattle decreases (VILT, 2006). Fifty percent of all cattle in Belgium belong to the DM-BBB breed (Hanset, 2004). Ninety five percent of all beef cattle are DM-BBB animals (Decuypere, 2002). The DM-BBB contributes for 65% to the total beef production and for 75% to the red meat production (Hanset, 2004). Decuypere (2002) also adresses on the importance of the DM-BBB as a terminal cross with dairy cattle. A calf born from a dairy cow and a DM-BBB sire is financially more interesting than a calf that is born of dairy cattle parents. The use of the DM-BBB as a terminal beef sire is internationally very successful and becomes increasingly popular in the dairy cattle industry. Hacour (2004) also reports on the use of DM-BBB sires in breeding programs of local beef cattle in order to improve its muscularity. He is convinced that the success of the internationalization of the DM-BBB breed is due to its use as terminal breed and not as pure breed. The Belgian and international AI centres sell a lot of DM-BBB sperm for these purposes. The Belgian Blue Group (BBG) sold 1,235,000 doses of DM-BBB sperm. Internationally, the sperm is used most frequently (65%) for cross breeding on dairy cattle. In Belgium, 75 % is used in pure breeding, while only 25 % is used for cross breeding (Bombeek, personal communication 2008).

2. The history of the DM-BBB breed

In 1841, the Shorthorn or Durham was introduced in Belgium to be crossed with local cattle. The results of these crosses were rather disappointing and at the end of the 19th century, the Shorthorn lost its importance. Nevertheless, some of its genes remained in the Belgian breeds. An example of such a gene is the roan locus, responsible for the typical blue coat colour of the breed but also for the white heifer disease (WHD) (Hanset, 1984a, 1984b, 1996a, 1996b; Haudfroid, 1996; Coopman *et al.*, 2000b).

A Herd Book was established in Belgium in 1896. This Herd Book was named “Herd Book Hesbignon” and aimed to create a breed that had less Durham blood. The blue cattle breed of

Limon was the first result. “Le Bleu du Limon” was quite successful and was used in crossbreeding with local breeds. On August 16th, 1919, this blue breed was officially approved by the government. All animals became pedigreed animals, their production capacities were measured and animals having extremely bad milk production and the ones having extremely poor (dairy types) or extremely developed (muscular hypertrophy; mh) muscling were eliminated. In fact, this was the first breed for which breeding standards were described. From 1938, breeders from the Hainaut region started with the selection of a uniform white coat colour. This resulted in “le grand plat (blanc) d’Ath”. Because of the poor muscling conformation and the increasing demand for meat products, it was not successful. At the same time in the Condroz and Hesbaye (Figure 1), the selection of a dual purpose type was more successful. Already in 1939, well muscled sires of this type were presented. In 1950, the Herd Book questioned the breeding standard and breeding goal of this type a first time: “Should one focus on meat and milk production (dual purpose breed) or on meat production (pure beef breed)?” In the Condroz, Famenne and the Ardennes (Figure 1), breeders started to select for a pure beef breed, irrespective of the decision made by the Herd Book to keep on focusing on both milk and meat production. The technique of the caesarean section (CS), practically applicable because of the discovery of antibiotics between the two world wars and the progress in veterinary practice in the late forties – early fifties, and the good prices paid for the extreme muscular types, made selection towards more meat possible and profitable. The final result was “le viandeux pur” or the so-called “Blanc Bleu Belge” (Belgian blue and white) (Hanset, 1984a, 1984b, 1996a, 1996b; Haudfroid, 1996).

In 1956, Gédéon du Vieux-château de Maurenne was used for AI, thereby introducing the mh-allele into the breed at a wide scale. Very soon, many AI sires were homozygous for the mh-allele. Despite the high demand for these homozygous sires, doubts on how the breed should evolve, continued to trouble the Herd Book head quarters, mainly because of some disadvantages of this breed (e.g. the high percentage of caesarean section). In 1969, the Herd Book decided once again that the Belgian Blue had to remain a dual purpose breed but now with emphasis on meat production. But still, animals being too muscled (= double-muscled) had to be excluded. Despite this decision, many of the AI sires were no dual purpose but DM cattle. The intensive use of these homozygous AI sires was the start of the selection for the extreme muscularity within the Belgian Blue, resulting in a new Herd Book (1973). This corresponds to the real beginning of the ‘Blanc Bleu Belge or Double-Muscled Belgian Blue beef breed’ and the ‘Herd Book du Blanc Bleu Belge’. In 1974, it was decided to focus on two lines, a so called mixed line (dual purpose) and a beef line (= DM-BBB) (Hanset, 1984a, 1984b, 1996a, 1996b; Haudfroid, 1996).

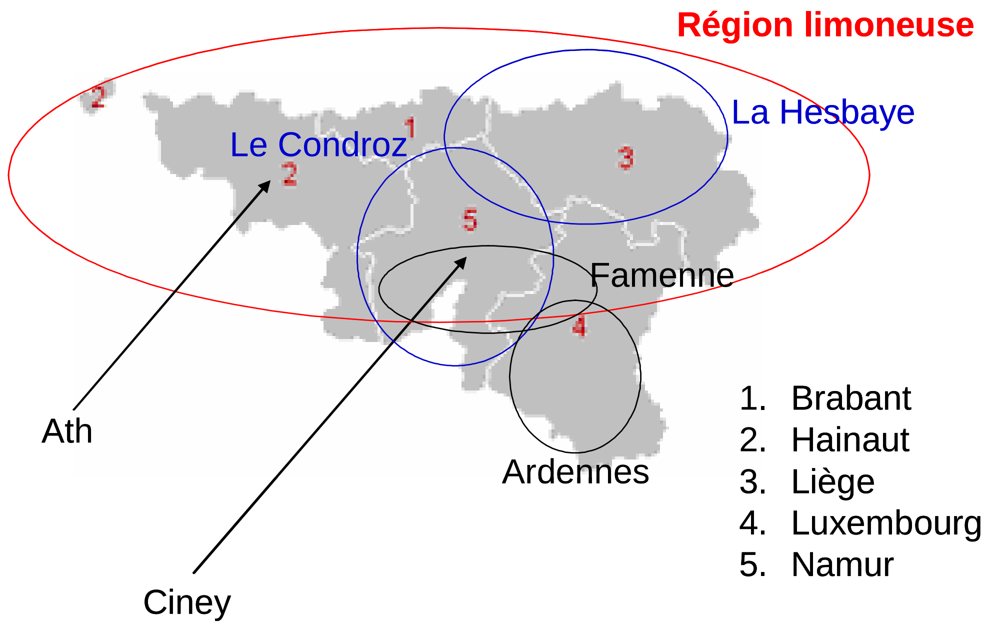

Figure 1. The different regions in the Southern part of Belgium (Walloon Region) that were of major importance in the creation of the double-muscled Belgian Blue beef breed.

Nowadays, one has homozygosity for the mh-mutation in the female and male DM-BBB population. Selection for improved muscular conformation (MC) in the beef line is therefore done by focusing on auxiliary genes influencing muscularity (Georges *et al.*, 1990; Hanset, 1996a). The increase of the muscling score and meat type seems to flatten in 2002, but still increases (Hanset, 2004). No data on the evolution of the muscularity from 2003 to 2007 have been found. In the dual purpose breed, heterozygous and homozygous AI sires are available. This dual purpose breed is still bred in the "Hainaut" region and in the northern part of France ("Frans-Vlaanderen"). It might be an interesting type within the breed to be used as a mother line, carrying the mh-mutation, but still having natural births with a sufficient milk production.

The evolution of the beef type was, is and will be depending on economic changes and demands (Haudfroid, 1996). Since 1988, the price per kg live weight (LW) has decreased. Despite the fact that prices for fattened bulls were rising in 2003 (Hanset, 2004), prices decreased in 2004 and 2005 again (VILT, 2006). Figures of the Flemish agricultural information centre show that in the period 1995 – 2005, the price per kg for DM-BBB bulls and cows fluctuated around 2.5 Euro and 2 Euro respectively indicating that prices have been stabile at this lower level (VILT, 2006). These lower prices are a warning to breeders that selection focussing primarily on MC is not the most optimal strategy. Weight and muscle conformation have to be combined in beef cattle breeding to optimize economic profit. To maintain a sufficient LW when selecting for a higher MC, the Herd Book advises a minimum withers height (WH) standard. This is logical because not only the MC but also the WH explains the variation in LW (Hanset, 1996b).

The most recent change in the DM-BBB selection program is the formation of the BBG in the Walloon region. This group is a merge of the two previous AI centres Linalux and Haliba. This merge was stimulated by the Walloon government who promotes the DM-BBB breed very intensively. Other AI centres such as KI Samen, Fabroca and others have been started by breeders that did not agree with the breeding policy of the BBG. They offer AI sires that are tall and that are out crossed. The Herd Book itself promotes not only the DM-BBB breed as a beef breed but also as a terminal beef breed in dairy cattle, both in Belgium and abroad (Herd Book, 2008). It is more interesting for AI centres to focus on selling sperm doses of DM-BBB sires to be used in cross breeding than in pure breeding.

3. Problems with the DM-BBB breed

3.1. Genetic disorders

A lot of disorders are described in the DM-BBB breed. Almost 10 % of the DM-BBB animals die between birth and the age of 12 months. Fifteen percent of these die because of inherited disorders, already or not yet present at birth. Some of the inherited disorders are not life threatening, but cause considerable economic losses. Other inherited disorders are invisible, causing higher rates of embryonic and foetal losses or higher rates of mummification, abortions, premature births or stillbirths (Rollin, 2000). According to Bergström and Oostendorp (1985a, 1985b), the extreme muscularity itself can already be considered as a genetic disorder. Macroglossia, congenital articular rigidity, muscular hypotony of the limbs, brachygnathia inferior and superior, fertility disorders, acute heart disruption with or without associated respiratory problems, dermatosparaxy, lethal spasticity, spastic paresis and many other disorders are present in the breed (Halipré, 1973; Hanset *et al.*, 1993; Losson *et al.*, 1999; Coopman *et al.* 2000a, 2000b; Danlois *et al.*, 2000; Rollin, 2000; van Winden and Kuiper, 2002; Danlois *et al.*, 2003). Many disorders, but not all, are related to the mh-allele (Coopman *et al.*, 2000b). Especially the cardio respiratory problems seem to be a recurrent and main problem at DM-BBB farms. A lot of research on the higher susceptibility of DM-BBB youngsters for this disorder was performed (Gustin *et al.*, 1987a, 1987b, 1988a, 1988b; Amory *et al.*, 1992a, 1992b, 1993, 1994; Genicot *et al.*, 1994; Lekeux and Van De Weerdt, 1996; Rollin *et al.*, 1997; Bureau *et al.*, 1999). Inherited disorders are not always that clearly present. Often there are chronic health problems that are due to selection for higher productions. The latter have a negative correlation with traits like fitness, fertility and disease resistance. Breeding goals should therefore implement also non-production traits in order to prevent a too strong and irreversible decline of these traits (Rauw *et al.*, 1998). The high level of inbreeding in the DM-BBB is considered to be involved in the high rate of genetic disorders. Efforts are therefore made to reduce the amount of inbreeding ("Calcul de consanguinité"; the Walloon breeding association). Some breeders are using French DM breeds to counteract the high level of inbreeding. In the mean time, they hope to restore the growth potential of their stock. Often, descendants of these outcrosses become pedigreed animals. In the last reports of the Herd Book (Herd Book, 2005, 2006), estimated breeding values (EBVs) on the major genetic problems are reported. For the two types of congenital muscular dystony (CMD I = SMA-like and CMD II = "veau spastique"), a genetic test has been developed (Georges, 2008). Very recently, a genetic test for the crooked tail syndrome (CTS), a disorder with increasing prevalence in the population, is developed as well (Georges, personal communication, 2008). The mutation that most likely is causing proportional dwarfism in the breed (see further on in the general discussion) is located but not yet identified (Georges, personal communication 2008).

3.2. Caeserean section, weight and daily weight gain

The future of the breed is at stake because of two additional points of discussion, viz: "the routinely applied CS and, according to many DM-BBB farmers and breeders, the loss of daily weight gain with too low weights at slaughter or sufficient weight at a too late age". According to Vissac *et al.* (1973) and Hanset (1981) and in the perception of many breeders, both problems are highly related with the mh allele. Muscular hypertrophy is characterized by high foetal and early post-natal muscle growth. At later age, growth is influenced negatively. This causes an imbalance between the size of the hindquarter and shoulder of the calf and the pelvic area size of the dam (Vissac *et al.*, 1973; Hanset, 1981), increasing the incidence of calving difficulties and the wish to preventively perform routine CS (Arthur *et al.*, 1988; Nugent *et al.*, 1991; Rice, 1994). In fact, the CS that allowed the proper delivery of living DM calves was introduced in the fifties, as already explained, and is the main reason why a DM breed can persist at such a large scale (Hanset, 2004).

3.2.1. The caesarean section

The routinely applied CS is criticized on animal welfare grounds (Grommers *et al.*, 1995; Christiansen and Sand∅e, 2000). European legislation exists that can force the Herd Book to select against routine CS in the DM-BBB breed (Lips *et al.*, 2001). Hanset (2004) claimed that any outside coercive measure aimed at reducing the incidence of the CS would go against the principle of subsidiarity asserted in the “Protocol on the protection and welfare of the animals”. Anyway, in the DM branch of the BBB, birth by CS has become a breeding peculiarity (Hanset, 1981; Nicks *et al.*, 1999; Vandenheede *et al.*, 2001), being performed as a matter of routine, especially in order to minimize risks for both mother and calf (Michaux and Hanset, 1986). To some, CS is performed out of ease, is time saving and is not always necessary. Dams do not get the proper time to prepare for a natural birth anymore. Therefore it is claimed that the frequency of CS is higher than what is really necessary and different calving ease scores should still be available in this breed, whenever needed. According to a Belgian discussion group (Groupe de reflexion, 1997), the DM-BBB may have less perinatal deaths because of the routine CS, but higher neonatal deaths. Hanset (1967) reported that a surgical intervention, much more frequent in the DM population, causes a permanent or temporary infertility, influencing the fertility parameters consistently. Mijten (1994) clearly showed that a CS is not without risk for the mother. Many complications occur during and after the CS. These complications affect the final income of the farmer immediately or on the longer term. Based on unpublished data that took in account all the complications of the CS, a CS has a cost of approximately 175 Euro. This means that a calf of a population that always needs a CS for surviving must be worth at least 175 Euro more than a calf of a population that has a natural calving rate of 100%. The price of a DM-BBB calf is in the range of 500 to 700 Euros at the age of two weeks (Decuypere, 2002). A two week old Holstein Friesian calf, almost always born naturally, is worth between 75 and 175 Euro. To date (February 7th, 2008), these prices are still realistic (Boerderij, 2008).

Selection for decreased CS in the current DM-BBB breed can only be done indirectly, using internal pelvic sizes of the dam (see Figures 2 and 3) and birth traits (broadest points = width of the hind quarters – BcW- or shoulder width – SW- ; see Figure 4) of the calf as basic data. This is because of the fact that, according to Hanset (2002) natural calving is no longer possible in the DM-BBB breed, despite the assumption of some that CS is only done out of ease and different calving ease scores can still be used to select for improved calving performance. It is preferable to use measurements and weights instead of estimates, the latter nowadays being still common practice in DM-BBB breeding. Measuring internal pelvic sizes of the dam (more specific the inner pelvic height and width) and measuring critical body traits of the newborn and recording the birth weight might be worthwhile to consider.

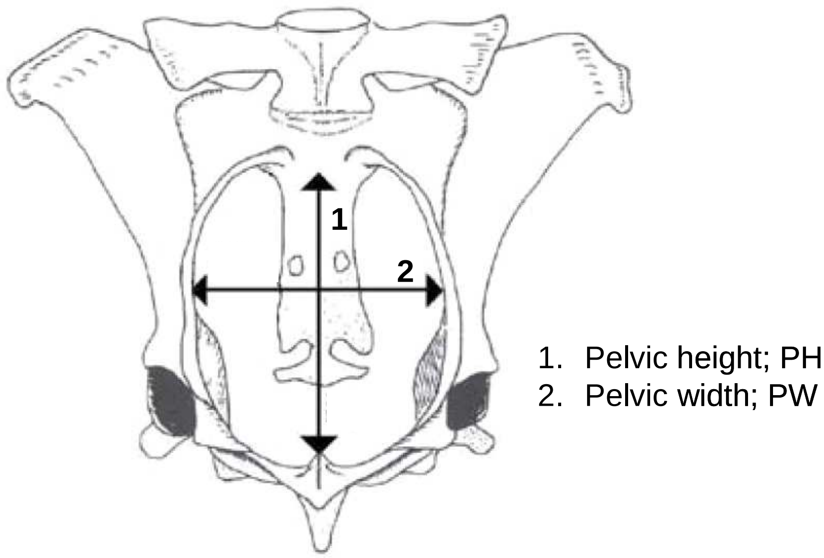

Figure 2. Bony structure of the pelvic region in cattle.

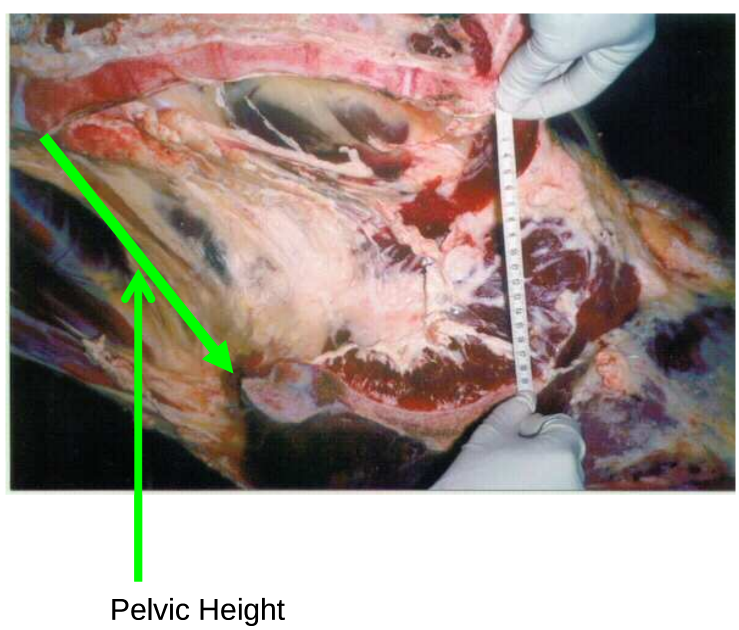

Figure 3. This figure shows that, besides bones, muscle and fat can limit the natural birth process as well.

Figure 4. Both the external width of the hind quarters (left) and shoulders (right) can be extreme in DM-BBB animals at all ages, making them both limiting factors of the natural birth process.

3.2.2. Weight and daily weight gain

For different reasons, LW is an important issue in cattle (Vos and Vos, 1967). Weight gain and weights at specific ages are largely determining profitability in beef production (Hanset *et al.*, 1987; 1988). The estimation of feed requirements can not be done without knowing the LW (Johansson and Hildeman, 1954). Growth is highly related with onset of puberty. The lesser animals grow, the lesser their weight at puberty, the later they get in heat and the more the financial income of the farmer is at risk (Tregaskes *et al.*, 1996).

Accurate determination of live weight data requires weighing on a balance (Cantet *et al.*, 1988; Gengler *et al.*, 1995; Guttierez *et al.*, 1997). However, in many cases, weighing animals is not feasible or too complicated to organise. For breeding purposes, it might be even more interesting to estimate weight out of easily accessible and economically interesting body measurements than to accurately determine LW.

Selection in the DM-BBB breed focuses primarily on muscular development and little on weight and weight gain (Hanset *et al.*, 2001). As a result, the genetic trend for better muscling and skeletal width, both related to carcass quality (Hanset, 2004) increases continuously while the genetic mean for weight and weight gain in the breed does not (Hanset *et al.*, 1989c) and has even shown a significant negative trend during the past few years (Hanset *et al.*, 2001). To counteract the negative trend, information on weight and weight gain is essential. In the DM-BBB breed, this information is only partially available. It is based on data collected in the performance test of males in selection centres (Hanset *et al.*, 1988; Gengler *et al.*, 1995). Only in rare instances data have been collected at farms (Hanset *et al.*, 1988). Therefore, breeders, farmers and consultants have no current sufficient and realistic information on weights and weight gains at farms.

Despite this negative trend of the genetic mean for weight and weight gain, no influence on financial income of the breeder is yet to be expected because the genetic gain for improved muscularity is economically more important. Although no scientific explanation has yet been found for the difference in the price per kg cold carcass weight paid (Coopman *et al.*, 2004), S-carcasses of DM animals are paid much better than E-carcasses. Even in the S-carcasses, distinction is made between good (S^-), better (S^0), and extreme (S^+) muscling, which is paid increasingly better per kg cold carcass weight. In some slaughterhouses, one gets even S^{+++}-qualifications.

The DM-BBB breed is indeed the most successful beef breed in Belgium and has some interesting economical features, but unfortunately also many disadvantages with some of them, but not all, related to the presence of the mh-allele. The DM-BBB breed is therefore not only the most interesting beef breed but also the most controversial one. The best way to better understand the DM-BBB breed and the challenges it faces is to study the role selection and genetics played and still plays in its development. It is of special interest to see how the Herd Book tries to deal with the criticism on the breed.

4. Selection and improvement of the DM-BBB breed

4.1. The genetic background

As biotechnology developed, scientists looked for the mutation that caused muscular hypertrophy (Grobet *et al.*, 1997; Kambadur *et al.*, 1997) in the DM-BBB breed. The genetic basis for the WHD, typical for the DM-BBB breed, was also elucidated (Charlier *et al.*, 1996). Some researchers hope to identify other genes that influence muscular conformation and Quantitative Trait Loci (QTL's) that are involved in the expression of continuous traits of economical importance in the DM-BBB breed. Microsatellites for parentage control in the DM-BBB breed are described by Peelman *et al.* (1998) and Mommens (2000).

Animals homozygous for the mutation in the mh locus have 20 % more muscles. Grobet *et al.* (1997) and Kambadur *et al.* (1997) localized the mh locus at 3.1 cM of the microsatellite TGLA44 at the centromeric end of chromosome 2. The mh locus is identical to the myostatin locus (MSTN). The myostatin gene is a member of the Transforming Growth Factor-β (TGF-β) super family of genes. The myostatin protein influences the muscle growth in cattle and mice in a negative way. An 11 base pair deletion deactivates the bioactive carboxyl end of the myostatin protein. Consequently extreme muscling is not prevented anymore and hypermuscular animals are created. The mutation affects other organs as well, as there are the internal organs and bony structures. The mh-allele of the myostatin (GDF8) locus is present in different cattle breeds (Grobet *et al.*, 1997; Kambadur *et al.*, 1997), but not all of them cause muscular hypertrophy (Grobet *et al.*, 1998; Dunner *et al.*, 2003). Besides its influence on the carcass quality, this allele also affects the meat quality. For many people, but not to all (Keele and Fahrenkrug, 2001) this effect means an improvement in meat quality, a fact which has led to increasing consumer demand (Sonnet, 1980; Hanset *et al.*, 1994). Unfortunately, the influence of the mh-allele is not positive in all aspects of meat quality (Coopman *et al.*, 2003). A low fat content in the carcasses, an elevated average daily weight gain and a low feed conversion rate, environmentally interesting, are additional positive features of the breed introduced by this mutation (Hanset *et al.*, 1989a; Istasse *et al.*, 1990).

Knowing the mechanism of the DM condition in cattle makes it possible to manipulate the mh-locus by transgenic or immune modulation in non-DM cattle (Grobet *et al.*, 1997; Kambadur *et al.*, 1997).

The silver factor (R), member of the roan locus, influences coat colour and is responsible for the WHD in the DM-BBB breed, having by this a pleiotropic effect. Animals that are homozygous (RR) for this silver factor (white animals) have a 1 to 15 % higher change to develop this disorder. Heterozygous (Rr) animals (blue animals) have a higher threshold for the disorder (Charlier *et al.*, 1996). Black animals with the rr-genotype lack the silver factor and do not suffer from WHD (Hanset, 1984b). The WHD is due to a partial underdevelopment of the primary genital organs (Charlier *et al.*, 1996). Seitz *et al.* (1999) found a point mutation in the seventh exon of the Mast Cell Growth Factor gene (MGF or steel locus) on chromosome five, proved the association between the mutation and the observed coat colour (white, blue or black) and the already known co-dominant way of inheritance. The revealed localization of the roan locus in the DM-BBB breed makes that the pleiotropic influence on the colour and fertility can be examined and that can be looked for different mutations within the locus that might influence coat colour and fertility (Charlier *et al.*, 1996).

Other loci influence the muscularity of cattle as well (Hanset and Michaux, 1985). They suppress or promote MC. A recent discovery on follistatin suggests that one gene might be a modifier of the myostatin gene action as well as an independent gene, acting positively on the muscularity (Lee, 2007). There are also observers claiming that some DM calves develop their typical MC at an older age (Bergström and Oostendorp, 1985a; te Pas and Hannewijk, personal communication, 1999), indicating that the muscular development might be suppressed *in utero* and promoted *ex utero*, which would be interesting in solving the conflict between the disliked high rate of CS in the breed and the desired double-muscling. Currently, efforts to solve this conflict are made using transgenic engineering (Grobet *et al.*, 2003; Pirottin *et al.*, 2005).

A QTL is a locus that is underlying a quantitative character (Lynch and Walsch, 1998b). A quantitative trait has a continuous variation and cannot be subdivided in different classes (Lynch and Walsch, 1998a). In the DM-BBB breed, birth weight, MC, WH and slaughter weight are examples of quantitative traits. Although in other breeds QTL's for such traits have been found (Elo *et al.*, 1999; Keele *et al.*, 1999), none of major importance have been exhibited within the DM-BBB breed.

4.2. Selection in practice

In the selection centres in Ciney (since 1973) and Ath (since 1994), future AI sires undergo a performance test. At farm level, characteristics of descendants of AI sires are evaluated. At both the selection centres and the farm level, animals are scored according to the linear classification system (Hanset, 1996a). In slaughterhouses, carcasses are classified according their level of muscularity and fat deposit. Carcass weights are collected. All data collected at the farms and selection centres, but not the ones collected in the slaughterhouses, are used for breeding value estimation.

4.2.1. Direct measurements of traits

<u>4.2.1.1. Performance testing in selection centres</u>

Calves arriving at the selection centre start their growth test at 7 months and end it at 12 or more recently at 13 months. Feed conversion is measured, but not in all cases. All animals undergo linear scoring (Michaux, 1995; see 4.2.1.3, linear classification). LWs and WH at 7 and 12-13 months and weight gain between 7 and 12-13 months, the result of weighing and measuring, are published (Boonen, 1995). Sires having a successful test are classified as category I or II sires. These sires are sold to the highest bidder at an auction and can spread their desired genes in the population through AI or natural service (Boonen, 1995).

<u>4.2.1.2. Collection of (re)production data at farm level (progeny testing)</u>

Many data are collected at farm level and used for breeding value estimation of the AI sires. These data are collected at a first and second visit on the farm (Michaux, 1995).

The evolution towards the systematically applied CS (Coopman *et al.*, 2001; Hanset, 2002) made it useless to collect data on calving ease, as was still done in 1988 (Coopman *et al.*, 2001). From 1996, no data on mortality of newborns (0-48 hrs) and calves between 48 hrs and 12 months were collected anymore. In 1999, only six traits were still examined, namely the estimated birth weight, the estimated conformation at birth, the gestation length, the WH measured at 13 months of age (Leroy and Michaux, 1999), the weight at 13 months (estimated out of the measured heart girth – HG - ; $LW13 = 0.0005691*(HG)^{2.607}$; Clauwers *et al.*, 1999) and the estimated value per kg LW of the observed animal presuming it will be slaughtered at the moment of inspection (Gengler *et al.*, 1995). While in earlier times, weight was estimated at the age of 12 months, this is now done at 14 months (Hanset, 2004; Herd Book 2005, 2006).

In the last reports of 2005, 2006 and 2007, many traits that were not mentioned in the 1999 report are re-established. Nowadays, the traits considered at birth (first visit) are the estimated muscular conformation, the gestation length, the estimated birth weight, the death rate, vitality and the presence or absence of 6 known inherited disorders. Also the ability to drink is evaluated. At 14 months (second visit), information on the muscular conformation, LW and WH is collected as well as information on inherited disorders, sound feet and legs and death rate (Herd Book, 2005, 2006).

Many traits are estimated and not measured in the DM-BBB data collection procedure. Only WH and HG are measured on a routine base. The general idea of measuring WH is to prevent a decrease of the growth potential of the breed and to make sure that the final weight of the animals remains satisfactory (Hanset *et al.*, 1990). This makes sense because Hanset *et al.* (1988) showed a strong relationship between LW and WH in this breed. No other measurements are considered. Because visual appraisals and the visual classification of traits do not seem to be very accurate (Orme *et al.*, 1959; Van Steenbergen, 1990) and because objective (linear) measurements are described as being good alternatives for visual appraisal of beef type, carcass characteristics and conformation scores (Brown *et al.*, 1950; Orme et al, 1959; Tallis *et al.*, 1959; Jansen *et al.*, 1985), it can be questioned why additional weighing and measuring is not considered in DM-BBB selection. Hanset (2004) does not support additional weighing and measuring. This author is convinced that in a DM beef breed, visual assessment plays a predominant role because an animal that is bred for beef simply displays the amount of meat it will supply. The phenotype is indicative of the genotype. Others state that visual assessments might not be that repeatable, but nonetheless sufficiently correct. An advantage of visual assessments is that it is fast en therefore cheaper and applicable under field conditions (De Smet, personal communication 2008; Thierens, personal communication 2007).

4.2.1.3. Linear classification

The linear classification was developed in 1987. In 1988 it was applied for the first time on the bulls that entered the selection centre. From 1994 it was extended towards the registered DM-BBB cow population. The aim of the linear classification is to express the functional trait ‘sound feet and legs’ and the production traits ‘size’, ‘muscular conformation’ and ‘meat type’ in a standardized and quantitative way. Using the linear classification report, comparison between different breeding animals and ranking herds is possible (Hanset *et al.*, 1990; Hanset, 1991, Hanset *et al.*, 1994).

The animal is scored in such a way that the score lies between the two extremes of the trait. These two extremes are valued as 0 and 50, except for general appearance (between 1 and 20). The average is 25 and increases or decreases with five units at a time. A high score does not mean that the animal is ideal for the trait judged. The twenty traits presented in Table 1 have to be judged by the inspector (Hanset *et al.*, 1990; Hanset, 1991, Hanset *et al.*, 1994).

The scores on the 20 traits in Table 1 are used to obtain five groups of traits. These groups are ‘size’, ‘muscular conformation’, ‘meat type’, ‘feet and legs’ and ‘overall appearance’. ‘Overall appearance’ is added to judge harmony between the different body parts. The scores of the five groups and the total linear score can be obtained as described by Baligant (1997).

Using the linear scores of the bulls in the selection centres, Hanset *et al.* (1994) found a correlation of more than 0.4 between chest width, pelvis width, shoulder, top and muscles of the pelvis with the price per kg LW, and a very high correlation between WH (0.73), body length, chest width, pelvis width and shoulder with the LW. Chest width, pelvis width and shoulder have an important influence on the price per kg LW and the LW, two economically important parameters. When selection focuses on these three linear traits, conformation and weight will improve simultaneously. From the genetic evaluation, it can be concluded that all three have a high heritability of 0.54 (chest width), 0.49 (pelvis width) and 0.48 (shoulder). Factor analysis shows that body length (BL) and WH jointly explain 60% of the variation in weight and 48% of the financial income. Other conclusions of the study of linear scores were that selection in the DM-BBB breed focuses on muscular conformation and not on size and daily weight gain. This is despite the fact that, looking at the figures, it is possible to find bulls that are very well muscled and extremely heavy at a time (Hanset *et al.*, 1994).

Table 1: Linear scores in the DM-BBB breed (Herd Book, 1999).

Trait	Criteria	Grading
Height	From small to tall	1-50
Body length	From short to long	1-50
Chest width	From narrow to wide	1-50
Pelvis width	From narrow to wide	1-50
Shoulder	From poorly muscled to extremely muscled	1-50
Top	From poorly muscled to extremely muscled	1-50
Rib	From flat to round	1-50
Skin	From thick to thin	1-50
Rump	From horizontal to strongly sloping	1-50
Pelvis length	From short to long	1-50
Tail set	From embedded to prominent	1-50
Thighs: side view	From straight to rounded	1-50
Thighs: rear view	From slight bulging to extreme bulging	1-50
Bone structure	From thick to fine	1-50
Shoulder (joint)	From prominent to smooth	1-50
Top line	From concave to convex	1-50
Forelegs	From open to knock-kneed	1-50
Hind legs	From open to cow-hocked	1-50
Hocks	From straight to bent	1-50
General appearance	From poor to excellent	1-20

The linear classification is still developing. A change to the system was proposed especially for the group of feet and legs. Two new traits are added to the twenty existing traits that were reported in Table 1. The inspector judges the side view of the pastern of the forelegs and the hind legs of the animals. He especially looks at the angle that is made by the pastern and the ball-and-socket joint. In classifying animals, clear disorders in the limbs have to be penalized. This new approach makes that bulls having bad feet and legs show up with a bad linear score. By this new approach, cows also have a decline of in average two points for the scoring of feet and legs (Herd Book, 2000). In recent reports however, no consistent information on the two additional traits could be found (Herd Book, 2005; 2006).

4.2.1.4. Carcass classification

DM-BBB carcasses are, according to the SEUROP classification system for conformation (Anonymous, 1991), mostly classified as “S” or “E”. An “S” carcass is an exceptionally DM carcass. “E” carcasses are considered as double-muscled as well but not being extreme. There is little doubt that both types of carcasses and the extreme muscularity are the result of homozygosity for the mh-mutation at the myostatin locus (Hanset *et al.*, 1987; Van de Voorde *et al.*, 1999) and the additional influence of independent loci and modifier genes of the mh/mh (major gene) genotype (Hanset and Michaux, 1985). Carcasses of all animals are weighed after slaughter (warm carcass weight).

4.2.2. Prediction of breeding values

Using AI, one particular sire can have a large number of descendants, enabling progeny-testing of such sires. Hanset and Michaux (1988, 1989b) and Leroy and Michaux (1995, 1996, 1997, 1999) introduced progeny testing and breeding value estimation using the sire model in the DM-BBB breeding policy. An important difference in the use of breeding values with dairy cattle breeding is that the use of DM-BBB AI sires is not fully restricted in time because young DM-BBB sires can be used continuously even when breeding values are not yet available. The traditional procedure in a dairy breed based on tested sires, waiting sires and approved sires (TWA-system) is not applied rigoureusly (Hanset, 2004). In the past (late eighties), a modified TWA-system was used and since April 2007 it is reintroduced again (VRV, 2007).

Breeding values for a particular trait can be estimated – or rather predicted - from a mixed model with the additive gene effects of the breeding animals as random effects. The predicted random effects (Best Linear Unbiased Predictors or BLUP) correspond to the EBVs. Fixed effects, such as sex, conformation of the calf (DM or not) and the parity and conformation of the mother, are included in the model for correction (Hanset and Michaux, 1988). The random effects are assumed to be normally distributed with mean zero. The animals can have a negative, positive or zero EBV. The animals can be ranked according to their EBV.

In 1996, a change to the sire model was introduced. In the calculations, the relationship between the sires was accounted for (Leroy and Michaux, 1996). No scientific reporting on the models used for current breeding value estimation in the DM-BBB could be found.

EBVs are converted to indices to make them more practical. The breeding value zero equals the mean index of 100. An index of 110 corresponds to a positive breeding value and an index of 90 to a negative breeding value. Ten units on the index scale correspond to one standard deviation of the random effects distribution.

In the DM-BBB breed, EBVs on (re)production traits have been or are published in different reports (Hanset and Michaux, 1988; Leroy and Michaux, 1999; Herd Book, 2005; 2006).

Over years, the availability of EBVs was different. Only EBVs of data collected on the farms were processed. The evolution towards the systematically applied CS made it useless to estimate breeding values on calving ease. From 1996, no EBV on mortality of newborns (0-48 hrs) and calves between 48 hrs en 12 months were published anymore. In 1999 (XXIIIth

report; Leroy and Michaux, 1999), only EBV on six traits were still reported, namely the estimated birth weight, the estimated conformation at birth, the gestation length, the WH measured at 13 months of age, the weight at 13 months and the estimated value per kg LW of the observed animal. The estimated value at slaughter age and the estimated LW at 13 months are the two components of the economical multi-trait index for the net income (the so-called index économique or INEC) that ranks AI sires and that reflects their genetic economic value. The higher the INEC, the higher the income of the farmer will be using that particular bull on his breeding cows. In the latest report, many EBV that were previously not mentioned anymore are re-established. Nowadays, EBVs on the MC at birth, the gestation length, the birth weight, the death rate, the vitality, the ability to drink and the presence or absence of 6 known inherited disorders are published. EBVs that reflect the genetic potential of AI sires to breed for descendants with a high MC, LW and WH at 14 months and having sound feet and legs, a low death rate and low amounts of inherited disorders are made available to the DM-BBB breeders (Herd Book, 2005, 2006).

In the XIIth report (Hanset and Michaux, 1988), additional information was provided. The test results in the selection centre of purebred BBB were published as well. This report described also the EBVs of the controlled animals estimated using the animal model. Not only are the results of the bulls themselves used but also the performances of parents, half sibs and descendants. By doing so, EBVs can be estimated even for sires that had never been in the selection centres, using their genetic relationship with controlled animals. In the estimation, one accounts for the year and month of the ending of the program. The calculated multi-trait index is a combination of initial weight, growth and value of the animal expressed as Euro per kg LW (= muscle conformation). Implementing initial weight in this index is justified because of the existing correlation with growth during the test (Michaux, 1995).

The genetic gain for daily growth is variable over years (Paquet *et al.*, 1997). Weight and stature are stabilising and even decreasing. The genetic gain for muscular conformation is increasing for years, stabilising from 1995 – 1996 (Hanset, 2002). The average estimated birth weight remained between 43.6 and 44.8 kg and gestation length remained between 281.9 and 283.1 days (Hanset and Michaux, 1988, 1989b; Leroy and Michaux 1995, 1996, 1997, 1999). In the current breeding policy, the Herd Book chooses to select for a stable birth weight in order to prevent exuberant birth weights (Herd Book 2005, 2006). Whether important economic and dystocia related traits are stabilising or changing due to the application of EBVs or not is hard to prove. A major question on this issue is whether DM-BBB breeders are using the EBVs in their selection program or only the phenotypic traits of the selected parents' generation. Some reports indicate that selection based on phenotypes is more common than the use of the estimated breeding values and indices (Coopman *et al.*, 2005; Hanset, 2004).

5. Closing remarks

Although the history of the DM-BBB breed goes back to 1841, the most important progress was made from 1973 onwards, with the establishment of an almost closed Herd Book specifically for this type of animal. In less than thirty years, a uniform breed was created.

It has become clear that the breed has its advantages but its disadvantages as well. The lack of sufficient daily weight gain and information on weights at fixed ages and the routine application of the CS are two problems that are reported the most (Groupe de reflexion, 1997).

One should look for possible solutions to deal with the opposition against the CS and should try to stop or stabilize the negative genetic trend of daily weight gain (Hanset *et al.*, 2001) without losing the progress made for the muscular conformation.

Unfortunately, selecting for improved calving ease by lowering the birth weight and conformation at birth may have antagonistic effects on maternal calving ease (smaller pelvic sizes) and financial revenue at slaughter age (lower weight and/or less muscular conformation) (Hanset, 1981). Therefore, solutions that deal with the disadvantages of the breed will be disturbed by the presence of antagonistic effects between production characteristics and calving ease difficulties (Hanset, 1981). It is the greatest challenge within the breed to deal with this kind of problems and to finally find a consensus between these antagonistic features.

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Chapter 2

Aims of the study

The double-muscled Belgian Blue beef breed is an interesting breed but is at the same time controversial. The routinely applied caesarean section is criticized on animal welfare grounds. Some farmers and breeders claim that there is a lack of growth in the breed.

This work studies the two major points of criticisms in the DM-BBB breed, predominantly using measurements, and suggests remedial measures whenever deemed required.

At first, we focus on the problem of the routinely applied caesarean section. In dealing with this problem, many questions and considerations arise. In this study, we consider:

1. whether it is possible to estimate inner pelvic sizes based on easily accessible external body measurements;
2. the question whether natural calving is still feasible in the DM-BBB breed.

Secondly, we deal with the live weight and daily weight gain issues in this breed. In this part of the study, we look for:

1. live weight data and related genetic and phenotypic parameters based on the information collected on animals that are housed on conventional farms and not on the selection centres or on the top breeding farms;
2. body measurements that are a reflection not only of live weight but also of the muscular conformation of the DM-BBB animals;
3. models, taking into account gender and age of the animal, which could predict live weight out of the body measurements that are found to be highly related to live weight.

Chapter 3

Estimating internal pelvic sizes using external body measurements in the double-muscled Belgian Blue beef breed

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Abstract

In the double-muscled Belgian Blue beef breed, caesarean section is being applied systematically as a management tool to prevent dystocia. As a matter of fact, CS is the only possible way of calving in the breed. High birth weight and a relatively small pelvic area are the main causes of dystocia and, in the DM-BBB breed, the reasons for the systematically applied CS. Selection for lower birth weight and larger pelvic sizes might reduce dystocia and routine CS. Few data on inner pelvic sizes of pedigree animals are available. Using external measurements to estimate the inner pelvic sizes might be an option to resolve this problem. In this study, animals of the DM-BBB breed were measured and weighed on farms and in abattoirs. External and internal pelvic sizes increased with live weight and age of the animals. Gender has a significant influence on inner pelvic traits. Increased muscular conformation was associated with decreased inner pelvic dimensions. Models with weight, gender, age, withers height and outer pelvic width (TcTc) can be used to estimate inner pelvic sizes (R^2 between 0.35 and 0.77). The estimated inner pelvic sizes can then be used to genetically evaluate pelvic traits in the DM-BBB breed. Improving weight, WH and TcTc width in combination with lowering muscular conformation may help to decrease the high rate of caesarean section in the DM-BBB breed.

Keywords: Beef cattle; Belgian Blue; Body measurements; Pelvis

1. Introduction

High birth weight of the calf in combination with a small size of the pelvic area of the dam is the main cause of dystocia and increase incidence of CS (Ménissier and Vissac, 1971; Laster, 1974; Meadows *et al.*, 1994; Murray *et al.*, 1999). The routine CS has been criticised on animal welfare grounds (Grommers *et al.,* 1995). Decreasing the incidence of dystocia without using CS as a preventive management tool can be done not only by selecting for lower birth weights, but also by selecting for higher pelvic height (PH), pelvic width (PW) and/or pelvic area (PA; Green *et al.*, 1988; Murray *et al.*, 1999). Genetic selection to change these traits requires routine measurement.

The PH, PW and PA of DM animals are significantly smaller than those of non-DM animals (Ménissier and Vissac, 1971). The proportion of os coxa, being the combination of the pelvis, the sacrum and the first two coccygeale vertebrae, to the total bone weight is also smaller in DM cows than in non-DM cows (Shahin *et al.,* 1991). The differences between non-DM and DM animals are in the anterior pelvic plane. The narrowing of this anterior pelvic plane is accompanied by a deformation, i.e. convergence of the iliac branches of the hip–bone, and even an accentuation of the pelvic crest (Vissac *et al*., 1973).

Measuring inner pelvic sizes on living animals can be done by using a pelvimeter (Rice and Wiltbank, 1972; Schwabe and Hall, 1989; Kriese *et al.,* 1994). The most common measurements taken are: PH (the narrowest distance between sacrum and pelvic crest) and PW (broadest points between right and left iliac branches of the hip–bone) (Taylor *et al.*, 1975; Neville *et al.*, 1978; Brown *et al.*, 1982). The pelvic area is defined as the product of the measured PH and PW (Morrison *et al.*, 1986). Murray *et al.* (1999) measured not only PH and PW, but also the external distance between the most lateral points of the tuber coxae (TcTc) and the external distance between the tuber coxae and tuber ischii (TcTi). Rice and Wiltbank (1972) measured pelvic sizes of carcasses (non-DM Aberdeen Angus) before they were halved to see whether there was a meaningful correlation with the measurements of live animals. Except for Murray *et al.* (1999), most studies have examined non-DM beef cattle, and where DM cattle were investigated, breeds other than the DM Belgian Blue beef (BBB) breed were examined.

Because of the fact that natural calving is no longer present in the breed, selection for decreased CS can, primarily only be done indirectly, using internal pelvic sizes of the dam and birth traits of the calf as basic data.

The routine collection of sufficient data of internal pelvic sizes *per rectum*, as done by Murray *et al*. (1999), on animals of known pedigree, for a genetic evaluation may pose a problem. Although risk can be minimised (Ménissier and Vissac, 1971), measuring internal pelvic sizes *per rectum* is both time-consuming and not without risk for the breeding animals and the technician. Internal measurements can also be done before (Rice and Wiltbank, 1972) or after slaughter. With this approach, one should be aware of the fact that many of the presented animals have no known pedigree, making these data useless for genetic evaluation. This means that an easier and more accessible method to collect sufficient data on internal pelvic sizes of animals of known pedigree for the DM-BBB breed is needed in order to start selection for wider internal pelvic sizes. Seeing that a regression model is available, it is possible to estimate inner pelvic sizes from external body sizes.

The aim of this paper is to serve as a guideline for developing such a model (or models). Some models have been developed and presented as examples. There is a description of the way in which the necessary data to develop these models can be collected. The results obtained from this preliminary study can be of help when discussing the overall breeding policy in the DM-BBB breed.

2. Materials and methods

2.1. Animals

The number of observations is presented in Table 1.

Table 1. Number of observations (range of ages of animals in days is given in parentheses).

		External body measurements	Internal pelvic measurements
*Abattoirs	1	192 (228-3234)	192 (228-3234)
	2	-----	140 (609-4251)
	3	200 (449-996)	-----
**Farm	1	165 (1-2478)	-----
	2	109 (unknown)	-----

**Abattoir 1 = Melle; abattoir 2 = Zele; abattoir 3 = Verbiest (Izegem).*
***Farm 1 = 2 DM-BBB farms near Ghent; Farm 2 = Clients of Ambulatory Clinic of Veterinary Faculty in Ghent breeding DM-BBB.*

All animals were of the DM-BBB breed and data were gathered over a period of six years (1995-2001), either at abattoirs (three) or at farms (two). In total, external body measurements of 666 animals were available, of which 109 had no age information. Internal body measurements of 332 animals were available. Of these, 192 animals had both external and internal body measurements. Pedigree information was available on only a small number of the farm animals. The age ranged from 1 to 2478 days for animals on farms, and from 228 to 4251 days for animals at the abattoirs. The slaughter date minus the birth date mentioned on the identification card of the animals was used to calculate the ages of the animals. The 109 animals with no age information had either questionable birth dates or no accessible ID card. The abattoirs and farms mentioned were the only ones willing to co-operate. In abattoir 1, pre-mortem and post-mortem measurements were possible and allowed. In abattoir 2, accommodation was inadequate for pre-mortem measurements. Abattoir 3 did not provide access to the carcasses for hygienic reasons.

2.2. Measurements

The external body measurements, weights, external and internal pelvic sizes that were taken are described in Table 2.

The internal pelvic measurements were done on halved carcasses. This means that PW could not be measured. All measurements were taken using a measuring-rod or measuring-tape. In total, 4 different inspectors helped to collect these weights and measurements. They had been well instructed by the chief inspector at the outset.

The visual appreciation of muscular conformation and fat percentage of the carcasses was done by the inspector of the abattoir according to the SEUROP classification method of the European Community (Anonymous, 1991; S = extreme muscularity to P = dairy type; 1= low fat content to 5 = extreme fat).

One inspector gathered external body measurements as well as internal pelvic sizes on 192 animals. The different pre-mortem and post-mortem measurements were done within a time lapse of 24 hours. These 192 animals, 186 animals with an S (extreme muscular hypertrophy) or E (plain muscular hypertrophy) classification were restricted to the so-called abattoir population. Measurements on the farms were done at the beginning of the winter season when animals were housed. Abattoir measurements were done on a weekly basis in November (winter).

Table 2 External body measurements and weights, and external and internal pelvic sizes of female (above) and male (below) DM-BBB cattle.

Trait		N	Min.	Max.	Mean	SE	Median
External	WH (cm)	174	64	140	122	20	129
		319	73	140	122	15	128
	SW(cm)	174	18	81	58	14	64
		319	20	80	63	11	66
	BcW (cm)	158	19	76	61	12	66
		304	18	76	60	8	63
	HG (cm)	174	78	272	205	50	226
		319	78	254	198	34	204
	LW (kg)	174	38	986	583	258	677
		319	38	1081	622	200	673
	CW (kg))	269	293	660	468	57	473
		260	200	739	467	57	469
	TcTc (cm)	225	15	66	50	10	54
		319	15	67	51	10	54
	TiTi (cm)	207	5	23	13	2.2	13
		94	6	19	10	2.3	10
Internal	PH (cm)	269	17	29	23	2.4	23
		58	16	25	21	1.5	21
	Pusca (cm)	269	21	31	25	1.8	25
		60	19	27	24	1.6	23
	Isscr (cm)	269	31	42	37	2.1	37
		60	26	42	34	2.4	33
	Issca (cm)	269	15	26	21	1.9	21
		60	16	23	19	1.5	19
	Sym (cm)	269	17	29	19	1.0	19
		60	16	23	19	1.2	19
	Sac (cm)	269	22	31	27	1.3	27
		60	20	30	25	1.6	25

WH: withers height; SW: shoulder width (distance between broadest points of the shoulder); BcW: back width (distance between the broadest points of the hindquarters); HG: heart girth (measuring half of the heart girth following the muscles on the thorax and then multiplying by two); LW: live weight; CW: carcass weight; TcTc: the external distance between the most lateral points of the tuber coxae; TiTi: the internal distance between the tuber ischii; PH or Puscra: pelvic height (pubis to sacrum cranialis); Pusca: pubis to sacrum caudalis; Isscr: ischium to sacrum cranialis; Issca: ischium to sacrum caudalis; Sym: length of the symfysis; Sac: length of the sacrum. N: number of animals; SE: standard error.

2.3. Statistics

SPSS 9.0 for Windows was used to explore and analyse the data phenotypically. Correlations between the external measurements, as well as the internal measurements, and weights were determined both with and without adjustments for age or weight effects. The correlations between internal and external measurements were based on the data of the abattoir population. To see whether SEUROP classification (S and E – animals) or gender influenced the internal traits, a general linear model was developed where the fixed effects were gender, SEUROP classification and the interaction between gender and SEUROP, and with the co-variates age and weight (live weight or carcass weight).

Data of the abattoir population were used to develop multiple regression models that estimate inner pelvic sizes from easily accessible external measurements. The stepwise multiple regression method was used. The influence of the sex was incorporated in the model by implementing the gender as an independent dummy variable (0 for the male and 1 for the female). In the case of age, a hyperbolic function was found and a transformation (1/Age) was therefore done. The trait 'SW' was not implemented in the model because preliminary graphical examination showed no clear relationship with any of the six internal pelvic measurements. As the data of the abattoir population were collected by only one inspector, this effect was not included in the model. Different models were developed to estimate the inner pelvic sizes and the reliability of these estimations and the estimation errors were calculated.

3. Results

3.1. Descriptive statistics

Table 2 shows descriptive statistics for all the external and internal measurements. Of the females with a known classification for carcass conformation, 55.4 % were classified under "S" and 42.4 % were classified under "E". Of the males, 67.2 % were classified under "S" and 31.7 % under "E". Females showed a higher level of fat deposition on the carcass (4.6% class "1"; 53.8 % class "2"; 40.8 % class "3") than males (5.1% class "1"; 79.4 % class "2"; 15.2 % class "3").

3.2. Simple Correlations

Simple correlations between the external and internal pelvic sizes are illustrated in Table 3.

It is clear that TcTc has a high correlation not only with pelvic height (male $r = 0.62$ and female $r = 0.47$, both $p < 0.01$), but also with other inner pelvic sizes in the male population (r 0.48 to 0.68; $p < 0.01$).

Table 3. Simple correlations (diagonally above) and correlations adjusted for age and weight (diagonally below) between the external and internal pelvic sizes for the female (above) and the male (below) population considered.

Trait		External				Internal			
		TcTc	TiTi	PH	Issca	Pusca	Isscr	Sym	Sac
External	TcTc		0.62**	0.47**	0.25**	0.37**	0.48**	0.28**	0.44**
			0.75**	0.62**	0.48**	0.55**	0.68**	061**	0.59**
	TiTi	0.1		0.13	0.22*	0.33**	0.12	0.19*	0.20*
		0.1		0.45**	0.43**	0.32*	0.38**	0.19	0.24
Internal	Puscra	0.18*	-0.07		0.64**	0.54**	0.80**	0.19**	0.47**
		0.21	0.26*		0.68**	0.60**	0.86**	0.58**	0.68**
	Issca	-0.06	0.08	0.26**		0.73**	0.60**	0.29**	0.36**
		0.03	0.25	0.33*		0.55**	0.71**	0.58**	0.43**
	Pusca	0.06	0.22*	0.06	0.47**		0.36**	0.35**	0.58**
		0.08	0.09	0.14	0.16		0.62**	0.71**	0.75**
	Isscr	0.17*	-0.09	0.71**	0.20*	-0.16		0.55**	0.55**
		0.25	0.10	0.60**	0.35**	0.05		0.80**	0.80**
	Sym	0.02	0.04	0.05	0.09	0.24**	0.40**		0.45**
		0.12	-0.15	-0.00	0.15	-0.00	0.46**		0.72**
	Sac	0.25**	0.07	0.29**	0.04	0.44**	0.25**	0.28**	
		0.14	-0.05	0.26*	-0.14	0.48**	0.49**	0.32*	

TcTc: the external distance between the most lateral points of the tuber coxae; TiTi: the distance between the tuber ischii; PH or Puscra: pelvic height (pubis to sacrum cranialis); Issca: ischium to sacrum caudalis; Pusca: pubis to sacrum caudalis; Isscr: ischium to sacrum cranialis; Sym: length of the symfysis; Sac: length of the sacrum.

A highly significant simple correlation ($r > 0.91$; $p < 0.01$) was found between live weight and carcass weight in both the female and male population. Live weight showed a highly significant correlation ($r \geq 0.89$; $p < 0.01$) with the four external body measurements for males and females. For the two external pelvic sizes, there was a high correlation r with live weight of at least 0.74 ($p < 0.01$). There were differences between the correlations of LW with the internal pelvic sizes in the male population ($r > 0.66$; $p < 0.01$) and the female population (r between 0.45 to 0.6; $p < 0.01$). The significant correlations found between age and all the external traits ($r = 0.54$ to 0.87; $p < 0.01$) were higher than the ones found between age and the internal pelvic sizes (r between 0.15 to 0.63; $p < 0.01$).

3.3. Adjusted Correlations

Correlations between the external and internal pelvic sizes, adjusted for age and weight effects, are shown in Table 3. Only very few adjusted correlations remain significant, highlighting the high correlation between inner pelvic sizes and LW. In males and females, the significant adjusted correlations show that SW (with PH, Isscr and Sym) and BcW (with PH) have significant negative correlations ($r = -0.25$; $p < 0.01$). WH has positive low (r

between 0.17 to 0.26; $p < 0.01$), but significant, adjusted correlations with inner pelvic sizes, indicating that taller animals, irrespective of their LW, tended towards wider pelvic sizes. All the external body measurements had positive partial correlations with both the external pelvic measurements (*r* between 0.28 to 0.59; $p < 0.01$).

3.4. General Linear Model

Gender and muscular conformation, expressed as SEUROP classification, have significant ($p < 0.01$) effects on internal pelvic sizes. It was only for Pusca and Issca that no significant effect of conformation was found.

3.5. Multiple regression-models

Table 4 shows different models to estimate inner pelvic sizes from external body sizes.

Table 4. Models to predict inner pelvic sizes from easily accessible external body measurements.

Y	Model	R^2	SE
PH	Y = 11.863 + 1.98*gender – 2024/age + 0.07*WH + 0.0047*LW	0.77	1.16
PH	Y = 8.08 + 1.42*gender – 2379/age + 0.103*WH + 0.069*TcTc	0.76	1.17
PH	Y = 9.04 + 1.49*gender – 2681/age + 0.126*WH	0.75	1.19
Isscr	Y = 13.22 + 2.11*gender – 1176/age + 0.134 WH +0.008*LW	0.72	1.41
Isscr	Y = 7.12 + 1.19*gender – 1898/age + 0.197*WH +0.092*TcTc	0.70	1.46
Isscr	Y = 8.40 + 1.29*gender – 2300/age + 0.228*WH	0.69	1.49
Issca	Y= 7.219 +1.66*gender –1134/age + 0.07*WH + 0.14*TcTc + 0.004 LW	0.66	1.25
Issca	Y = 5.92 + 1.46*gender – 1816/age + 0.128*WH	0.64	1.28
Pusca	Y = 10.53 + 1.3*gender – 894/age + 0.079*WH + 0.16*TcTc + 0.004 LW	0.59	1.30
Pusca	Y = 9.22 + 1.10*gender –1625/age + 0.134*WH	0.56	1.34
Sac	Y = 10.58 – 1034/age + 0.102*WH + 0.071* TcTc	0.46	1.15
Sym	Y = 7.51 + 0.070*WH + 0.0038*LW	0.40	0.82
Sym	Y = 3.25 + 0.125*WH	0.35	0.86

PH or Puscra: pelvic height (pubis to sacrum cranialis); Isscr: ischium to sacrum cranialis; Issca: ischium to sacrum caudalis; Pusca: pubis to sacrum caudalis; Sac: length of the sacrum; Sym: length of the symphysis. Gender: male = 0 and female = 1; WH: Withers height; LW: Live Weight; TcTc: the external distance between the most lateral points of the tuber coxae; R^2: adjusted *R* square; SE: Standard error of the estimate (cm);

For all the models shown, the assumptions of normal distribution and homoscedascity of the dependent variable were fulfilled. It is clear from these models that especially the external traits LW, TcTc and WH are good estimators of internal pelvic sizes, confirming the simple and adjusted correlations.

4. Discussion

The purpose of this investigation was to draw up a guideline to develop a model that can help estimate inner pelvic sizes from external body measurement and to describe a method to collect the data needed for the development of such model. Because correlations exist between external body traits (LW, TcTc and WH) and internal pelvic sizes, models can be developed as shown. Repeating the measurements on abattoir animals on a much larger scale can help create a model that is representative of the total DM-BBB breed. This model can then be used to estimate inner pelvic sizes from external body traits taken from numerous pedigree animals. These estimated inner pelvic sizes can be genetically evaluated and finally result in estimated breeding values to be used in selection. Using male data as well increases the total amount of available data, and therefore the reliability of a genetic evaluation.

When repeating the research to create a representative model for the DM-BBB breed, one should remember that it will be breed-specific. Breed is known to influence pelvic traits (Bellows *et al.*, 1971; Laster, 1974; Brown *et al.*, 1982 and Morrison *et al*., 1986). Focusing on females between 24 months (first parity) and 48 months (third parity and mature) and males between 18 and 24 months (slaughtering age) the development of separate models for males and females should be considered. Gender significantly influences pelvic sizes (this study) and age influences variation of the pelvic size (this study; Glaze *et al.*, 1994). When measuring TcTc, a clear distinction must be made. TcTc can be measured not only on the ventro-lateral (Murray *et al.*, 1999; this investigation), but also on the dorso-medial point of the tuber coxae. Measuring before the carcass is halved may result in an additional important inner pelvic trait (pelvic width).

The fact that the results of Murray *et al.* (1999) have been confirmed by the results of this study increases the possibility that the results of both studies are very likely to be representative of the breed.

Once a representative model confirming the best estimators of inner pelvic sizes, namely LW, WH and TcTc has been created, collecting weight and TcTc on a routine basis, as is already being done for WH (Hanset *et al.*, 1990; Gengler *et al.*, 1995; Leroy and Michaux, 1999), should be encouraged. Tuber coxae measurements should not be done on DM–BBB animals around calving time, because there are pelvic changes that can bias the results (Ménissier and Vissac, 1971; Murray *et al.* 1999).

The method described to obtain a large quantity of data on pelvic traits indirectly is much more accessible than the direct method of pelvimetry as presented by Murray *et al.* (1999).

The inspector needs no veterinary skills and there is a limited risk for the animals. What is more, internal pelvic height and pelvic width measurements have a lower repeatability (0.61 and 0.49, respectively) than external measurements (0.78 to 0.96; Ménissier and Vissac, 1971).

The negative-adjusted correlation of SW and BcW, both MC traits, with inner pelvic sizes, and the result of the general linear model, indicate that increased MC within the DM-BBB breed is related with decreased inner pelvic dimensions. However, it must be made clear that in DM-BBB breed, animals having the same SW (and therefore comparable MC), show a great variety of pelvic height.

Recent research by Hanset *et al.* (2001) shows that average weight in the DM–BBB breed keeps decreasing but conformation is still rising. This negatively influences PH and other inner pelvic traits, thereby increasing the degree of dystocia in the DM-BBB breed even more. To improve the rate of natural calving in the DM-BBB cattle, selection must be adapted. A possible adaptation would be the creation of a line of suckler breeding cows, with a strong emphasis on maternal calving ease, high weight, wide TcTc, acceptable MC and good height. From an economic point of view, it is worthwhile considering the creation of a line with a strong emphasis on beef characteristics (extreme MC) and direct calving ease (low weight and muscular conformation at birth) to breed with this breeding suckler line.

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Chapter 4

Comparison of external morphological traits of newborns to inner morphological traits of the dam in the double-muscled Belgian Blue Beef breed

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Abstract

In the double-muscled Belgian Blue beef breed, caesarean section is used as a routine management tool to prevent dystocia. This practice is criticized on animal welfare grounds. With unassisted (natural) births, difficulties arise because of disproportion between the sizes of the newborn and inner pelvic sizes of the dam. In this study external morphological traits of newborns are compared with inner morphological traits of the dam. Results of this study indicate that in the DM-BBB breed, CS is the only means to successful calving. Therefore, no calving ease scores are available to select for less dystocia in this breed. Selection for fewer CS must be achieved by focusing on lower birth weight (BW) and decreased muscular conformation at birth, both having a sufficiently high heritability. Simultaneously, pelvic sizes of the dam should be increased. It is very likely that the look of the DM-BBB breed will change when selecting for less dystocia.

Keyword: Caesarean section; Inner pelvic sizes; External morphological traits

1. Introduction

Citizens criticize routinely applied caesareans on animal welfare grounds (Grommers *et al.*, 1995; Christiansen and Sandøe, 2000). Because of European legislation, it can be expected that, in the DM-BBB breed, the Herd Book will finally be forced to select against routine CS (Lips *et al.*, 2001).

Muscular hypertrophy is characterized by high foetal and early post-natal muscle growth. At later age, growth is influenced negatively. This causes an imbalance between the size of the hindquarter and shoulder of the calf and the pelvic area size of the dam (Vissac *et al.* 1973; Hanset, 1981), increasing the incidence of calving difficulties and the wish to preventively perform routine CS (Arthur *et al.*, 1988; Nugent *et al.*, 1991; Rice, 1994). In the double-muscled branch of the BBB, birth by CS has become a breeding peculiarity (Hanset, 1981; Nicks *et al.*, 1999), being performed as a matter of routine, especially in order to minimize risks for both mother and calf (Michaux and Hanset, 1986).

Although in literature, incompatibility of the sizes of the foetus and the dam's pelvis is mentioned as the most important cause of dystocia in beef cattle (Rice, 1994), no combined measurements of both sizes are described. Only the weight of both the dam and the calf are compared, as in the classical study of Joubert and Hammond (Rice, 1994), or only pelvic sizes are mentioned (Murray *et al.*, 1999). Body traits of newborns have not been measured, especially not in the DM-BBB breed.

The aim of this research is to compare external morphological traits of newborns to inner morphological traits of dams of the DM-BBB breed and to see, purely geometrically, if natural calving in the DM-BBB breed is still possible.

2. Material and methods

2.1. Animals

The number of observations is presented in Table 1.

All animals were of the DM-BBB breed and data were gathered over a period of 6 years (1995 to 2001). Two herds had a large number of observations. A large group of herds (75) in northern Belgium had only a low number of observations per herd. In the analysis this latter group was treated as one common herd. The data collected in herds 1 and 2 were spread over the six-year period, while the data in herd 3 were collected only during the year 1999. Most

Table 1. Number of observations.

Herd number	BW and BT	BW only	BT only	Total
Herd 1	203	336	-	539
Herd 2	35	113	-	148
Herd 3	181	323	32	536
Total	419	772	32	1223

Herd 1: Oostwinkel; Herd 2: Waarschoot; Herd 3: compilation of 75 herds in northern part of Belgium; BW: birth weight; BT: body conformation measurements.

calves were therefore measured and/or weighed in that year. Calves were born mostly in winter (541). In total, 1191 calves (572 males and 619 females) were weighed directly after birth. Body conformation measurements were performed on 419 of these calves within 48 hours after birth. Thirty-two other calves were measured, but their birth weights (BW) were not recorded, which means that 451 calves had known body conformation measurements at birth. In total, data were available on 1223 calves.

In total 79 calves had an unknown pedigree; only the sire information was available on 453 and 691 had a known sire and dam. In total 41 sires were used. Nine were natural service sires having between 50 to 60 descendants each. Spread over all three herds, some dams (= 21), being embryo transplantation donors, had an average of 3.78 calves. All other calves (611) had a different dam. Out of these 611 different dams, 113 had no additional pedigree information available.

The dams, whose internal pelvic heights were used for the comparison with the body conformation measurements of the calves, are selected out the ones described by Coopman *et al.* (2003). They are all of the DM-BBB breed.

2.2. Measurements

Birth weights were gathered directly after birth. The four body conformation traits measured are: Withers height, shoulder width (distance between the broadest points of the shoulder), width of the hind quarter (distance between the broadest points of the hind quarters) and heart girth (measuring the left half of the heart girth following the muscles on the thorax and then multiplying by two). They were measured within 48 hours after birth. All measurements were taken using a measuring rod or measuring tape. Unpublished data reveal a repeatability of > 0.9 within and between inspectors for these kinds of measurements. Three different inspectors did the data collection in herd 3. Only one inspector did the data collection in Herds 1 and 2.

For one animal, BcW, WH and SW were excluded from the data set. The WH of eleven other animals was not available.

2.3. Statistics

SPSS 10.0 for Windows was used to explore and analyze the data phenotypically. Simple phenotypic correlations between birth weight and birth traits were calculated once for the female and male calves separately and once for the overall population. Correlations with the birth weight held constant, were calculated once for the male and females separately and once for the total population of newborns as well.

A linear model to estimate BW out of the four body conformation traits was developed. The stepwise multiple regression method was used. Effects due to different inspectors, herd, year and season of birth were evaluated. Gender was incorporated in the model as a dummy variable (male = 0; female =1).

Out of the 232 DM-BBB animals that had internal pelvic measurements (Coopman *et al.* 2003), 190 females with ages of between 671 (calving at 22 months) and 1,830 (calving at 5 years) days and having a SEUROP classification of S or E (Anonymous**,** 1991) were selected. Internal pelvic height within this group ranged from 18 to 28 cm. This group was divided into four groups of different parity. The mean, minimum and maximum values of pelvic height of each group were calculated.

2.4. Genetic parameters estimation

Genetic parameters for birth weight and external body measurements were estimated using an animal model, including the animals having unknown or incomplete pedigree information. They were listed in the pedigree file having an unknown sire and/or dam (= 0). Preliminary calculations showed no maternal effects on any of the birth traits considered; therefore this effect was not included. Effects included in the model were herd (3), year (1996-2002) and season of birth (1-4), as well as sex and inspector (3). Heritability and genetic correlations between all birth traits considered were estimated using REMLF 90 (Misztal, 2002).

3. Results

The features of the weights and the four body conformation traits of female and male DM-BBB calves at birth are listed in Table 2.

Table 2. Weight and external body measurements of DM-BBB calves (males first line; females second line) at birth.

Trait	N	Mean	SD	Min.	Max.
Birth weight (kg)	572	51.58	8.26	28	81
	619	47.60	7.52	23	77
Withers height (cm)	181	72.15	4.39	57	82
	226	71.17	4.22	54	84
Shoulder width (cm)	189	24.76	2.44	17	33
	229	23.76	2.44	18	33
Back width (cm)	189	25.96	2.53	18	34
	229	25.56	2.51	19	34
Heart girth (cm)	189	86.90	7.84	63	104
	230	85.59	6.02	70	100

N, number of animals; SD, standard deviation

The phenotypic correlations on the total population are described in Table 3. The phenotypic correlations calculated on the female and male population were similar to the ones calculated for the total population. That's why they are not presented separately. The genetic correlations and heritability (h^2) estimates of the five birth traits are also listed in Table 3.

Table 3. Correlations between weight and measurements at birth. Above diagonal genetic correlations; beneath diagonal, phenotypic correlations, with the correlations with BW held constant for the overall population on the second line. The heritability estimates (h^2) are on the diagonal.

Trait	BW	WH	SW	BcW	HG
Birth weight	0.33	0.19	0.56	0.48	0.35
Withers height	0.67	0.68	0.62	0.49	0.52
Shoulder width	0.71	0.50	0.75	0.98	0.72
Back width	0.69	0.51	0.84	0.73	0.72
			0.68		
Heart girth	0.56	0.59	0.40	0.33	0.82
		0.32	-0.12		

All phenotypic correlations are significant at $P < 0.001$; except for HG-BcW ($P < 0.05$).

Creating the linear model, it was found that birth year, birth season, herd or inspector had no effect on the BW, but gender did. The four body conformation traits measured at birth significantly influence BW, as can also be seen in Table 3. Both gender and BcW were excluded from the multiple regression models because there was no additional reliability of the model. Birth weight can therefore be estimated with a reliability of 0.68 (R^2) and with a standard error of +/- 4.8 kg out of three body conformation measurements at birth. The assumption of normal distribution and homoscedascity of the dependent variable was fulfilled. The following formula can be used:

$$BW = -54.74 + 1.668*SW + 0.639*WH + 0.228*HG$$

In Table 4, mean, minimum and maximum values of PH are given according to parity.

Table 4. Mean, minimum and maximum values of pelvic height (cm) over different parities.

Parity group	N	Mean	SD.	Min.	Max
1	6	22.5	1.25	20	24
2	64	21.8	2.03	18	26
3	35	22.4	2.35	18	27
4	85	23.4	2.02	20	28

1, 22-28 months (first parity); 2, 28-36 months (second parity); 3, 36-42 months (third parity); 4, 42-54 months (fourth parity); N, number of animals; SD, standard deviation.

4. Discussion and conclusion

The aim of this research was to compare external morphological traits of newborns to inner morphological traits of dams of the DM-BBB breed and to see, purely geometrically, if natural calving in the DM-BBB breed is still possible. To some, CS is performed out of ease, is time saving and is not always necessary. Dams do not get the proper time to prepare for a natural birth anymore. Therefore frequency of CS should be much higher than really necessary and different calving ease scores should still be available in this breed, whenever needed.

The results indicate that birth weights in DM-BBB breed are high and in 20 % of the cases can be defined as foetal gigantism, being a weight higher than 59 kg at birth (Holland and Odde 1992). According to Hanset (2002), mortality in such calves is higher than average. Extremely bulky calves were also found.

Visually, it is clear that the width of the hindquarters and the shoulder width are the broadest points of a newborn DM-BBB calf. On average, the BcW is broader than the SW (Table 2). Therefore, the hindquarter, geometrically speaking, is the limiting factor for natural calving as seen from the calf's side. It is known from literature that pelvic height is wider than pelvic width (Morrison *et al.*, 1986; Murray *et al.* 1999), making pelvic height the limiting factor as seen from the dam's side. Comparison of the external body traits of the newborn and the internal pelvic size of the dam can therefore be limited to the width of the hindquarter and the pelvic height, when geometrically considering natural calving ability. On average (Table 2) and individually (database), BcW of the DM-BBB calves is too broad to pass the pelvic height (Table 4) of the DM-BBB dams investigated in this study. Maximum values of the hindquarter width of the calves are far beyond the maximum pelvic height values of the dams considered. Within the DM-BBB breed these results are indications of incompatibility in the sizes of the pelvis of both the foetus and the dam and this is, besides other causes, the single most important cause of dystocia in beef cattle (Rice, 1994). Considering the facts that the weight of the dam is positively correlated not only with the pelvic height (Coopman *et al.*, 2003), but also with the weight of the calf (Rice and Wiltbank, 1972; Taylor *et al.*, 1975), and that the birth weight positively correlates with the width of the hind quarter ($r = 0.69$; $p < 0.001$), it is not to be expected that small calves will be born out of large dams. This therefore indicates that there is a low chance that natural calving will occur.

It can therefore be concluded that birth by CS in the DM-BBB breed, performed systematically at rates between 96.06 to 99.21 % (Hanset, 2002), and considered as a management tool, is indeed the only means and only option to successful calving. Therefore, no calving ease scores, as used in many other breeds (Anderson *et al.*, 1993; Wang *et al.*, 1997; Carnier *et al.*, 2000), are available to select for less dystocia in the DM-BBB breed. Although Burfening *et al.* (1978) and Hanset (1981) prefer selection using calving ease scores, selection for less dystocia and fewer CS's in the DM-BBB breed can only be achieved by increasing internal pelvic sizes of the dam and by lowering the weight and/or size of the newborn calf. Internal pelvic sizes have a high heritability (Anderson *et al.*, 1993; Morrison *et al.*, 1986), as do the body conformation traits and weight at birth (Table 3; Anderson *et al.*, 1993; Glaze *et al.*, 1994; Arthur *et al.*, 1997), making this approach possible.

Focusing selection on a lower birth weight in the DM-BBB breed will cause calves to have smaller shoulders ($r_g = 0.56$) and hindquarters ($r_g = 0.48$) and therefore to be less muscular at birth, but not very much shorter ($r_g = 0.19$). Selection may also be focused on MC (BcW and SW), thus creating another, smaller type of newborn (r_g BcW-WH = 0.49).

When selecting for lower birth weight, one should not produce calves of < 36 kg. The mortality rate in this group increases (Holland and Odde, 1992; Hanset, 2002) and the probability that one is selecting for insufficient growth (Naazie *et al.*, 1991) and even dwarfism (Anthony *et al.*, 1995), increases. Taking into account the increased mortality rate for calves over 56 kg (Hanset, 2002), a recommendable range for the birth weight is therefore between 36 and 56 kg. Restricting the statistical analysis to the calves within this range teaches one that they have a mean value of the width of the hindquarter of 25.06 +/- 2.13 cm. For the females investigated in this study and for each parity group (Table 4) this mean value is still too large when geometrically considering natural calving ability. This indicates that simultaneous selection according to birth weight and pelvic sizes is indeed necessary to solve the problem.

Coopman *et al.* (2003) have already suggested that dams should be heavier, taller and less muscular in order to have wider pelvic sizes. In this article, it is advised that calves should weigh less and have less muscular conformation at birth. The look of the DM-BBB breed will therefore inevitably change, and typical features present in the current DM-BBB breed may change, as feared by Hanset (2002).

The creation of two lines within the DM-BBB breed may be the solution to combine economical points of interest with the calving ease request. Coopman *et al.* (2003) already described this first line, the so-called "suckler" line. A second line must emphasize beef characteristics (extreme muscular conformation at slaughtering age) and direct calving ease (low weight and muscular conformation at birth as suggested in this report). In order to create such lines, there is an urgent need for a well-organized data collection within the DM-BBB breed.

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Chapter 5

Estimation of phenotypic and genetic parameters for weight gain and weight at fixed ages in the double-muscled Belgian Blue beef breed using field records

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Abstract

In the double–muscled Belgian Blue beef breed, selection focuses on muscular conformation and not on weight gain and higher weight. There are very few studies on growth in the DM-BBB breed using field records. Therefore, farms have no available useful figures on weight at fixed ages and weight gain for the DM-BBB breed. This study describes and evaluates live weights of DM-BBB animals. All the data were gathered on farms in Belgium. It was found that a male DM-BBB weighs on average of 51 kg at birth, 98 kg at 3 months, 242 kg at 7 months, 430 kg at 13 months and 627 kg at 20 months. Between the age of 7 and 20 months, weight gain is more than 1200 g a day. Females weigh 47 kg at birth, 96 kg at 3 months, 189 kg at 7 months and 332 kg at 13 months. For males, estimates of heritability for weights at 7, 13 and 20 months were between 0.21 and 0.36. The heritability for weight gain between 13 and 20 months was 0.13. This demonstrates that it is possible to select for higher weights and for increased growth between 13 and 20 months. Animals having high weights at a young age (7 and 13 months) tend to have also high weight at slaughtering age (20 months; r_g between 0.81 to 0.98), but no additional growth between 13 and 20 months (r_g between -0.09 and 0.00). High weight at 20 months is partially due to growth between 13 and 20 months (r_g = 0.49).

Keywords: Beef breed; Belgian Blue; Live weight; Weight gain

1. Introduction

The selling price in cattle is determined by the live weight of the animal multiplied by its value per kg live weight. In double-muscled cattle, this selling price is especially linked to the live weight of the animal (Hanset and Leroy 1979), because of the high value per kg LW determined by the muscularity in this type of cattle. Despite this, selection in the DM-BBB breed focuses primarily on muscular development and little on weight and weight gain (Hanset *et al.,* 2001). As a result, the genetic mean for weight and weight gain in the breed does not increase continuously (Hanset *et al.,* 1989) and has even shown a significant negative trend during the past few years (Hanset *et al.,* 2001).

To counteract the negative trend, information on weight and weight gain is essential. In the DM-BBB breed, this information is available, but only partially. It is based on data collected in the performance test of males in selection centres (Hanset *et al.,* 1988; Gengler *et al.,* 1995). Only in rare instances have data been collected at farms (Hanset *et al.,* 1988). Therefore, breeders, farmers and consultants have no current sufficient and realistic information on weights and weight gains at farms.

Weight records of male and female DM-BBB at different ages collected at farms have been used in this study. With these field records as a starting point, relevant information on weight and weight gain at farm level may be obtained. Different models were sought that would be able to estimate the average weight at whatever age in the DM-BBB population and that would help to predict the weight of any DM-BBB animal at any age.

2. Materials and methods

2.1 Animals

All animals (10,100 intact males and 800 females) were of the DM-BBB breed. Live weights were repeatedly gathered over a six-year time span (January 1996 – January 2002) using a mobile balance. Information on date of birth, herd, inspector, sex and age at weighing was collected. All animals had a known sire and dam. Additional information on ancestors was added from different sources.

As a result, 31 775 live weights were collected on 270 DM-BBB herds in Belgium. Year of birth ranged between 1987 and 2002. Altogether 4135 (41.7 %) animals were born in winter (January – March), 2927 (29.5 %) in spring (April – June), 1344 (13.5 %) in summer (July – September) and 2494 (25.1 %) in autumn (October – December). The age at weighing of the animals ranged from 0 (birth) to 3452 days (9.5 years). A total of 10 inspectors participated in collecting the weights. One group of inspectors collected 28 906 live weights in the southern part of Belgium. In the northern part of Belgium, one inspector collected 2253 live weights while the remaining inspectors collected the data for 616 in equal proportions. In total 30 766 weights of males and 1393 weights of females were available. The number of weighing sessions ranged from 1 to 11 per animal (an average of 3 times per animal).

Pedigree information of 23 139 animals was available up to the birth year 1949.

2.2. Statistical analyses and data standardization

First the complete dataset was thoroughly explored and scatter plots were studied separately for females and males.

Secondly, in order to find models that estimate the average weight at whatever age in the DM-BBB population, the relationship between live weights and age was analysed. This was done separately for males and females using the linear regression procedure. In order to find the best models, all data or data over certain age periods were considered. Because segments of the growth curve were non-linear, a transformation of age (age^2) was considered.

Eventually, starting from the weights of all animals younger than 2 years old, standard weights (LW) at 3, 7, 13 and 20 months were calculated using a linear within animal adjustment by interpolation between two consecutive weights and ages. The estimation of LW3 was done using the data of animals between 31 and 153 days of age. For LW7, this age interval was 153 - 305 days, for LW13 it was 305 - 488 days and for LW20 the age interval was 488 - 732 days.

The results of this standardization procedure and the average birth weight reported by Coopman *et al.* (2004) were used to estimate average daily growth – ADG – (birth to 3 months; ADG B-3; 3 to 7 months ADG 3-7; 7 to 13 months ADG 7-13, and 13 to 20 months ADG 13-20) over the consecutive time spans. The phenotypic correlations were estimated between the standardized records.

SPSS 11.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

2.3. Estimation of genetic parameters

The characteristics LW7, LW13, LW20 and average daily growth between 13 and 20 months (ADG 13-20) of the male population were used to obtain the genetic parameters using an animal model. Only these traits were considered because there were at least 1000 observations. Preliminary calculations showed no maternal effects on any of the traits considered, so this effect was not included. A contemporary group effect was included in the model based on herd, year, and season of birth and sex. Heritability estimates and genetic correlations between the traits considered were estimated using REMLF 90 (Misztal, 2002).

3. Results

Table 1 lists the different models used to estimate the expected LW of an average DM-BBB animal at whatever age. No reliable prediction for weight was obtained for animals older than 20 months. The transformation of age improved R^2 only in two cases (model 5 and 6).

Table 1. Linear regression models to predict live weight of DM-BBB male and female (bold) animals at different ages between birth and two years of age.

No.	Model	Age period	R^2
1	LW = 35.60 + 0.964*age	0 – 732	0.99
2	**LW = 42.96 + 0.704*age**	0 – 732	0.92
3	LW = 50.92 + 0.508*age	0 – 91.5	0.54
4	**LW = 47.29 + 0.418*age**	0 – 91.5	0.49
5	LW = 51.42 + 0.006*age²	0 – 91.5	0.58
6	**LW = 47.54 + 0.005*age²**	0 – 91.5	0.51
7	LW = 46.64 + 0.870*age	0 – 213.5	0.82
8	**LW = 46.35 + 0.586*age**	0 – 213.5	0.86
9	LW = 13.73 + 1.054*age	91.5 – 213.5	0.40
10	**LW = 25.55 + 0.728*age**	91.5 – 213.5	0.50
11	LW = 0.05 + 1.083*age	91.5 – 610	0.73
12	**LW = 23.53 + 0.755*age**	91.5 – 610	0.78
13	LW = 29.66 + 0.981*age	213.5 – 396.5	0.40
14	**LW = -0.62 + 0.858*age**	213.5 – 396.5	0.43
15	LW = 0.813 + 1.082*age	213.5 - 610	0.98
16	**LW = 32.15 + 0.738*age**	213.5 - 610	0.58
17	LW = 63.38 + 0.912*age	213.5 - 732	0.95
18	**LW = 28.93 + 0.748*age**	213.5 - 732	0.56
19	LW = -3.46 + 1.09*age	396.5 - 610	0.36
20	**LW = -50.05 + 0.893*age**	396.5 - 610	0.29
21	LW = 110.37 + 0.854*age	396.5 - 732	0.38
22	**LW = -45.74 + 0.884*age**	396.5 - 732	0.48
23	LW = 526.35 + 0.187*age	610 - 732	0.00
24	**LW = 176.71 + 0.55*age**	610 - 732	0.02

An overview of the average standard weights and growth between different ages, obtained by the standardization procedure, can be found in Table 2. Only the averages that are the results of at least 30 standardized data have been listed.

Table 2. Weights at fixed ages and weight gain between fixed ages of DM-BBB males (first line) and females (second line) obtained by using the standardization procedure.

Trait	N	Mean	SD	Min.	Max.
LW3 (kg)	43	98	16	68	153
	35	96	14	65	129
LW7 (kg)	1094	242	42	117	465
	54	189	37	133	277
LW13 (kg)	4904	430	70	167	652
	34	332	78	234	690
LW20 (kg)	2441	627	99	238	956
	NA	NA	NA	NA	NA
ADG B-3 (g/day)	32	560	160	315	1087
	33	555	140	283	815
ADG 7-13 (g/day)	172	1297	276	538	1910
	NA	NA	NA	NA	NA
ADG 13-20 (g/day)	1020	1214	225	370	2004
	NA	NA	NA	NA	NA

N: Number of data; SD: standard deviation; LW3: live weight at 3 months; LW7: live weight at 7 months; LW13: live weight at 13 months; LW20: live weight at 20 months; ADG B-3: average daily growth from birth to 3 months; ADG 7-13: average daily growth from 7 to 13 months; ADG 13-20: average daily growth from 13 to 20 months; NA: not available.

Because of the standardization procedure in the study, many weight records (42.75 %) remain unused in the estimation of phenotypic and genetic parameters for weight gain and weight at fixed ages.

The phenotypic and genetic correlations and the heritability estimates are listed in Table 3.

Table 3. Estimates of genetic correlations (above the diagonal), heritability (on diagonal) and phenotypic correlations (below diagonal) for life weights at 7, 13 and 20 months of age (LW 7, LW 13 and LW 20) and for average daily gain between 13 and 20 months (ADG 13-20). The phenotypic standard deviation is in the last column. The standard errors of estimates are in brackets. Only the male population was studied.

Traits	LW 7 (SE)	LW 13 (SE)	LW 20 (SE)	ADG 13-20 (SE)	Phenotypic SD
LW 7	0.26 (0.03)	0.98 (0.11)	0.81 (0.12)	-0.09 (0.15)	32.1 (5.8) kg
LW 13	0.74 (0.05)	0.36 (0.04)	0.87 (0.12)	0.00 (0.15)	50.7 (6.7) kg
LW 20	0.69 (0.05)	0.80 (0.05)	0.21 (0.03)	0.49 (0.19)	75.2 (11.3) kg
ADG 13-20	0.33 (0.05)	0.22 (0.05)	0.76 (0.05)	0.13 (0.03)	211.6 (23.8) g

LW 7: live weight at 7 months; LW 13: live weight at 13 months; LW 20: live weight at 20 months; ADG 13-20: average daily growth from 13 to 20 months; SE: Standard error of the estimate; SD: Standard deviation.

4. Discussion

The study deals with weights of male and female DM-BBB animals. The animals were of different ages and housed on farms. Starting from these field records, relevant information on weight and weight gain at farm level may be obtained. Different models that estimate the average weight at any age in the DM-BBB population and that can help to predict the weight of a DM-BBB animal at any age were sought for.

A linear regression model for males and females (model 1 and 2) was found that estimates live weight between birth and 24 months with a high reliability (99 and 92 %). Despite this high reliability, it is found that the birth weight and weight at 3 months, predicted with model 1 or 2, differs from the average birth weight (Coopman *et al.,* 2004) and the fixed weight at 3 months of age (Table 2). Therefore it is recommended to use other models (3–8) that are created using data from a shorter age interval to estimate weight at an early age. Within a shorter age interval, growth is more linear and estimation errors smaller. The differences between the predicted weights at 7, 13 and 20 months, obtained by using the linear regression models 1 and 2, and the standard weights at 7, 13 and 20 months (Table 2) are rather small. One can use model 1 and 2, but also other models to estimate LW for animals of age between 3 to 20 months with an acceptable accuracy.

Although it is obvious that estimation errors might occur, the models with a sufficient reliability are good candidates to be used as a benchmark in overall farm management and selection. Weights of farm animals that are far below values which one might consider as standard averages within the DM-BBB population can be an indication that farm management should be improved in order to achieve at least the average weight at a certain age. Animals showing performance far above the expected figures might be considered as potential breeding animals.

Males at test stations were between 100 and 130 kg heavier at standardized ages than males on farms (Hanset *et al.,* 1988; Gengler *et al.,* 1995). The average weights of males and females at the standard ages (Table 2) are lower than the field records presented by Hanset *et al.,* (1988). This might be because the records of Hanset *et al.* (1988) were from farm animals that were officially tested for breeding purposes and that were highly ranked within the breed. In our study, no such selection was done. Therefore, the results of our study may represent a more realistic situation of weights on farms.

According to Molina *et al.* (1999), selection for weights at early age's results in satisfactory results for weights at later ages. This is seen also in the DM-BBB breed. The genetic correlations (LW7 – LW13 – LW20) in our study and the genetic correlations (W7 – W13) found by Gengler *et al.,* (1995) support the finding.

Gengler *et al.* (1995) also found a strong negative genetic correlation between average daily weight gain (7 to 13 months) and weight at seven months (-0.68). In our study, a negative, but smaller, correlation between LW at seven months and average daily growth between 13 and

20 months was found. Both negative correlations indicate that animals that are heavy at seven months do not seem to grow more consistently at later ages.

The earlier heritability estimates for weight at fixed age and daily gain in beef cattle (Winder *et al.,* 1990; Nunez-Dominguez *et al.,* 1993; Gengler *et al.*, 1995; Gregory *et al.,* 1995a; 1995b; Parnell *et al.,* 1997; Kaps *et al.,* 2000; Albera *et al.,* 2001), are slightly higher than the figures found in our study. Still, these parameters are high enough to consider improving the traits by selection. Heritability for final weight in DM-BBB animals estimated by Hanset *et al.* (1987) agrees well with our estimate. Heritability of daily weight gain between 7 and 12-13 months for DM-BBB males at the selection centre has been found to be 0.55 (Gengler *et al.,* 1995), 0.44 (Hanset *et al.,* 1987) and 0.29 (Hanset *et al.,* 2001). The daily weight gain between 7 and 12-13 months at the selection centre reflects the daily weight gain between 13 to 20 months at farms. In both cases, bulls are fed *ad libitum* and fattened. At the farm, daily weight gain between 13 and 20 months seems less heritable than the daily weight gain between 7 and 12-13 months for DM-BBB males at the selection centre. This is not surprising, because the environmental variation at the farm is much higher than at the selection centres. Also, the comparison of the heritability of final daily weight gain of DM-BBB males between the selection centre and the farms is not directly possible because the DM-BBB males at the selection centre and at the farms are fattened at different intervals of age and length and with slightly different weights at the start and end of the fattening.

In the DM-BBB breed, selection is focused primarily on MC. For selection and monitoring, breeding values for weight at 13 months are calculated using field records of progeny of the AI sires and are, together with MC, combined in an Economical Index (INEC; Leroy and Michaux 1999). Considering the genetic correlations between the four growth traits in the study, selection based on the INEC creates high weights at 20 months but no additional growth between 13 and 20 months. Hanset *et al.* (1987) made similar remarks. Using weight at 20 months, selection for high weight at 7, 13 and 20 months is successful and results also for weight gain between 13 and 20 months, which may work towards altering the genetic base of late maturing animals. This genetic variation is not used when focusing on weight at 13 months, which might induce the loss of this specific genetic ability. The significant negative genetic trend for growth, as seen in the past few years in this breed, (Hanset *et al.*, 2001) might indicate the disappearance of the genetic potential for the final growth. An INEC based on MC, weight at 20 months or on LW13, LW20 and growth between 13 and 20 months may help to stop and reverse this negative trend. Higher weights at 20 months, combined with the higher muscular conformation obtained in the last decade, will increase the DM-BBB breeder's financial income. It must also be emphasized that selection for increased final growth in the DM-BBB breed will most likely increase muscularity as well. Based on data in the selection centres, Gengler *et al.*, (1995) found a small, but positive, genetic correlation between average daily growth and muscularity. Selection for increased growth between 13 and 20 months will therefore be beneficial for both muscularity and total income.

It is obvious that the standardization procedure used in this study leaves lots of records outside the analysis in the phenotypic and genetic parameter estimation. This is because the distance between individual growth points in age was in some cases too long, especially in LW at 3 months and growth between 3 and 7 months of age. To better utilize the data, the Brody or Richard's non-linear growth function could be used to estimate missing growth points. One disadvantage of this estimation is a mild overestimation of weight, (Kaps *et al.*, 2000) particularly below the age of 18 months. To overcome this problem, it might be better to improve the organization of field data collection in order to have data on a regular basis [every month (Meyer 2000) or every three months (Albuquerque & Meyer 2001)] and to standardize the records as done in our study. Breeding organizations should coordinate the field data collection and farmers should adapt their infrastructure to weigh animals more easily and on a more regular basis.

5. Conclusions

Based on current and earlier results (Coopman *et al.*, 2004), it may be concluded that at farm level, male DM-BBB weigh on average 51 kg at birth, 98 kg at 3 months, 242 kg at 7 months, 430 kg at 13 months and 628 kg at 20 months. On average, a male DM-BBB animal grows more than 1200 g per day between the ages of 7 months and 20 months. On average, females weigh 47 kg at birth, 96 kg at 3 months, 189 kg at 7 months and 332 kg at 13 months. Female growth rate is about 719 g per day from birth to 13 months. To predict the average weight at other ages, different models can be used. Heritability estimates show that selection for higher weight at fixed age and for increased growth between 13 and 20 months is possible. Animals having high weight at young age tend to have higher weights at slaughtering age, but do not show any additional growth between 13 and 20 months.

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Chapter 6

Parameters for the estimation of live weight and the visual appraisal of the muscular conformation in the (double-muscled) Belgian Blue beef breed

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Abstract

In the double-muscled Belgian Blue beef breed, withers height and hearth girth are routinely measured. This is mainly done to prevent a decrease in growth potential when selecting for increased muscular conformation. The muscular conformation itself is subjectively scored. It was questioned if additional body measurements may improve the accuracy of estimating live weight and whether some of these body measurements may yield information for evaluating the muscular conformation hence the slaughter value of a live animal. It was found that hearth girth and shoulder width have a high correlation with the live weight of slaughter bulls. The width of the hind quarters and withers height are good estimators as well. Models combining these different traits to estimate live weight have reliability up to 83%. Shoulder width and width of the hind quarters are a good reflection of the value of the slaughter bull, which is expressed as Euro per kg cold carcass weight. The withers height is negatively correlated (r = - 0.40) with the muscular conformation of the slaughter bulls. Hearth girth has no clear relation with the muscular conformation. The four body traits, withers height, hearth girth, shoulder width and width of hind quarters are interesting traits related to economical traits in the double-muscled Belgian Blue beef breed. Using these body measurements in selection might be worthwhile to consider.

Key Words: Live weight; Muscular conformation; Body measurements; Belgian Blue beef breed

1. Introduction

In the double-muscled Belgian Blue beef breed, body traits such as WH and HG are gathered on a routine base. The measured heart girth is used to estimate the live weight of yearlings (LW = 0.0005691*(HG) $^{2.607}$; Clauwers *et al.,* 1999). This estimated LW is then used to estimate the economical index (INEC) that ranks artificial insemination sires and that reflects their genetic economic value. The WH of yearling calves is measured as well and used to calculate estimated breeding values for WH (Leroy and Michaux, 1999). The general idea of measuring WH is to prevent this breed will lose its growth potential and to make sure final weight of the animals remains satisfactory (Hanset *et al.*, 1990). Hanset *et al.* (1988) showed a strong relationship between weight and WH in this breed.

No other measurements are considered. The assessment of slaughter value of the yearlings, another economical important trait, that is used to estimate the INEC as well, is the result of a visual appraisal. It is expressed as Euro per kg LW as if the animal would be sold for slaughter at the moment it is scored (Gengler *et al.*, 1995).

A question that arises is whether additional important body traits should be considered in DM-BBB selection. Older literature data report on good relationships of LW with other body traits (Vos, 1969). On the other hand, visual appraisals and the visual classification of traits seem not to be very accurate (Orme *et al.*, 1959). Objective (linear) measurements are described as being good alternatives for visual appraisal of beef type, carcass characteristics and conformation scores (Brown *et al.*, 1950; Orme et al, 1959; Tallis *et al.*, 1959; Jansen *et al.,* 1985; Kmet *et al.,* 2000; Marle-Köster *et al.*, 2000). Therefore the question might be restricted to whether there are body measurements that can help improving the estimation of LW and whether some of them are interesting tools to evaluate the slaughter value of a live animal.

The aim of this report is to provide some background information on the relationship between body measurements and traits that are of economical importance in DM-BBB breeding. Based on the results and conclusions of this preliminary investigation, implementation of body traits other than WH and hearth girth, might be considered in the selection of the DM-BBB breed.

2. Materials and methods

2.1. Animals

During July, August and September of 1996, a group of animals (N = 224; males) was selected at one abattoir (Verbist Izegem; Belgium). Animals were between 449 and 996 days of age and belonged to the Belgian Blue beef breed. The two inspectors who measured the animals evaluated the DM phenotype visually. Only DM animals were considered. Therefore it was concluded that all animals were DM-BBB animals.

2.2. Collection of raw data

The bulls were placed on an electronic balance and live weight was registered. Eleven body conformation traits were recorded on the animals using a measuring rod and tape:

1. withers height;
2. the external distance between the most lateral points of the tuber coxae;
3. shoulder width, the distance between the broadest points of the shoulder;
4. width of the hind quarters, the distance between the broadest points of the hind quarters;
5. heart depth (HD);
6. the length of the back (LB), measured from the first vertebra of the tail up to the point that's directly behind the line cutting the elbow perpendicular;
7. thickness of the skin (TS), measured on the chest behind the shoulder;
8. thickness of the tail (TT), measuring the broadest distance at the fifth vertebra of the tail;
9. heart girth, measured right behind the shoulders, being half of the heart girth following the muscles on the thorax and then multiplied by two;
10. most narrow circumference of the front long bone (FLB) and
11. most narrow circumference of the rear long bone (RLB).

After the bulls had been measured, they were slaughtered. Before chilling, the carcass was scored according to the SEUROP classification (Anonymous, 1991; conformation class S = extreme muscularity to P = poor; fat class 1= low fat covering to 5 = extremely fat) and weighed (warm carcass weight; WCW). Additional weighing was done 48 hrs after slaughter (cold carcass weight; CCW). Birth date, slaughter date, value of the cold carcass (Euro per kg cold carcass weight) being the mean values paid by 16 Belgian abattoirs in the year 1996 per SEUROP class, were gathered as well.

2.3. Calculated data

Some of the live body measurements were combined in order to derive a muscular conformation trait (MCT) that could replace the financial value of the animal estimated by visual inspection. A first muscular conformation trait (MCT_1) was designed as proposed by

Hanset and Michaux (1985). According to these authors, a high HG/WH is typical for beef breeds. Two variants on this muscular conformation trait were designed; MCT_2 = BcW/WH and MCT_3 = (HG*BcW)/WH. The width of the hindquarters was used as an alternative because Orme *et al.* (1959) found significant correlations of 0.4 to 0.5 ($p < 0.05$) between width measurements and percent primal cuts. Also this body trait is used as a reflection of muscularity by inspectors judging financial value of DM-BBB animals on contests and as part of the progeny test on the farms (Leroy and Michaux, 1999).

MCT_1, MCT_2 and MCT_3 were multiplied with LW to obtain an objective estimate of the total value of the live animal (TVL_1-TVL_2-TVL_3). The total value of a slaughter animal (TVS) in this study was the result of CCW * price per kg CCW and is considered as the gold standard.

Age was calculated using the birth date mentioned on the Sanitel identification card and the slaughter date. Average daily weight gain (ADG) was calculated as the final LW lowered with 45 kg, the average birth weight of DM-BBB calves (Leroy and Michaux, 1999) divided by the age ((LW-45)/age).

2.4. Statistics

SPSS 11.0 for Windows was used to explore and analyse the raw and calculated data. Simple correlations and, if needed, weight corrected correlations between all traits considered were calculated.

Stepwise multiple regression was applied to estimate LW from a combination of body measurements.

3. Results

One hundred and eighty one animals were classified as “S”, 31 as “E” and 12 as “U” and “R”. Only six animals had fat coverage of 3, all others showed a fat coverage of 2.

The mean, maximum, minimum and standard error of all weights, measurements and calculated data are listed in Table 1.

Table 1. Descriptive statistics for the different body traits, age, value per kg cold carcass weight and total value of the slaughter animal.

Trait	Mean	s.d.	Minimum	Maximum	N
WH	129.1	3.83	119	139	224
TcTc	56.6	4.15	42	67	223
SW	66.8	4.18	52	79	224
BcW	62.5	3.64	46	71	224
HD	72.5	3.07	61	80	219
LB	81.2	4.48	70	95	222
TS	1.2	0.18	0.8	1.7	214
TT	7.4	0.62	6.2	10.6	214
HG	203.3	7.40	178	226	217
FLB	22.6	1.00	20	25.5	213
RLB	24.1	1.00	22	26.5	216
LW	699	47.1	476	864	224
WCW	465.3	54.4	307.0	585	218
CCW	451.5	53.0	298	577	218
Age (days)	661	173.3	449	996	212
ADG (kg/day)	1.01	0.19	0.58	1.66	212
P (Euro)	3.47	0.24	2.52	3.56	157
TVS (Euro)	1570.18	124.20	1434.06	2056.82	217

WH: withers height; TcTc: the external distance between the most lateral points of the tuber coxae; SW: shoulder width, the distance between the broadest points of the shoulder; BcW: width of the hind quarters, the distance between the broadest points of the hind quarters; HD: heart depth; LB: the length of the back, measured from the first vertebra of the tail up to the point that's directly behind the line cutting the elbow perpendicular; TS: thickness of the skin, measured on the chest behind the shoulder; TT: thickness of the tail, measuring the broadest distance at the fifth vertebra of the tail; HG: heart girth, measured right behind the shoulders, being half of the heart girth following the muscles on the thorax and then multiplied by two; FLB: most narrow circumference of the front long bone; RLB: most narrow circumference of the rear long bone; WCW: warm carcass weight; CCW: cold carcass weight; ADG: average daily weight gain; P: price per kg cold carcass weight; TVS: total value of the slaughter animal.

Not all animals allowed all measurements because some were hard to handle. Because of data correction and lack of sufficient information that was provided by the slaughterhouse, some data are missing.

The significant phenotypic correlations between the different data are listed in Table 2, 3 and 4.

WH had a significant ($p < 0.05$) positive correlation with daily weight gain of 0.52. When MC was held constant, this correlation between WH and ADG became 0.61.

Different models to estimate live weight out of body measurements were obtained. Two such models, one using HG, SW and WH ($LW = -1349.5 + 3.65*HG + 8.33*SW + 5.71*WH$) and another one using SW, WH and HD ($LW = -1180.7 + 10.8*SW + 5.50*WH + 6.16 HD$) predict LW from body measurements with a reliability of 0.83 and 0.81 and an estimation error of 31.0 kg and 32.9 kg respectively. Models including other body traits were found as well.

Table 2. Simple correlations between the live body measurements.

Trait	LW	WH	TcTc	SW	BcW	HD	LB	TS	TT	HG	FLB
WH	0.63*										
TcTc	0.60*	0.28*									
SW	0.78*	0.33*	0.61*								
BcW	0.63*	0.24*	0.75*	0.70*							
HD	0.62*	0.53*	0.42*	0.37*	0.38*						
LB	0.40*	0.39*	0.09	0.20*	0.03	0.32*					
TS	0.12	-0.02	-0.03	0.00	-0.08	0.12	0.19*				
TT	0.20*	0.11	-0.08	0.05	-0.06	0.20*	0.32*	0.30*			
HG	0.80*	0.50*	0.36*	0.65*	0.44*	0.54*	0.44*	0.17**	0.28*		
FLB	0.46*	0.37*	0.10	0.26*	0.13	0.33*	0.19*	0.04	0.27*	0.37*	
RLB	0.43*	0.42*	0.18*	0.22*	0.18*	0.36*	0.21*	-0.02	0.19*	0.35*	0.65*

*Trait abbreviations see Table 1; * = p < 0.05 and ** = p < 0.01.*

Table 3. Simple and weight corrected correlations between the live body measurements, muscular conformation traits and total value of the live animal with the total value of a slaughter animal (TVS) and the price paid per kg cold carcass weight (P).

Trait	WH	WH£	SW	SW£	BcW	BcW£	HG	HG£	HD£
TVS	0.40*	-0.40*	0.82*		0.65*		0.77*		
P			0.50*	0.48*	0.46*	0.43*	0.31*	-0.14*	-0.15*

*Trait abbreviations see Table 1; £ = weight corrected; * = p < 0.05 and ** = p < 0.01.*

Table 4. Simple and weight corrected correlations between the muscular conformation traits (MCT) and total value of the live animal (TVL) with the total value of a slaughter animal (TVS) and the price paid per kg cold carcass weight (P).

Trait	MCT_1	MCT_1£	MCT_2	MCT_2£	MCT_3	MCT_3£	TVL_1	TVL_2	TVL_3	Seurop
TVS	0.45*		0.51*		0.74*		0.89*	0.84*	0.89*	
P	0.36*	0.39*	0.48*	0.43*	0.45*	0.42*				0.92**

*£ = weight corrected; * = p < 0.05 and ** = p < 0.01.*

4. Discussion

The aim of this report is to provide some background information on the relationship between body measurements and traits that are of economical importance in DM-BBB breeding. The specific aim is to verify whether there are body measurements that allow estimating LW better than HG or WH and whether some of these body measurements might be interesting tools to evaluate the MC hence the slaughter value of a live animal.

Not all of the measured and weighed slaughter bulls were classified as “S” or “E”, which are the SEUROP classes that are commonly considered to encompass all DM animals. This indicates that visual appraisal of the DM phenotype either in live animals or on carcasses may diverge. When selecting the bulls for measurement, both inspectors obviously misjudged the the level of muscularity. The only good method to be sure about the DM character of the animals considered is molecular genetic testing. Only animals that are homozygous for the mutation at the myostatin locus are true DM animals (Grobet *et al.*, 1997; Kambadur *et al.*, 1997; Kobolac and Gocza, 2002).

HG and SW have a correlation with LW that is clearly higher then the correlation between WH and LW. WH and BcW have a slightly higher correlation with LW then HD and TcTc. The correlation of HD with LW is considerably lower then the correlation between HG and LW. Because HD has a comparable relationship with MC as HG, HD is not an interesting candidate. WH and TcTc have a comparable correlation with LW, but WH gives more information on the MC ($r = -0.40$) and on daily weight gain ($r > 0.5$). It is therefore more interesting to have information on the WH then on TcTc. The correlations between HG and WH, HG and SW, HG and BcW are positive and significant, but different from 1. Yet all four body measurements have high and significant correlations with live weight. This might indicate that combining HG with the body traits SW, WH and BcW to estimate LW can be interesting. A model was found that combines HG, SW and WH and that estimates LW with a reliability of 83 %. Comparing the reliability and estimation errors of models based on HG alone or combined with other body traits, developed with many more data and on different ages, and taking care only pure bred DM-BBB animals are used, may resolve the question whether one should keep on using the HG only or include also other body traits.

The high correlation between the SEUROP classification and price per kg CCW is logic. It becomes clear out of this small study that SW and BcW are moderately related with the price per kg cold carcass value. Both SW and BcW reflect the MC of a slaughter animal, expressed as the price per kg CCW, the best. Hearth girth is no such good reflection of price per kg as can be concluded out of the weight corrected correlation.

It is interesting that the individual body traits SW and BcW measured on a living animal are good reflections of the total carcass value. Especially SW is interesting. It has a higher correlation with TVS then HG with TVS. The good reflection of the TVS by both SW and BcW is not surprising because they do not only reflect MC (related to price per kg CCW) but also LW. WH on its own has not such good relation with this slaughter value because with higher weight due to an increased WH, the animal becomes less muscular and will be paid less per kg CCW. Although HG on its own does not reflect MC that well, it has a high correlation with the total slaughter values. This can be explained by the huge correlation between LW and HG. This ascertainment emphasizes the importance of sufficient weight at slaughter age. Muscular conformation is of great importance in the DM-BBB breed and is a typical characteristic of this breed, but weight at slaughter age is considered relatively more important, especially if this weight is due to MC (BcW and SW) rather than by size of the animal (WH). The clear increase in correlation between all three MCT values with TVS if multiplied with LW (resulting in the TVL-values) confirms the importance of LW. These considerations reflect the opinion of Hanset *et al.* (1990) and confirm the results of earlier studies (Coopman *et al.*, 1999).

The overall observation of this study is that a better muscled animal, compared to a less muscled animal having the same weight, has a broader BcW, width of the tuber coxae and SW. It has a less deep breast, a smaller skin, smaller long bones and tail thickness and a shorter back. Although the animal is smaller and has an absolute smaller hearth girth, it has a relatively higher HG/WH ratio. The differences between a better muscled and a lesser muscled animal having the same weight, are especially more clearly for BcW and SW (better muscled animal broader in shoulder and hind quarters) and WH (better muscled animals are small).

The results showed that withers height, hearth girth, shoulder width and width of the hind quarters are interesting body traits that allow estimating LW and evaluating muscularity from an economical point of view in the double-muscled Belgian Blue beef breed. Whereas WH and HG reflect weight related to the size of the animal, SW and BcW reflect weight related to the MC of the animal. WH (negatively), SW and BcW (both positively) reflect MC of the animal as well. Studies at different ages and using these body measurements in combination with the traditional approaches can provide new insights and finally help to improve selection in this double-muscled beef breed.

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Chapter 7

Live weight assessment based on easily accessible morphometric characteristics in the double-muscled Belgian Blue beef breed

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Abstract

Live weight is an important trait in cattle farming. Weighing is not always feasible and therefore live weight is often estimated from easily accessible data. In different species and different cattle breeds it was found that heart girth is the best predictor of live weight. Nevertheless, other body traits and data such as age are described to predict live weight in conventional and double-muscled beef breeds. In this study, data on live weight, age and gender, and four body measurements, withers height, heart girth and width of the shoulders and hind quarters of double-muscled Belgian Blue beef farm animals were used to develop multivariable non-linear and linear regression models that predict live weight from these easily accessible data. The relationship between the logarithm of the live weight and the logarithm of time is adequately described by a general logistic function. The age period from 100 to 600 days of age is contained in the linear part of the logistic function. This region is of particular economic interest because it contains the yearling age and slaughter age that are important in DM-BBB breeding and management. We therefore concentrated further on that age region. Adding one of the body traits in the linear models that contain age and gender as fixed effects decreases the coefficient of variation. A model with withers height and shoulder width has the lowest coefficient of variation, with no further significant improvement when adding either heart girth or width of the hind quarters.

Keywords: Double-muscled; Belgian Blue beef breed; Live weight prediction, Body measurements

1. Introduction

For different reasons, LW is an important issue in cattle (Vos and Vos, 1967). Weight gain and weights at specific ages are largely determining profitability in beef production (Hanset *et al.,* 1987; 1988). Estimating feed requirements can not be done without knowing the LW (Johansson and Hildeman, 1954).

Collection of accurate live weight data requires weighing on a balance (Cantet *et al.,* 1988; Gengler *et al.,* 1995; Guttierez *et al.,* 1997; Coopman *et al.,* 2007a). However, in many cases, weighing animals is not feasible or too complicated to organize. Therefore, since long, across different species and in different cattle types, LW is estimated from easily accessible body measurements, of which WH and HG are the most used (Branton and Salisbury, 1946; Johansson and Hildeman, 1954; Vos and Vos, 1967; Nelsen *et al.,* 1985; Badi *et al.,* 2002; Atta and El Khidir, 2004; de Aluja *et al.,* 2005; Afolayan *et al.,* 2006). The lack of the accurate LW and the obligation to use relevant body measurements is not discarded as an extreme disadvantage by Simm *et al.* (1983) and Hanset *et al.* (1988). WH is seen as a better reflection of the size and the growth potential than LW itself (Hanset *et al.,* 1988). LW variation due to effects of gut fill and fattening are avoided when using WH (Simm *et al.*, 1983; Hanset *et al.*, 1988).

Other body measurements have been used to predict LW as well. Vissac (1966) reported on the estimation of LW using the so-called “tour-spirale” or spiral girth that is a combination of the body traits chest depth and body length. Hip height (Nelsen *et al.,* 1985), width of the thighs, width of the shoulder and width of the hind quarters (White and Green, 1952; Woodward *et al.,* 1960; Coopman *et al.,* 2004a and 2007b) have been used to predict LW.

In current DM-BBB breeding, there is a prominent role for the body measurements WH and HG. For breeding value estimation purposes, LW is estimated from the measured HG of young yearling bulls (Clauwers *et al.,* 1999). A strong relationship (r = 0.7) between LW and WH has been reported in this breed (Hanset *et al.*, 1988 and 1990; Gengler *et al.,* 1995). A minimum WH at fixed ages is imposed in DM-BBB breeding that traditionally focuses on MC, to guarantee sufficient live weight at certain ages (Hanset *et al.,* 1988). Breeding values for the WH for yearling males have been estimated since long (Hanset and Michaux, 1988; Herd Book, 2005).

Previous reports (Coopman *et al.,* 2003, 2004a and 2007b) confirmed the strong relationship of LW with WH and HG in the DM-BBB breed, but showed that other body measurements had high significant phenotypic and genetic correlations with LW as well. It was also found

that the combination of the body measurements WH, SW, and HG can predict birth weight (Coopman et al, 2004a) or LW at slaughter age (Coopman *et al.*, 2007b) more accurate than the body measurement HG alone. Evidently, it was also found that age explains a lot of the variation of live weight of DM-BBB animals (Coopman *et al.*, 2007a).
The aim of this study is to develop models that can be used to assess live weight in the DM-BBB breed more accurately than the current and commonly used model based on the HG.

2. Materials and methods

2.1. Data collection

Live weights and body measurements (WH, SW, BcW and HG) were repeatedly gathered on animals of the DM-BBB breed over a six-year time period (January 1996 – January 2002) using a mobile balance and measuring rod and tape as described in earlier studies (Coopman *et al.*, 1999, 2003, 2004a, 2004b, 2005 and 2007b). The data collection was done on herds that were localized in the northern part of Belgium. Age was deduced from known birth date and measuring date. Gender was noted at measuring time.

2.2. Statistical Analysis

The overall relationship between age and live weight is studied through the following non-linear mixed model

$$\ln(y_{ij}) = \beta_1 + u_i + \frac{\beta_2}{1+\exp(\beta_3(\ln(age_{ij}) - \beta_4))},$$

thus assuming a logistic function relationship between the logarithm of the live weight ($\ln(y_{ij})$) and the logarithm of the age ($\ln(age_{ij})$) and including a random animal effect u_i to accommodate for the repeated measures within an animal. Such growth curves were separately fitted for cows and bulls. The main region of interest (100 – 600 days) is contained in the linear part of the logistic function. In the further analyses, the models are restricted to this main region of interest (containing both yearling and slaughter age, two important landmarks in DM-BBB breeding). Within this region of interest models were developed investigating the relationship between the logarithm of the LW and age and the four body measurements incorporating all covariates at the logarithmic scale according to Brody's formula (1945). Models were compared using the coefficient of variation. Furthermore, prediction intervals for the different models at the age of 13 and 18 months were derived. Kendall's tau correlations between the observed LW and the LW predicted using the model containing age, gender, WH and SW were estimated within intervals of 14 days, to screen for regions with good prediction. All analyses were done in SAS (SAS 9.01).

3. Results

3.1. Data collection

The data collection was done on 65 herds. In total 6 inspectors performed all measurements, with one inspector (first author) gathering approximately 80 % of the data. Three inspectors gathered each 6 % of the data and the two other inspectors the remaining 2 %. Sixty-one % of the data originated from the male population and 39 % from the female population. Animals were measured repeatedly up to 8 times (average number per animal: 2.6).

3.2. Data exploration

The numbers of observations, range, mean, median and standard deviation of all data are listed in Table 1.

Table 1. Number of observation, range, mean, median and standard deviation of all data and of the data of the males (italic) and females separately.

Body trait		Number of observations	Range	Mean	Median	SD
Live weight (kg)	Total	1825	27-1081	318.3	219.0	263.4
	Males	1112	28-1081	354.3	278.5	263.6
	Females	713	27-986	262.0	155.0	253.3
Withers height (cm)	Total	1746	54-146	99.2	97.0	22.8
	Males	1062	57-140	102.6	105.0	22.3
	Females	684	54-146	93.9	87.5	22.7
Shoulder width (cm)	Total	1547	17-82	44.6	41.0	17.9
	Males	946	17-80	48.1	48.5	17.9
	Females	601	17-82	39.1	34.0	16.5
Width of the hind quarters (cm)	Total	1516	18-77	44.4	44.0	16.3
	Males	933	18-76	47.8	51.0	15.7
	Females	583	19-77	41.0	37.0	16.3
Heart girth (cm)	Total	1510	63-272	151.5	144.0	55.8
	Males	907	63-270	159.4	168.0	53.6
	Females	603	68-272	139.6	124.0	57.0

The average age of all animals is 367.8 days, with a range of 0 to 3452 days. The average age of the males is 340.4 days, with a range of 0 to 2495 days and the average age of the females is 410.6 days, with a range of 0 to 3452 days.

3.3. The prediction models

The overall relationship between ln(age) and ln(LW) was estimated separately for males and females. The parameter estimates of the logistic functions are given in Table 2, and the logistic growth curves are shown in Figure 1. It is clear from these graphs that the region of interest (100 – 600 days, on the logarithmic scale 4.6-6.4) is contained in the linear part of the logistic function.

Table 2. The parameter estimates of the logistic function relationship between ln(age) and ln(LW) of DM-BBB males growth curves of male and female DM-BBB animals.

Parameter	Males		Females	
	Estimate	SD	Estimate	SD
β_1	7.405	0.061	6.910	0.031
β_2	-3.431	0.065	-3.031	0.035
β_3	1.338	0.031	1.235	0.026
β_4	5.704	0.030	5.562	0.023

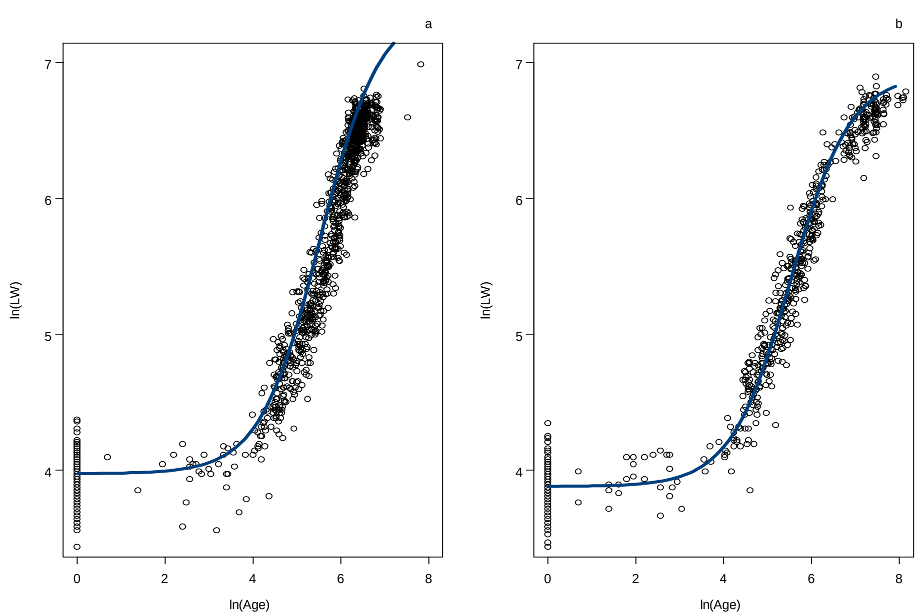

Figure 1. The logistic function relationship between ln(age) and ln(LW) of DM-BBB males (a) and females (b) from birth to adulthood.

Figure 2 shows the relationship of the four body measurements on the logarithmic scale with ln(LW) between the age of 100 to 600 days for bulls. Similar relationships were found for cows. Based on this visual presentation, we assume a linear relationship between the logarithm of any of the four body measurements and ln(LW).

The different models that predict LW using ln(age) and selections of the four different body measurements for females and males between the ages of 100 to 600 days are listed in Table 3.

The 95% prediction intervals of the models 1 to 6 at 13 months (a) and 18 months (b) are shown in Figure 3, using the average values of the covariates WH (=112 - 123 cm), SW (=54 – 63 cm), BcW (54 – 62 cm) and HG (183 – 208 cm) at the respective age. The lower and upper limit of prediction for an animal with a HG of 183 cm (13 months) is +/- 8 kg and with a HG of 208 cm (18 months) +/- 12 kg, while for an animal that is 112 cm tall and has a SW of 54 cm (13 months) or a WH of 123 cm and a SW of 63 cm (18 months) these limits are +/- 5 and +/- 7 kg respectively.

The Kendall’s tau correlation coefficient between the observed LW and the LW predicted through the model with age, gender, ln(WH) and ln(SW) is visualised in Figure 4. The Kendall’s tau correlation coefficient is obtained for each 14-days interval.

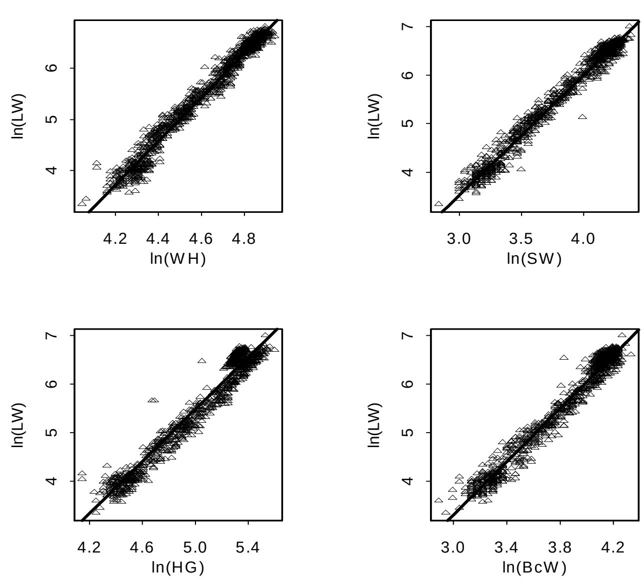

Figure 2. Linear relationship between the logarithmic scale of live weight and the logarithmic scale of the four body measurements withers height (WH), shoulder width (SW), heart girth (HG) and width of the hind quarters (BcW) for the male population between the ages of 100 to 600 days.

Table 3. Different linear regression models that predict ln(LW) out of easily accessible data using animals between the age of 100 to 600 days.

Independent variables considered	#	Model	CV (%)
		Ln(LW) =	
Age and gender	1	- 0.0313 + (0.2575*gender) + (0.09665*lnage)	3.99
Age, gender and	2	- 9.7406 + (0.0995*gender) + (0.2494*lnage) + (2.9914*lnWH)	2.27
single body measurement	3	- 2.2585 + (l.0886*gender) + (0.3694*lnage) + (1.4906*lnSW)	2.07
	4	- 2.6002 + (0.2204*gender) + (0.6317*lnage) + (0.8850*lnHG)	3.41
(= 1 for males and 0 for females)	5	- 2.2514 + (0.1830*gender) + (0.5176*lnage) + (1.2469*lnBcW)	2.80
Age, gender, ln(SW) and ln(WH)	6	-7.3620 + (0.0408*gender) + (0.0980*lnage) + (1.0940*lnSW) + (1.7663*lnWH)	1.51

LW: live weight; WH: withers height; SW: shoulder width; BcW: width of the hind quarter; HG: heart girth; CV: coefficient of variation.

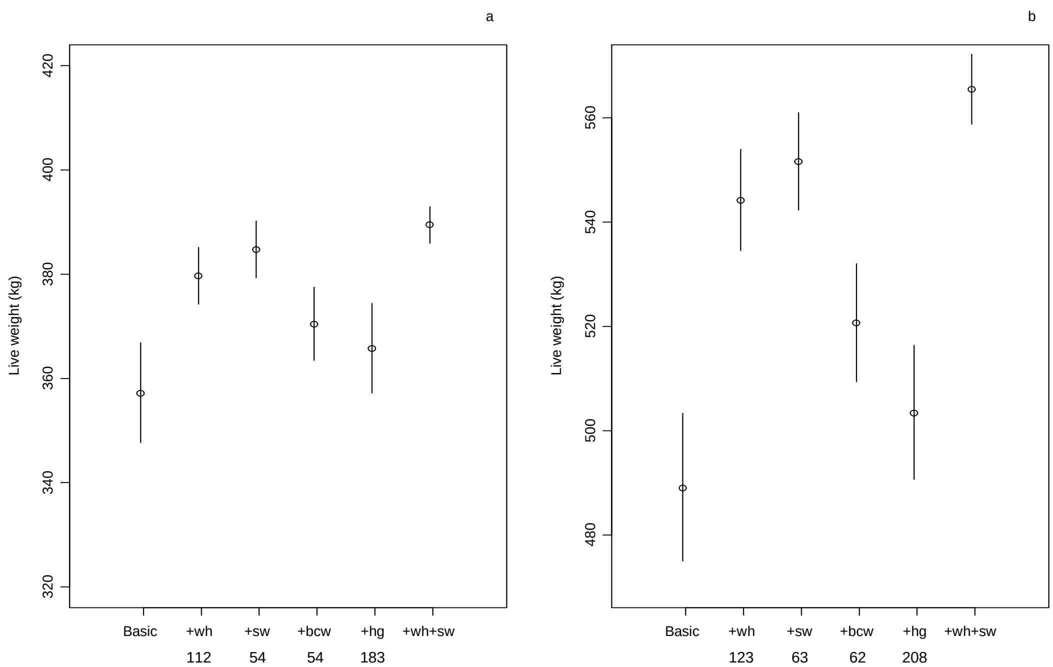

Figure 3. The prediction intervals (95%) of the models using age and gender with or without the different body traits separately or combined (WH and SW) are visualized at the age of 13 (a) and 18 (b) months.

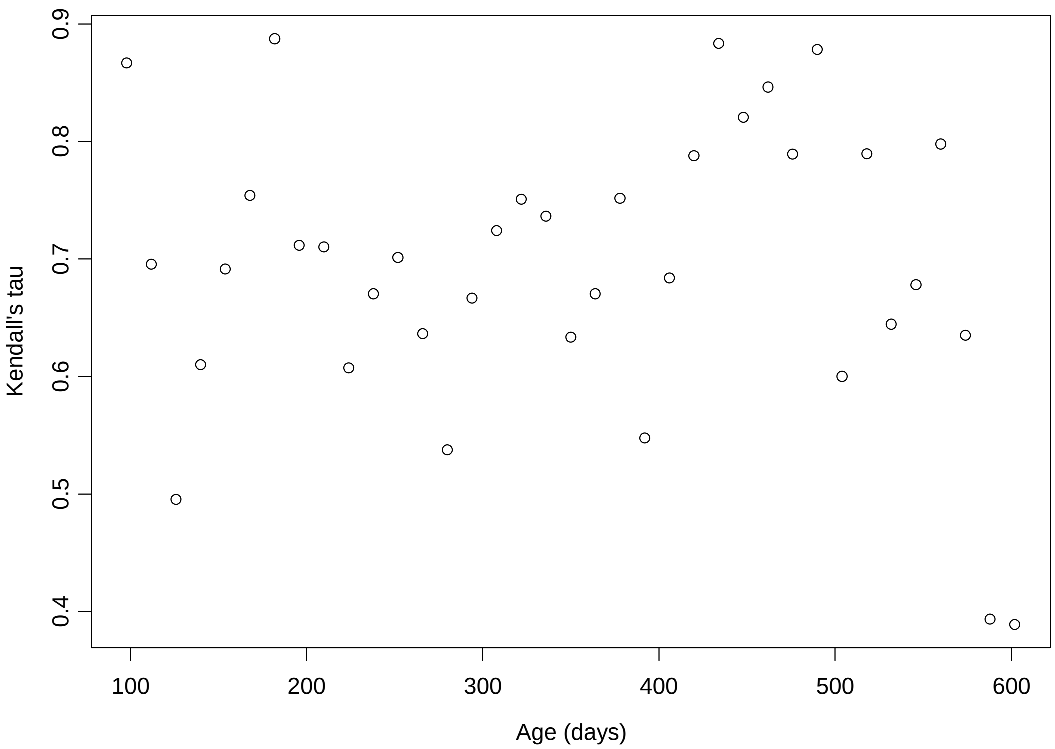

Figure 4. The Kendall's tau correlation between the observed and predicted live weight as a function of age between 100 to 600 days.

4. Discussion

The aim of this study was to find morphometric characteristics that are much better estimators of live weight of double-muscled Belgian Blue Beef animals than the commonly used heart girth.

A model with age, gender and heart girth is less accurate (higher CV and 95% prediction interval) than the models with age, gender and one or two of the three other body traits (WH, SW and BcW), indicating that the use of the HG, as used in many species and cattle breeds (Branton and Salisbury, 1946; Johansson and Hildeman, 1954; Vos and Vos, 1967; Nelsen *et al.*,1985; Clauwers *et al.*,1999; Badi *et al.,* 2002; Atta and El Khidir, 2004; de Aluja *et al.*,2005; Afolayan *et al.,* 2006) is not the best method to predict the LW of DM-BBB males between 100 to 600 days in the cases that no balance is available. Our results clearly show that LW can be estimated more accurately if age, gender and the body traits WH and SW are combined. To the knowledge of the authors, this is the first time that it is shown that such a combination is more accurate in predicting live weight than the heart girth. The results even show that WH and SW on themselves are better predictors of LW than HG. Additionally, both body traits are more easily accessible than HG. Another advantage of both body traits over heart girth was already described in previous scientific reporting. Coopman *et al.* (2007b) showed that both are more informative on MC than HG (r MC-HG = 0.32; r MC-SW = 0.50; r MC-WH = -0.40). WH is also informative on the size (Hanset *et al.,* 1990), the skeletal development (Gregory, 1933; Goyache *et al.,* 2001) and on the average daily weight gain (ADG) potential of the DM-BBB animal (r ADG-WH = 0.52; Coopman *et al.,* 2007b). Therefore, the DM-BBB Herd Book should decide not only to focus on the WH (as it already does; Herd Book, 2005), but also on the SW and to abandon the measuring of the HG.

The Kendall's tau correlation measures the agreement between the observed and predicted live weight. The higher the Kendall's tau correlation, the higher the model respects the ranking of the considered animals according their actual LW. In light of the breeding value estimation of live weight, it is reasonable to consider this parameter as important, because the final aim of estimating live weight is to rank breeding sires according to their ability to breed high live weights at slaughter age. The ranking of males, based on the observed observation, between 100 to 600 days of age is sometimes highly respected, but not always. It should be noted that the variability of agreement between observed and predicted might influence the breeding value estimation of LW. On the other hand, there is a small lower and higher error of prediction of LW when using the model containing age, gender, WH and SW that minimizes the negative effect of a low Kendall's tau correlation seen in some cases.

A model having an even higher accuracy might be a model that does not only contain the body traits WH and SW but body length as well. Different studies have investigated the phenotypic and genetic relationship between live weight and daily weight gain with the measured or visually assessed body length (Woodward *et al.,* 1960; Green and Carmon, 1968; Hanset *et al.,* 1990; Gilbert *et al.,* 1993a and 1993b). A model with WH, SW and body length combines the three dimensions of an animal's body. Unfortunately, a huge problem one faces with body length is the extreme difficulty to find proper fixed measuring points on the living animal, especially in the neck, which makes body length a character that is hardly assessable in practice.

5. Conclusion

Based on the results of this study, it is concluded that in cases where live weight data of DM-BBB animals can not be measured because there is no balance available it is recommended to predict the live weight using a multivariate linear regression model that combines age, gender, withers height and shoulder width rather than the commonly used heart girth.

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Chapter 8

General discussion and conclusions

1. Introduction

The DM-BBB breed is an interesting breed but is at the same time controversial. The routinely applied CS is criticized on animal welfare grounds. Farmers and breeders discuss the lack of growth potential in the breed.

This work has studied these two major points of criticisms in the DM-BBB breed, predominantly using measurements, and suggested remedial measures whenever deemed required. We focused on the problem of the routinely applied CS and on the live weight and daily weight gain issues in this breed. We investigated the possibility to estimate inner pelvic sizes and live weight based on easily accessible data. It was questioned whether natural calving is still feasible in the DM-BBB breed and whether body measurements could be used as a reflection of muscular conformation in the breed. We were also interested to gain more insight in genetic and phenotypic parameters based on the live weight and daily weight gain information collected on animals that are housed on the farms.

2. The routinely applied caesarean section

The first part of our study indicates that:

- Inner pelvic sizes can be estimated from external traits such as live weight, withers height and the distance between the tuber coxae.
- The larger and the heavier the animal, and the wider the external pelvic sizes, the larger the inner pelvic sizes.
- The more muscular the animals are, the smaller their pelvic sizes.
- From a geometrical point of view, natural calving is no longer possible in the DM-BBB breed.

Reflecting on these results and looking beyond the scope of the study, we can conclude that in the DM-BBB breed, gender, age, live weight, withers height, the distance between the tuber coxae and the muscular conformation traits shoulder width and width of the hindquarters, are highly related to the inner pelvic sizes (Coopman *et al.*, 2003). It was also found that, from a geometrical point of view, a DM-BBB calf can no longer be born naturally (Coopman *et al.*, 2004a). This goes together with the fact that in practice birth by CS in the DM-BBB breed is performed almost systematically at rates of between 96.06 to 99.21 % (Hanset, 2002).

Therefore CS is indeed the only means and only option to successful calving, which nowadays is to be considered as a management tool. Lowering the high rate of routinely applied CS in the DM-BBB breed can therefore only be achieved by increasing the pelvic sizes of the dam and by lowering the muscular conformation and the birth weights of the calves.

Because of the results shown in our study (Coopman *et al*., 2003, 2004a) and in other studies (Woodward *et al*., 1960; Burfening *et al*., 1978; Simm *et al*., 1986; Naazie *et al.*, 1991; Meyer *et al*., 1993; Glaze *et al*., 1994; Meyer, 1994; Bennet and Gregory, 1996), selection to increase the pelvic size of the dam and to lower the muscular conformation and the live weight of the calves at birth, will inevitably alter the shape and conformation of the DM-BBB animals and have a negative influence on the production traits such as weight at fixed ages, average daily weight gain and the muscular conformation at slaughter ages.

Combined selection for both lower birth weight and desirable traits (e.g. growth rate) is preferable to selection towards lower birth weight alone. For instance, combined selection for growth (increased or constant growth) and moderate birth weight makes that both gestation length (lower) and growth curve will be changed positively (Bourdon and Brinks, 1982). Alternatively, selection for lower birth weight can be combined with selection for higher yearling weight (Dickerson *et al*., 1974). Doing so, gestation length will be shortened allowing a higher prenatal growth rate without adverse effects on calving ability.

On the other hand, selection for a too low (< 36 kg) birth weight or size should be avoided because it can have a negative effect on perinatal survival (Holland and Odde, 1992; Bennett and Gregory, 1996; Hanset, 2002) and the probability that one is selecting for dwarfism increases (Anthony *et al.*, 1995). The lower limit of the birth weight in a double-muscled breed is restricted due to the myostatin mutation effect (Vissac *et al*., 1973), but should not prevent the possibility of natural calving in a DM beef breed (Carnier *et al.*, 2000).

Whether the pelvic sizes reported in our study (Coopman *et al*., 2003, 2004a) and used for the geometrical comparison between the inner pelvic sizes of the dam and the outer morphological traits of the newborn are a correct reflection of the pelvic sizes at birth is a matter of discussion. Pelvic changes seem to occur around calving time due to hormonal influences, but also due to mechanical, calf related reasons (Ménissier and Vissac, 1971; Henson *et al.*, 1989; Murray *et al.*, 1999; Kolkman *et al*., 2008). It would be interesting to consider these pelvic changes in future research in defining the actual pelvic size of the dam around parturition and the maximal dimension of muscular conformation of the calf in relation to the possibility of natural calving in the DM-BBB breed. Such a study must allow the animals to calve naturally, has to measure pelvic sizes pre-, peri- and postpartum and the sizes of the newborn calves immediately after birth (one should not forget to implement the "compressability" of the calf) and compare the characteristics of the mother with the characteristics of her calf. Inevitably, dystocia related problems will occur in such an approach. These possible problems and the fact that Vandenheede *et al.* (2001) and Hanset (2002) consider the routinely applied CS as beneficial on the well being of the cow, make this methodology ethically questionable.

An additional result of our study (Coopman *et al.*, 2004a) was the finding that 20 % of the newborn DM-BBB calves can be classified as cases of foetal gigantism (> 56 kg), which might result in a higher perinatal death (Holland and Odde, 1992; Bennett and Gregory, 1996; Hanset, 2002) and in a higher incidence of congenital disorders such as congenital articular rigidity (CAR) (Coopman *et al.*, 2000b). Calves that weigh a lot and that have an extreme muscular conformation at birth are difficult to raise and exhibit a lot of complications, such as umbilical cord infections, pneumonia and ambulatory problems (Coopman *et al.*, 2005), which causes additional financial losses. It has also been shown that especially in primiparous cows, a negative effect on first ovulation post-partum is seen if the weight of the newborn is high (Guedon *et al.*, 1999). Therefore, beside the fact that selection for a lower birth weight or size and muscular conformation at birth can be of help to lower the incidence of the routinely applied CS (Bennett and Gregory, 2001; Coopman *et al.*, 2004a), it can also be of help to lower the incidence of perinatal death, morbidity and congenital disorders caused by foetal gigantism, to ease calf rearing and to improve farm fertility.

Selection for lower birth weights and less muscular calves is possible due to the sufficiently high heritability in the DM-BBB breed for weight, shoulder width and width of the hind quarters at birth (Coopman *et al.*, 2004a).

The creation of two lines, a beef line and a mother line within the DM-BBB breed (Coopman *et al.*, 2004a) or combining the dual purpose BBB and the DM-BBB breed in cattle farming (see introduction) or even transgenesis (Grobet *et al.*, 2003; Pirottin *et al.*, 2005) might be tools to solve the dystocia related problem that go hand in hand with the myostatin mutation.

3. Live weigh and daily weight gain

The second part of our study has learned that:

- a male DM-BBB weighs on average 51 kg at birth, 98 kg at 3 months, 242 kg at 7 months, 430 kg at 13 months, 628 kg at 20 months and grows more than 1200 g per day between the ages of 7 months and 20 months.
- On average, females weigh 47 kg at birth, 96 kg at 3 months, 189 kg at 7 months and 332 kg at 13 months and grow about 719 g per day from birth to 13 months.
- Selection for higher weights at fixed ages and for increased growth between 13 and 20 months is possible.
- Animals having high weights at young age tend to have higher weights at slaughtering age (= early maturing), but lack the additional growth between 13 and 20 months that late maturing animals still posses.
- High weights at slaughter age are not only due to high weights at yearling age but also due to an additional growth between 13 to 20 months (late maturing).
- The measured shoulder width and measured width of the hindquarters are positively correlated with the muscular conformation and live weight of DM-BBB animals.
- The measured withers height is positively correlated with the live weight, the size and the average daily weight gain of a DM-BBB animal, but negatively correlated with the muscular conformation.
- A model combining age, gender, withers height and shoulder width has a higher accuracy in predicting live weight of DM-BBB animals between the ages of 100 to 600 days than a model containing only the body trait heart girth.
- Live weight prediction does not always respect the ranking of the animals based on their observed live weight. This might influence the accuracy of the breeding value estimation of live weight and might influence the INEC estimation of the DM-BBB breed that combines the estimated live weight and the muscular conformation at 13 or more recently at 14 months.

More explicitely, we can state that the daily weight gain curves of DM-BBB males and females are non-linear between birth and adulthood. Between the ages of 100 to 600 days, a linear relationship exists between the logarithm of the time and the logarithm of the weight (Coopman *et al.*, 2008).

The average weights of males and females at the standard ages in our study were lower than the weights of males at test stations (Hanset *et al.,* 1988; Gengler *et al.,* 1995) and the field records presented by Hanset *et al.* (1988). We strongly believe that the results of our study (Coopman *et al.*, 2007a) represent a more realistic situation of weights on farms, because all animals were weighed and not only the highly ranked ones of the breed, as is done in both the studies of Hanset *et al.* (1988) and Gengler *et al. (*1995).

The genetic correlations between the live weight (LW) at 7, 13 and 20 months reported in our study (Coopman *et al.,*2007a) support the finding of Molina *et al.* (1999) that selection for higher weights at early ages results in satisfactory results for weights at later ages. A negative, but small, correlation between live weight at seven months and average daily growth between 13 and 20 months suggests that animals that are heavy at seven months (and therefore are early maturing) grow more slowly at later ages. Because of the high correlation between LW at 13 months and 20 months, selection in the DM-BBB population focuses on LW at the age of 13 months only. Our study has shown that animals might have high weights at 20 months, not only due to a high weight at 13 months, but also due to high average daily weight gain between 13 and 20 months (late maturing). If weight at 20 months is the most important trait to consider in DM-BBB selection, selection should therefore focus on weight at 20 months in order to preserve the genetic ability for this late maturing mechanism between the ages of 13 to 20 months. On the other hand, if weight at 20 months but also meat quality is an important issue, one should focus on extreme early maturing animals with high weights at 13 months (and consequently high weights at 20 months) with the period between 13 months and slaughter to be used for maturation of the muscles. It is the opinion of some to select for both the early and late maturing property in the breed to have not only high weights at 18 to 20 months, but also at ages of 4 years, when females have given birth to three calves and have grown since than up to 1000 kg. At these ages, DM-BBB females are still paid well per kg LW because of the exceptional meat quality. Also they will than still grow while carrying their calf, increasing their economic value.

Live weight is obviously one of the main selection criteria for a beef breed (Johansson and Hildeman, 1954; Vos and Vos, 1967; Hanset *et al.*, 1987a, 1987b, 1988). Collection of accurate live weight data requires weighing on a balance (Cantet *et al.*, 1988; Gengler *et al*, 1995; Guttierez *et al*., 1997; Coopman *et al*., 2007a). However, in many cases and also in the DM-BBB population, weighing animals is not feasible or too complicated to organize. In current DM-BBB breeding, live weight of yearling males is predicted using the body trait heart girth (Clauwers *et al*., 1999).

The reported preliminary study (Coopman *et al*., 2007b) indicates that heart girth (HG) is indeed highly related with live weight (LW), but, beside other body traits, withers height (WH), shoulder width (SW) and width of the hindquarters (BcW) are good predictors of live weight as well. It was also found that combining body traits in predicting live weight improves the accuracy of the prediction compared to predicting live weight out of one of the body traits alone. A follow-up study (Coopman *et al*., 2008) was performed, using many more data on many more animals and seeking for the best models that predict live weight out of easily accessible morphometric characteristics in the DM-BBB breed. This resulted in a model that combines age, gender, withers height and shoulder width to predict live weight of DM-BBB animals between the ages of 100 to 600 days (economically the most important period). To the knowledge of the authors, this is the first time that it is shown that such a combination is more accurate in predicting live weight than the heart girth. The results even show that withers height and shoulder width by themselves are better predictors of live weight than heart girth. Additionally, both body traits are more easily accessible than heart girth. Coopman *et al.* (2007b) also showed that WH and SW are more informative on MC than HG (r MC-HG = 0.32; r MC-SW = 0.50; r MC-WH = -0.40). Withers height also supplies information on the size (Hanset *et al.,*1990), the skeletal development (Gregory, 1933; Goyache *et al*., 2001) and on the average daily weight gain potential of the DM-BBB animal (r ADG-WH = 0.52; Coopman *et al*., 2007b). Therefore, the selection should focus on the withers height (as it already does; Herd Book, 2005), but also on the shoulder width and should abandon the heart girth parameter. Measuring the shoulder width, rather than a visual appreciation can also be implemented in the linear classification system (Hanset *et al.*, 1990).

Although the model with age, gender, WH and SW predicts live weight with a higher accuracy, ranking of animals based on the observed live weight can differ substantially from the ranking based on the predicted live weight. Further studies should focus on the question whether breeding value estimation based on live weight prediction differs consistently from breeding value estimation based on the measured live weight. If ranking between AI – sires based on live weight breeding values differs, live weight registration should be done using the observed rather than the predicted live weight.

Future studies should also focus on the use of body length as a third covariate in the prediction model. Studies have shown the relation of body length with live weight (Woodward *et al*., 1960; Green and Carmon, 1968; Hanset *et al*., 1990; Gilbert *et al*., 1993a, 1993b). However, the measuring points should first be clearly defined in order to obtain a sufficiently high accuracy and repeatability. Maybe one should consider defining body length very broad as the distance from nose to the tail, to the most pronouncing part of the rear thighs, the half of the rear thighs or even the basis of the rear thighs. Considering the basis seems theoretically the best choice, but may have the disadvantage that it is not easy to assess, as is the case for the heart girth.

One of the complaints of many DM-BBB breeders is the lack of sufficient growth and too low weights at fixed ages compared to other beef breeds. In Table 1, a comparison for different traits is made between the DM-BBB breed and other beef breeds of the conventional meat type. Comparing these data presented in Table 1, there is no indication that supports the complaint of DM-BBB breeders concerning the growth potential. On the other hand, if one looks at the results presented by Coopman *et al.* (2007a), low minimum and average live weights and some very low daily weight gains were registered in the farm population discussed in this study. Maybe the segregation of the mutation causing dwarfism (proportional and CTS) in the breed is the cause of this perception. A breeding policy to eliminate this growth retarding mutation using the available molecular diagnostic test should be started.

A result that additionally supports the complaint of the DM-BBB breeders is the finding of Hanset *et al.* (2001) that there is a genetic trend towards insufficient average daily weight gain. Nevertheless, financial income of the farmer is not yet at stake because muscular conformation shows a positive genetic trend. In the discussion whether average daily weight gain is evolving negatively, one should define daily weight gain for a beef breed more correctly. The aim of the DM-BBB breed is to produce a lot of marketable meat. It would therefore be better to define average daily weight gain as the daily increase of marketable meat in a DM-BBB animal, for which this negative trend might not exist. The observed increase, assessed using the body traits width of the hind quarters and of the shoulder, in muscular conformation has a positive influence on live weight (Coopman *et al*., 1999, 2003, 2004a, 2004b, 2007b) and on the percentage of marketable meat (Coopman *et al*., 2004b).

A low weight and muscular conformation at birth (calf), a high weight and good muscular conformation at slaughter (slaughter bulls), a high weight but low muscular conformation when giving birth (dams), a high weight and muscular conformation at the age of four (dams that only produce three calves) or a low weight and muscular conformation at older ages to minimize maintenance costs (> 3 calves producing dams) are the requests for a DM-BBB breed that is financially and economically acceptable. To find a compromise between these antagonistic traits, selection in the DM-BBB should evolve to a selection for an ideal growth curve, rather than focusing on just one time point in the DM-BBB life. In literature, studies already exist that focus on growth curve characteristics (Bathaei and Leroy, 1998). Selection for an ideal growth curve will only be possible if the live weight registration system (comparable with the milk production registration system in dairy cattle) focuses on live weights at different ages. Because of the information provided by the withers height and

Table 1. Averages and ranges of different traits for conventional and DM-BBB animals.

(Re)Production traits	Non DM breeds [1]	DM-BBB breed [2]
Production		
Weight at 3 months (kg)	NA	65-153
Weight at 7 months (kg)	148-423	117-465
Weight at 13 months (kg)	219-496	167-715
Start weight at finishing (kg)	100-320	193-370
Final weights (kg)	237-740	405-720 (E) 492-880 (S) 238-1081
Carcass weight (kg)	133-428	339-630(E) 277-494(S) 293-660
Dressing (%)	55.11-67.2	68-73 (S) 68-69 (E)
Retail Product yield (%)	49.10-71.9	76-80 (E) 76-85 (S)
Age at slaughter	540-570	426-820
ADG birth-3 months (g/day)	NA	283-1087
ADG birth-7 months (g/day)	702-1050	950
ADG birth/slaughter (g/day)	NA	580-1660
ADG of finishing (g/day)	660-1850	1020-2086
Withers height	57-158	54-146
Shoulder width	NA	17-82
Width of the hind quarters	NA	18-77
Heart girth	122-211	63-272
Survival to weaning (%)	86-95	92-93
Survival weaning-finishing (%)	98	98
Reproduction		
Age at puberty (days)	337-406	339
Age at first calving (months)	722-1098	671-997
Pregnancy Rate (%)	79-93	88
Calves born alive (%)	88-95	93-98
Calving interval	370-380	402-414
Unassisted births	8-97	0
% CS	1-15	54-99
# of produced calves/dam	4-6	3
Pelvic area (cm^2)	105-447	196-516
Pelvic height (cm)	11-22	14-29
Pelvic width (cm)	10-19	13-21
Birth Weight (kg)	13-70	23-81
Birth withers height (cm)	648-71	54-84
Birth shoulder width (cm)	15-21	17-33
Birth heart girth (cm)	67-82	63-104
Birth body length (cm)	48-66	NA
Gestation length (days)	279-290	281-283

NA: data not available; S and E are the carcass classification scores according the Seurop classification system (Anonymous, 1991) and ADG: average daily weight gain.

[(1)] *Gregory, 1933; Bourdon and Brinks, 1982; Rutter et al., 1983; Morrison et al., 1985; Schwabe and Hall, 1989; Baker and Lunt, 1990; Chewning et al., 1990; Reynolds et al., 1990; Naazie et al., 1991; Nugent et al., 1991; Holland and Odde, 1992; Glaze et al., 1994; Meadows et al., 1994; Phocas, 1995; Voisinet et al., 1997; Greiner, 2002; Özlütürk et al., 2004 ; Afolayan et al., 2007; Herd Book Charolais, 2007.*
[(2)] *Hanset et al., 1989a; Hanset et al., 1989b;Gengler et al., 1995; Groupe de reflexion,1997; Coopman et al., 1999; Coopman et al., 2000a; Coopman et al., 2001; Hanset, 2002 ; Coopman et al., 2003; Coopman et al., 2004a; Coopman et al., 2004b; Coopman et al., 2007a; Coopman et al., 2008.*

shoulder width on muscular conformation, average daily weight gain and size, both body traits should be measured at any of the mentioned times as well.

Nevertheless, suggested changes in the data collection and altered selection procedures should always be done taking in account the costs and the related genetic gain one can expect. Also, one should be aware that changing one issue affects much more than just the one trait that is to be improved. Selection is multifactorial and breeding goals reflect the improvement of many, often negatively correlated traits that are not always a reflection of production abilities or economic important traits. In the DM-BBB breed, contests are considered important as well and often are the main breeding goal of some DM-BBB breeders.

Implementing measurements to lower the amount of CS will not be easy or even impossible, because farmers and breeders consider it as a management tool and a method to improve animal welfare, opposite to the public’s opinion that natural calving is much more beneficial for animal welfare. Creating two lines is seen as economically not interesting in Belgium.

The history of the breed has already shown that the breeders themselves decide which way to go. It is up to the Herd Book, supported by scientific evidence, to guide the breeders and make suggestions which breeding direction they should go.

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Summary

The double-muscled Belgian Blue beef (DM-BBB) breed is famous for its extreme muscularity and high yields of marketable, high quality meat. This extreme muscularity is due to a mutation in the myostatin gene. Because of this mutation, parturition is compromised which results in the routine application of the caesarean section. The viability of youngsters is moderate, a relatively high amount of inherited and congenital disorders is seen and there is a perception of and reports on a too low daily weight gain. In DM-BBB breeding, there is no consistent pattern in dealing with the criticism on some of the breed characteristics. The main focus of breeders and breeding organization is the improvement of the muscularity and the weight at 12-13 and lately 14 months. Most data are collected using visual appraisal of the characteristic or by estimating the trait rather than measuring it. There is no attempt to or to less discussion on improving the natural calving rate in the breed. Neither is it generally tried to improve the weight at slaughter ages (18 to 20 months) or to search for the best ratio between muscularity and slaughter weight (**chapter 1**).

This study has looked for answers concerning the remarks on the parturition problems, more specifically on the routinely applied CS, and on the perception and reported trend of decreased daily weight gain, decreased weight at fixed ages and related issues. We used morphometric rather than visual appraisal of traits (**chapter 2**).

At first, we focused on the routinely applied CS (**chapter 3 and 4**). We defined measurements on both the dam (inner pelvic height and inner pelvic width) and the calf (width of the hindquarters) that are related to dystocia problems. In the dam, inner pelvic sizes are important while for the calf, the broadest points of the body can be considered to be dystocia related.

In a first study (**chapter 3**), we found that inner pelvic sizes, measured on halved carcasses, were correlated with external body measurements. Because of this finding, it is possible to predict the pelvic height, being the limiting factor for natural calving ability from the dams' side, out of easily accessible external measurements, without a need for veterinary skills. On the contrary, when performing pelvic measurements using a pelvimeter, one does need veterinary skills. Accessible measurements allow collecting a lot of data on inner pelvic sizes

at relatively low costs. As a conclusion of this study it was found that the more muscular the animal is, the smaller the inner pelvic sizes are, but the taller and heavier, the bigger the inner pelvic sizes. Selection for increased pelvic sizes will inevitably change the breed type.

When comparing the inner pelvic sizes of the dams with the width of the hind quarters of the calves (**chapter 4**), it became clear that, from a geometrical point of view, a DM-BBB calf can no longer be born naturally out of a DM-BBB dam, not even at high parities. When accidentally a calf is still born naturally, it is because, contradictory, a small calf is born out of a huge cow. No direct dam-calf comparison was done, and neither was the influence of hormones and mechanical forces during calving taken into account in this study. Therefore, limits of pelvic sizes/width of the hind quarters considering natural calving ability might be smaller or broader than considered in our study.

Within a breed, selecting for even more meat, live weight and daily weight gain is a concern because of the negative correlation between muscularity and live weight characteristics. Although many studies report on live weight issues in the DM-BBB breed, only little report on field records, and when they do, they mainly report on the better animals of the breed. When dealing with live weight issues, this study focused on field records of all animals, also the ones that have low weights and daily weight gains (**chapter 5**). Live weight and daily weight gains are highly variable within the breed with extremes in both directions. Here it is confirmed that animals with a high live weight at 13 months have high weights at 20 months (slaughter age). An additional and new finding of this study is that animals with relatively moderate weights at 13 months might weigh a lot at 20 months because of the additional genetic growth potential between 13 to 20 months (= late maturing). Because of the current breeding policy that focuses on early maturing animals, this genetic potential is not selected for. Therefore our finding proves that the genetic ability for late maturing animals is still present in the DM-BBB breed even though one is not selecting for late maturing animals.

In beef breeds, live weight and muscular conformation are important production traits. Measuring the live weight is often not feasible or too complicated to organize and is then predicted out of body measurements. Evaluating the muscularity is often done by visual appraisal, a method that is not very accurate. In the DM-BBB breeding policy, muscular conformation is evaluated visually and live weight is predicted using the heart girth. Another trait that is measured and used as a reference in this breed is the withers height. In a preliminary study (**chapter 6**), other body traits were considered as well. The relation of these body traits with the economical important production traits muscular conformation, live weight and daily weight gain was investigated. This study revealed that shoulder width and width of the hindquarters are also highly correlated with live weight in the DM-BBB breed. Additionally, both width measurements are highly correlated with the muscular conformation score of slaughter bulls. Withers height has a negative correlation with this muscular conformation, but a high positive correlation with weight gain potential. Combining different body traits to predict live weight seemed to result in a higher accuracy.

A follow-up study (**chapter 7**) with many more data gathered on many more animals focused on predicting live weight out of easily accessible morphometric characteristics. A non-linear growth pattern was found with a linear part between the age of 100 to 600 days, a period of great economical importance in the breed. In this age period, withers height or shoulder width predicts live weight more accurately than heart girth. Additionally, withers height informs on daily weight gain and size and is better related with muscular conformation than heart girth. Shoulder width not only predicts live weight more accurately than heart girth, it also informs on the muscular conformation of the considered animal much better. As a conclusion, hearth girth predicts live weight with lower accuracy and does not inform as good on daily weight gain nor on muscular conformation as withers height and shoulder width do respectively. In view of practical breeding, it was therefore recommended to keep on measuring withers height, to abandon hearth girth, and to start using the body trait shoulder width. Both the withers height and shoulder width, combined with age and gender in one linear multivariate model can be used to predict live weight if no balance is available to measure the live weight and to evaluate muscular conformation, average daily weight gain and size of the animal.

Finally, the general discussion (**chapter 8**) deals with the obtained results from a broader point of view. Moreover suggestions were made for additional research efforts concerning with the routinely applied CS, the potential segregation of dwarfism in this breed (currently finished (CTS) or in progress (proportional dwarfism) at the Veterinary faculty in Liège) and the development of a model with body length as a third dimension.

Samenvatting

Het Belgisch witblauwe (BWB) dikbilras, oorspronkelijk alleen voorkomend in Midden- en Hoog-België, is bekend voor zijn enorme spiermassa en de hoge opbrengsten van verkoopbaar vlees van hoge kwaliteit. De extreme spierontwikkeling is het gevolg van een mutatie in het myostatine gen. Hierdoor is het natuurlijke geboorteproces in het ras verstoord, zodat de geboorte nog enkel kan gebeuren via het routinematig toepassen van de keizersnede. De leefbaarheid van de jonge dieren is omwille van deze mutatie verlaagd en er zijn relatief hoge aantallen erfelijke en aangeboren aandoeningen te zien. Veehouders klagen over de te lage dagelijkse gewichtsaanzet, terwijl de BWB-fokkerij de kritieke raskenmerken niet consistent aanpakt. De fokkers en de fokkersorganisatie richten hun pijlen vooral op de verbetering van de spierontwikkeling en het verhogen van het gewicht op de leeftijd van 12-13 maand en meer recentelijk op de leeftijd van 14 maand. De meeste beschikbare gegevens zijn het resultaat van visuele beoordelingen of schattingen eerder dan dat ze het resultaat zijn van een meting. Er zijn geen pogingen en te weinig discussies over de mogelijkheid en noodzaak om het aantal natuurlijke geboorten in dit ras te verhogen. Er zijn ook geen initiatieven om het slachtgewicht op de leeftijd van 18 tot 20 maand te verhogen of om op zoek te gaan naar de beste verhouding tussen spierontwikkeling en lichaamsgewicht op slachtleeftijd (**hoofdstuk 1**).

Deze studie heeft getracht antwoorden te vinden op de afkalfproblematiek die in dit ras gekenmerkt is door het routinematig toepassen van de keizersnede. Ook is er aandacht voor de klacht van de veehouders over de veronderstelde gedaalde dagelijks gewichtsaanzet, de veronderstelde gedaalde gewichten op geijkte leeftijden en de daarmee gepaard gaande problemen. In deze studie werd gebruik gemaakt van metingen en niet van visuele observaties (**hoofdstuk 2**).

Eerst werd de problematiek van de routinematig toegepaste keizersnede (**hoofdstuk 3 en 4**) bestudeerd. Er werden lichaamsmaten gedefinieerd die in nauw verband staan met het niet natuurlijk kunnen kalven. Bij de moeder zijn dit de inwendige bekkenhoogte en de inwendige bekkenbreedte; bij het kalf is dit de breedte van de achterhand. De relatie tussen de inwendige bekkenmaten van de moeder en de breedste punten van het kalf is primordiaal in het vlotte verloop van het geboorteproces.

In een eerste studie (**hoofdstuk 3**) werd een correlatie gevonden tussen de inwendige bekkenmaten, gemeten op halve karkassen, en externe lichaamsmaten. Verder bouwend op dit resultaat werd vastgesteld dat het mogelijk is de inwendige bekkenhoogte (die de limiterende factor is in het vlotte verloop van het geboorteproces vanuit het standpunt van het moederdier) te voorspellen op basis van gemakkelijk te meten uitwendige lichaamsmaten. Voor deze externe metingen is er geen nood aan een dierenarts, die men wel nodig heeft als men inwendige metingen wil uitvoeren met behulp van een pelvimeter. Via het meten van externe lichaamsmaten is het mogelijk zeer veel informatie over de inwendige bekkenmaten te verzamelen aan relatief lage kosten. In deze studie werd het ook duidelijk dat bij toenemende spierontwikkeling de inwendige bekkenmaten kleiner werden, maar dat deze groter werden wanneer de dieren zwaarder en groter in gestalte werden. Op basis van de gevonden correlaties kan besloten worden dat selectie naar hogere inwendige bekkenmaten het uitzicht van het ras ontegensprekelijk zal veranderen.

Bij het vergelijken van de inwendige bekkenmaten van het moederdier met de breedte van de achterhand van het kalf (**hoofdstuk 4**) werd duidelijk dat, puur geometrisch bekeken, het onmogelijk is dat een BWB dikbilkalf op een natuurlijke wijze kan geboren worden uit een BWB dikbilkoe, zelfs niet wanneer deze koe al meerdere malen heeft gekalfd. In de weinige gevallen waarin toch nog een natuurlijke geboorte voorvalt, is dit omdat toevallig en buiten de verwachtingen, een klein kalf wordt geboren uit een grote koe. In deze studie werd wel geen directe moeder-kalf vergelijking gedaan en werd ook geen rekening gehouden met hormonale invloeden en met de mechanische krachten die inwerken op het bekken tijdens het kalven. Omwille van deze beperkingen is het mogelijk dat de juiste limieten kleiner of hoger kunnen uitvallen dan deze die in deze studie naar voor werden gebracht.

Wanneer men bij een vleesras focust op een toenemende spierontwikkeling, loopt men het risico dat het levende gewicht en de dagelijkse gewichtsaanzet zullen verminderen. Dit is te verklaren door de negatieve correlatie tussen spierontwikkeling en gewichtsparameters. In het BWB dikbilras wordt regelmatig verslag uitgebracht over gewichtsparameters. Deze rapporten vertellen zelden over veldgegevens en indien ze dat toch doen, betreffen ze meestal alleen de betere dieren. In deze studie werden enkel dieren gewogen en gemeten op landbouwbedrijven. Bovendien was er geen voorselectie op basis van het gewicht en de dagelijkse gewichtsaanzet (**hoofdstuk 5**). Zodoende werden sterk gevarieerde gewichten en groeicijfers vastgesteld met extreme waarden in beide richtingen (dus van extreem laag tot extreem hoog). Het feit dat dieren die een hoog gewicht hebben op de leeftijd van 13 maand ook een hoog gewicht vertonen op de leeftijd van 20 maand (slachtleeftijd) werd hier bevestigd. Een bijkomende bevinding was het feit dat dieren met een gemiddeld gewicht op 13 maand toch nog een hoog gewicht op 20 maand konden bereiken dankzij de aanwezigheid van het kenmerk laatrijpheid. In de huidige fokstrategie richt men zich op vroegrijpe dieren, wat betekent dat op deze laatrijpheid niet wordt geselecteerd. Het resultaat van onze studie geeft hierdoor aan dat deze genetische laatrijpheid nog altijd aanwezig is in het ras ondanks het feit dat hier niet wordt op geselecteerd.

In vleesrassen zijn het lichaamsgewicht en de spierontwikkeling van groot economisch belang. Het bepalen van het lichaamsgewicht is meestal niet mogelijk of zeer moeilijk te organiseren. Om dit probleem op te lossen wordt het lichaamsgewicht voorspeld met behulp van lichaamsmaten en wordt de gespierdheid meestal visueel beoordeeld. Deze visuele beoordeling is niet zo accuraat. In het BWB dikbilras wordt het lichaamsgewicht voorspeld uitgaand van de borstomtrek en wordt de graad van spierontwikkeling ook visueel gescoord. Een andere belangrijke gemeten en als parameter gebruikte referentie in het ras is de schofthoogte of stokmaat. In een voorbereidende studie (**hoofdstuk 6**) werden hier nieuwe lichaamsmaten geïntroduceerd wiens relaties met de economisch belangrijke kenmerken gewicht, spierontwikkeling en dagelijkse groei onderzocht werden. De studie bracht aan het licht dat de gemeten schouderbreedte en de gemeten breedte van de achterhand een goede weergave waren van het lichaamsgewicht en de gespierdheid van een BWB dikbildier. De schofthoogte had een negatieve correlatie met de spierontwikkeling, maar een hoge positieve correlatie met het groeipotentieel van het dier. Er waren ook aanwijzingen dat het combineren van verschillende lichaamsmaten een correcter voorspelling van het lichaamsgewicht toeliet.

Een bijkomende studie die voortbouwde op deze resultaten werd opgezet (**hoofdstuk 7**). Er werden nu veel meer gegevens verzameld op veel meer BWB dikbildieren. De vraag werd gesteld met welke lichaamsmaten en gemakkelijk te verzamelen gegevens de beste voorspelling van het lichaamsgewicht mogelijk was. Er werd een niet lineair groeipatroon aangetroffen met een duidelijk lineair gedeelte tussen de leeftijd van 100 tot 600 dagen, een periode met een groot economische belang in dit ras. In dit leeftijdsinterval voorspellen schofthoogte en schouderbreedte het lichaamsgewicht veel preciezer dan de borstomtrek. De schofthoogte informeert ook over de dagelijkse gewichtsaanzet en de afmetingen van het dier en zegt meer over de spierontwikkeling van het dier dan de borstomtrek. Schouderbreedte voorspelt niet alleen het lichaamsgewicht beter dan de borstomtrek, maar geeft meer informatie over de spierontwikkeling dan de borstomtrek. Anders geformuleerd kan gesteld worden dat de borstomtrek het lichaamsgewicht minder correct voorspelt en minder informatie geeft over de groei en spierontwikkeling dan de schofthoogte en de schouderbreedte. In het dagdagelijkse fokgebeuren kan men zich dan ook beter toespitsen op het meten van de schofthoogte en de schouderbreedte en afstappen van het meten van de borstomtrek. De schofthoogte en de schouderbreedte kunnen dan samen met de leeftijdsgegevens en het geslacht worden gebruikt in een lineair multivariansmodel om het lichaamsgewicht te voorspellen wanneer weging met een veebalans niet mogelijk is. Tegelijkertijd kunnen beide kenmerken dan ook gebruikt worden om de spierontwikkeling, groei en afmetingen van het dier te gaan beoordelen.

Om af te sluiten werden de verkregen resultaten breder besproken in de algemene discussie (**hoofdstuk 8**). Bovendien werden daar suggesties naar voor geschoven om nieuw en aangepast onderzoek te doen naar de routinematig toegepaste keizersnede en om bijkomend onderzoek te doen naar de mogelijke aanwezigheid van dwerggroei (op dit moment afgewerkt (CTS) en in volle uitwerking (hypofysaire dwerggroei) aan de faculteit diergeneeskunde in Luik) in het ras. Er werd ook gesuggereerd om te onderzoeken in hoeverre de lichaamslengte als derde dimensie in de voorspelling van het lichaamsgewicht kan gebruikt worden.

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Curriculum Vitae

Frank Omer Jenny Coopman werd geboren te Waarschoot op 27 augustus 1965. Na de lagere school volgde hij eerst de Latijn-Griekse richting en stapte vervolgens over naar de Latijn-Wetenschappen. In zijn laatste jaar humaniora maakte hij voor het eerst kennis met de wetten van Mendel; de start van de ongebreidelde interesse voor genetica en selectie. Deze interesse was mede verantwoordelijk voor de keuze om de dierenartsen studie aan te vangen. In 1990 studeerde hij af als doctor in de diergeneeskunde met onderscheiding. Zijn eindwerk handelde over E. Coli-mastitis bij de Holstein Friesian. In het kader van zijn keuzevak veeselectie schreef hij een werk over de geschiedenis van de selectie naar hogere melkproductie bij de Holstein Friesian.

Na zijn studies was hij actief als fokker van zowel runderen (Holstein en Belgisch Witblauw (BWB); beroepsmatig) als van honden (Duitse Herder; hobby). In december 1990 volgde hij een cursus embryotransplantatie en tijdens zijn legerdienst (reserve officier) volgde hij een cursus voor jonge beginnende ondernemers aan de Vlerickschool van de Universiteit van Gent.

Het eigen vleesveebedrijf werd uitgebouwd tot een integrale keten waarbij vlees van eigen gefokte runderen als panklare gerechten aan particulieren werden verkocht onder de naam van Filet d'Or. Dit bedrijf en bijhorend concept werd op 1 januari 1999 overgelaten, de dag waarop hij van deeltijds naar voltijds assistent op de dienst Genetica binnen de vakgroep dierenvoeding, dierlijke genetica, veeuitbating en ethologie evolueerde. Tot op de dag van vandaag is dit bedrijf actief met in totaal 200 Belgisch Witblauwe runderen en 50 afgemeste stieren die versneden worden tot panklare gerechten.

Het assistentschap startte op 1 juni 1995 en stond in het licht van het onderzoek bij het BWB dat heeft geleid tot het voorbrengen van dit proefschrift. Als assistent heeft hij menig student helpen opleiden in de genetica en begeleid bij het schrijven van hun scriptie. Binnen een 5b-project van de Europese gemeenschap was hij verantwoordelijk voor de opvolging van de groeiprestaties van ET-kalveren. Gedurende twee jaar heeft hij de werkgroep KI en Zoötechnie wetenschappelijk begeleid.

In het kader van zijn doctoraatsopleiding, waarvan hij een getuigschrift verkreeg op 06/02/2003, behaalde hij het diploma van specialist in diergeneeskundig toezicht op eetwaren van dierlijke oorsprong met grote onderscheiding. Zijn scriptie betrof de foktechnische benadering van vleeskwaliteitsproblemen bij varkens.

Tussen 1 januari 2002 en 15 juni 2006 was hij de coördinator van de Belgische Nationale commissie voor erfelijke skeletaandoeningen. Hij is de eerste Belgische dierenarts die full member werd van de PennHIP screening organisatie. Het afgelopen jaar behaalde hij het diploma van master in de moleculaire medische biotechnologie met onderscheiding.

Zoals aangegeven in de hiernavolgende lijst is Frank Coopman auteur of mede-auteur van nationale en internationale publicaties. Hij werkt actief mee aan de postuniversitaire opleidingen voor practici. Hij is door verschillende organisaties gevraagd om te spreken over erfelijkheidsleer. Hij was spreker op drie internationale workshops (GIFT-Wageningen, november 1999; ECVDI-Ghent, september 2004; VEE annual meeting november 2004). Hij werd door de organisatoren van de voorjaarsdagen uitgenodigd om te spreken over de beginselen en de toekomstmogelijkheden van de diergeneeskundige medische genetica op de editie 2007. Sinds juni 2007 is hij bestuurder in een beursgenoteerd familiaal bedrijf. Per 1 oktober 2007 is hij als lector dierlijke productie aangesteld in de Hogeschool Gent.

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