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Double Muscle Animals: The Physical, Farming Characteristics and Their Future in Food Production

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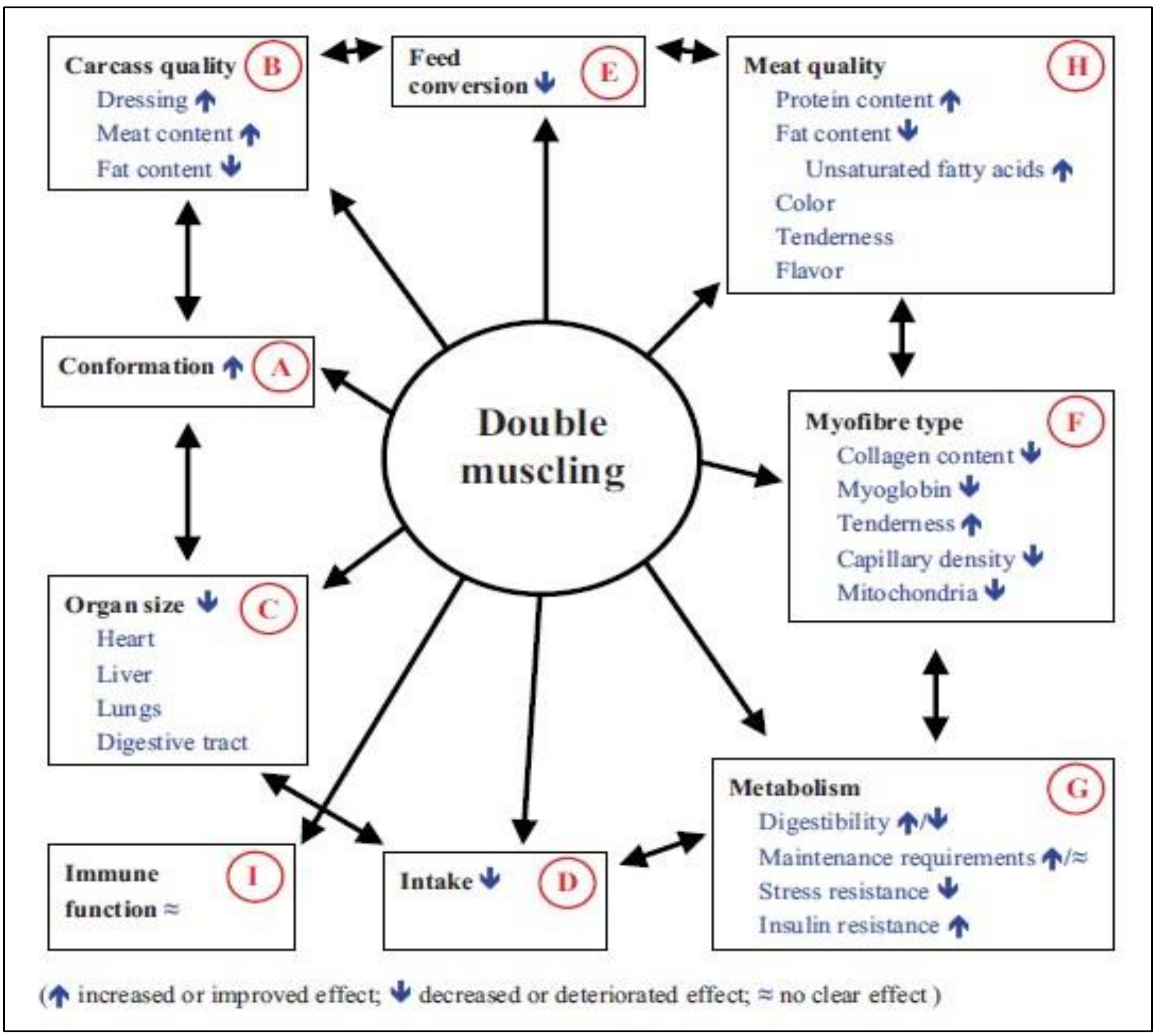
1.1. Introduction

Double Muscled (DM) Animals are being widely produced around the world in different species for better meat quality, high amount of yield of carcasses, more improved nature of food metabolism, enhanced organoleptic textures for both the consumers and the producers. The high carcass yield is also desirable to the butchers for better cuts and profits as well as for the buyers. So, the number of producing Double Muscled Animals is increasing per annum. The reduced activity of Myostatin (MSTN); a growth differentiation factor present in some animals Deoxyribose Nucleic Acid (DNA) is responsible for the hypertrophic nature of the Double Muscled Animals. Though the MSTN works as the agent to increase the volume on the same time the hypertrophic nature of the Double Muscled Animals creates risk and disease for the Double Muscled Animals. The major organs including heart, lungs, kidney, liver, reproduction system, breeding and metabolism are different than the ordinary animals. Moreover, the DM Animals rely upon modified high nutritive diets. These differences create life threatening risk, susceptible nature to catch diseases for the Double Muscled Animals. For these reasons farming of DM Animals is not popular and cost efficient among the farmers all around the world since it requires extra supervision, different environment and diet maintenance. Apart from all the shortcomings the DM Animals are making an influential impact on the food industry for their larger yield than other farming animals. The following chapters will discuss the nature of the DM Animals and their role in the food production industry.

2.1. The Origin of the Double Muscled Animals and Role of Myostatin (MSTN)

Charles Darwin in his famous scientific work “On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life” mentioned that the animals as we see in the present day are not same as their beginning. Some of them have changed their nature both internally and externally due to survive the changing environment and some of them were altered by humans through selective breeding, domestication and hybridization [1]. The inactivation of MSTN Gene is responsible for the hypertrophic nature of the DM Animals [2]. The removal of 11 base-pare is primarily need for the hypertrophic state of the Belgian Blue Double Muscled (BBDM) cattle [3]. MSTN is a myocyte-secreted protein that is thought to be a negative regulator of Skeletal Muscle hypertrophy and growth. MSTN is a protein that is expressed by cells in the developing Skeletal Muscle during embryogenesis and regulates the amount of muscle fibers. Skeletal Muscle releases MSTN into the bloodstream as people age, limiting muscle fiber development [4]. MSTN belongs to the transforming growth factor superfamily, which includes a broad range of secreted growth and differentiation factors that play critical roles in tissue homeostasis and development [5]. The hypertrophic nature due to the inactivation or deletion of MSTN from the gene not only generates increased amount of butcher it affects the bone and skeletal development, variation in sizes of the major organs, reproduction system, breeding and metabolism. Adjoint these phenomena and their impacts will be discussed.

Figure 1: Impact of double muscling on some important animal characteristics [6]



2.2. The Nature of Bones in DM Animals

The tissues of DM animals differ from those of non-DM animals because they contain less collagen. As a result, bone strength compromised since collagen functions as shock absorber and lubricator in the bone junctions. Capillary density is also decreased in DM animals. This might be crucial for nutrition absorption in the bones and hooves. If the higher phosphorus need of heavier DM-animals is not met, bone development may suffer. As a result, special considerations for DM cattle's diet and confinement are required. In one study, it was shown that Double Muscled bulls had much less bone in the femur than either Hereford (HE) or Beef Synthetic (SY), that they had significantly less os coxae than HE and significantly more sternum than HE but did not vary from SY for this bone. The DM bulls had much less bone in total long bones but significantly more bone in costae than SY but did not vary from HE in this regard. There were no variations in the weight of the humerus, radius and ulna, atlas, vertebrae cervicale and thoracicae, patella, tibia, tarsus, or vertebrae lumbales across breed types [7]. In the same study, DM Animals tended to have more bone in the sternum, but less in the os coxae and femur, whereas SY tended to have more bone in the costae and scapula, but less in the femur and total long bones. SY, on the other hand, tended to have more bone in total long bones but less in the scapula and os coxae when compared to HE.

DM Animals exhibited a larger hypotrophic impact on hindlimb bones than on forelimb bones. It might be suggested that the comparatively smaller amount of bone in the proximal hindlimb in DM Animals is due to the high development rate of muscle in this location rather than endocrine gland failure after a certain age. Except for the vertebral column, the growth rate of DM Animals did not differ from that of the more regular breed types when compared to total side bone. When comparing DM Animals' corpses to the more typical breed type, there were changes in bone weight distribution towards the thoracic area at the same total side bone. DM bulls exhibited decreased bone in the proximal hindlimb. When comparing the same total side muscle, there was overall but not uniform bone hypotrophy. However, when the same total side bone was compared, there was differential bone hypotrophy and bone hypodevelopment in the animals [8].

As a result, time spent standing is 13% lower in DM bulls. This might be harmful to blood circulation in the hooves as well as the production of new horn. The tiny limb bones of DM-animals, as well as the smaller circumference of the cannon bone and the femur, support this.

Inhibiting collagen formation in connective tissues may also reduce tendons and ligaments' mechanical and structural adaptability [9].

Table 1: Unadjusted means and standard deviations (s.d.) of side weight, and major carcass tissues by breed [10]

	Beef Synthetic		Double Muscled		Significance of Difference	Ratio DM/SY
	Mean	s.d.	Mean	s.d.		
Age (days)	2603		1844		NS	1.103
Side Weight (kg)	145	11.4	160	28.0	P<0.05	1.197
Total Side Muscle (kg)	93.5	5.3	111.9	24.5	NS	1.000
Total Side Fat (kg)	30.3	8.2	30.3	6.1	P<0.05	0.883
Total Side Bone (kg)	19.7	1.7	17.4	2.6	P<0.01	1.333
Muscle:Bone Ratio	4.8	0.4	6.4	1.0	P<0.01	1.071
Muscle in Side (%)	64.8	3.0	69.4	4.5	NS	0.928
Fat in Side (%)	20.7	4.4	19.2	4.2	P<0.01	0.796
Bone in Side (%)	13.7	1.6	10.9	1.1		

2.3. Physiological and Metabolic Aspects of DM Animals

In DM animals, a shift from an oxidative to a more glycolytic metabolism is caused by a shift towards quicker glycolytic myofibers. When DM Belgian Blue bulls were compared to non-DM Belgian Blue bulls, they had considerably lower aerobic and higher anaerobic fiber ratios. The lower number of mitochondria in rapid glycolytic myofibers is consistent with anaerobic or glycolytic metabolism. It should be highlighted that the reduced number of mitochondria is not owing to poorer mitochondrial expression, but rather to the glycolytic muscle type having fewer mitochondria. There is less possibility for fatty acid oxidation in DM animals because the number of mitochondria is decreased. This is because DM animals have a low-fat content, therefore the number of fatty acids that should be oxidized following breakdown is relatively little. Furthermore, because of the decreased capillary density, oxygen delivery is limited, and the rate of lactate removal may be hampered. For oxygen delivery, hemoglobin in red blood cells and myoglobin in muscle cells work together. Myoglobin concentration is lower in DM finishing cattle than in non-DM finishing cattle [11]. When the DM Animals acquire weight, locomotory or movement flexibility issues might become a concern. Up to one year of age, DM Animals are more susceptible to respiratory illnesses, resulting in increased calf mortality. The underdevelopment of the cardiorespiratory system is most likely the cause. The higher vulnerability to exercise weariness and heat stress is also due to the reduced respiratory capacity combined with the increased muscle mass. Reduced oxygen transport decreases aerobic metabolic activity of the muscle, increased heat generation and reduced heat dissipation capability all contribute to increased stress vulnerability [12].

2.4. Muscle Characteristics and Meat Quality

The meat from double-muscled (DM) animals is extremely lean. They can be described as a sort of late developing animal. They are frequently classified as animals having hypertrophy of the muscles [13]. The proportion of muscle in the hip and stifle region is higher in Double Muscled animals than in other breed varieties. In the pectoral girdle, shoulder and elbow DM Animals have greater muscle than SY but did not vary from HE in these areas. In costly muscle groups, DM Animals have a larger percentage of muscle [14]. Animals with double muscles produce meat that is more tender. When compared to 'normal' cattle, intramuscular fat content in DM cattle has decreased by 30 to 50 percent, with fat in DM cattle having a greater iodine value. In comparison to 'regular' beef animals, DM cattle's intramuscular fat contains a larger proportion of polyunsaturated fatty acids (PUFA) than polysaturated fatty acids (PSFA) and a similar proportion of conjugated linoleic acids (CLA). From the standpoint of human health, this is a beneficial trait. The higher the proportion of PUFA to SFA, the better. CLA has been linked to beneficial biological benefits such as the prevention of cancer and atherosclerosis [15].

2.5. Changes in Organ Sizes Due to Double Muscling and Their Consequences

When DM animals are compared to non-DM animals, some internal organs are smaller. When compared to non-DM bulls, Charolais DM bulls slaughtered at 15 or 20 months had reduced weights (percent reductions) for the spleen (30%), liver (20%), heart (20%), blood (14 and 20 percent, respectively), and lungs (10 and 24 percent, respectively). BBDM bulls showed similar findings, with decreases ranging from 10% for the adrenal glands to 15% for the heart, 17 percent for the liver and digestive system, 19 percent for the lungs, 37 percent for the spleen, and 51 percent for the thymus. The digestive system was found to be 18 percent smaller, the liver and kidneys 16 percent smaller and the heart 14 percent smaller when measured in g per kg empty body weight. A larger ratio of empty body weight to body weight in DM animals demonstrates the decreased digestive tract. In BBDM cows and bulls, this ratio was 90 and 93 percent, respectively. Non-DM animals have been reported to have ratios of 72 percent, 79–86 percent, and 84 percent. In addition to internal organs, skin weight is decreased in DM animals, ranging from 20% to 29%. The lower weight of internal organs, skin, head, and legs results in a significant reduction of the fifth quarter and as previously noted, a high dressing percentage. The loss of lung weight affects not only the weight of the fifth quarter and carcass weight, but it may also have a significant impact on DM animals' respiratory activities. When compared to the mammalian average, bovine lungs have roughly 25% more lung capacity per unit of body weight. The small airway resistance in DM calves is much greater than in non-DM calves, which may explain their vulnerability to severe bronchopneumonia. Furthermore, as compared to ordinary cattle, DM cattle tend to be more prone to alveolar hypoxia and hypoxemia. Inflammation of the respiratory tract in DM calves may be aggravated by an imbalance in the autonomic nervous system's cholinergic bronchoconstrictor and beta-adrenergic bronchodilator components, which might explain their vulnerability to respiratory illnesses. As a result, when respiratory infections are present, DM animals appear to be handicapped. So special considerations should be given to the housing of DM Animals. When DM calves are kept in outdoor hutches, they have a lower incidence of pneumonia than those kept in indoor confinement. Aside from the growth hormone axis, it's probable that a lower feed intake capacity is also responsible for the reduced liver weight in DM animals. The drastically reduced liver mass found in steers following food restriction is consistent with a lower liver weight in DM animals. After a 90 kg live-weight reduction, liver weight was lowered by 25% when concentrate consumption was reduced to roughly 55% of ad lib intake. However, the link between decreased consumption and liver weight in animals is unclear. To compensate for the lower feed intake capacity of DM animals, the diet must have a higher nutritional density. Furthermore, for high lean meat deposition, a high dietary protein content is required. Dietary protein is transformed into body protein more effectively in DM Animals. Animals with double muscles are known to be “slow turning over" depositing significant quantities of muscle protein and having a higher capability for protein synthesis than animals without double muscles [16].

2.6. Requirement of Energy

In comparison to non-double-muscled cattle, double-muscled cattle have more fast-glycolytic fibers. Glycolytic fibers have a lower protein turnover than oxidative fibers. Protein turnover may account for roughly 15% of energy consumption, implying that DMBB cows' maintenance energy requirements are lower than those of other genotypes. Furthermore, double-muscled calves have smaller organs, and organ mass is inversely proportional to energy consumption. Another reason to believe that double-muscled calves have reduced maintenance energy requirements is because of this. The maintenance energy needs of DMBB bulls were reported to be 8% lower than those of non-DMBB bulls, however it is unclear if the difference was substantial. The energy needs of DMBB cows for maintenance are relatively comparable to those of other beef genotypes. The larger muscle mass in DMBB animals, as well as the fact that lean tissue is physiologically more active than fat tissue, may offset the lowering effect of decreased protein turnover [17]. Table 2 below illustrates the comparison between the DM Animals and other Genotypes.

Table 2: Comparison of metabolizable (MEm) or net energy (NEm) requirements (MJ/kg BW0:75) for maintenance of beef cows of different genotypes; modified from [18]

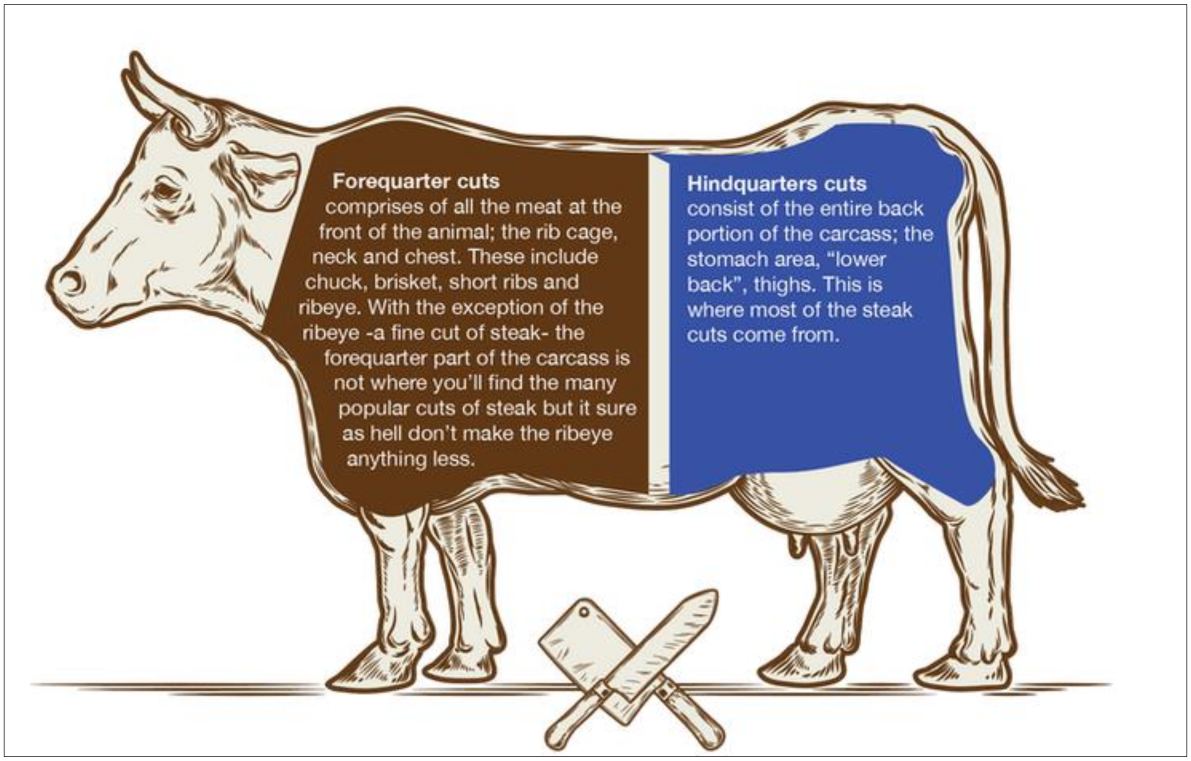
Genotype	MEm	Genotype	NEm
Angus-Hereford crossbreds	0.534	Angus	0.304
Angus-Hereford crossbreds	0.544	Not Specified	0.322
Charolais crossbreds	0.565	Angus, Exp. 1	0.373
Simmental crossbreds	0.699	Angus, Exp. 2	0.389
Angus	0.418	Angus, Exp. 3	0.378
Hereford	0.452		
Angus	0.656		
Crossbreds, low milk yield	0.556		
Crossbreds, moderate milk yield	0.636		
Crossbreds, low milk yield	0.615		
Angus	0.433		
Simmental	0.517		
Charolais	0.490		
Angus-Hereford crossbreds	0.503		
Mean (n = 14)	0.544	Mean (n = 5)	0.353
SEM	0.023	SEM	0.017
DMBB (current experiment)	0.569	DMBB	0.332

2.7. Distribution, Growth of Fat and their Effects on Meat Quality

In an independent study concerning the DM Bull, Hereford (HE) and Beef Synthetic (SY) were serially butchered. The weight of the animals varied from 250 to 800 kilogram in form of liveweight. For finding out the fat percentage and distribution Total Side Fat (TSF), Carcass Cavity Fat (CCF), Subcutaneous Fat (SCF) and Intermuscular Fat (IMF) were separated, weighed to calculate the Total Side Fat (TSF) and analyzed for the distribution and growth of fat.

The study revealed that DM Animals did not differ significantly in analysis of CCF, IMF and SCF for Fat Growth Rate. On the other hand, the Total Side Fat (TSF) content the other breeds had faster growth rate for fat development than the DM bulls.

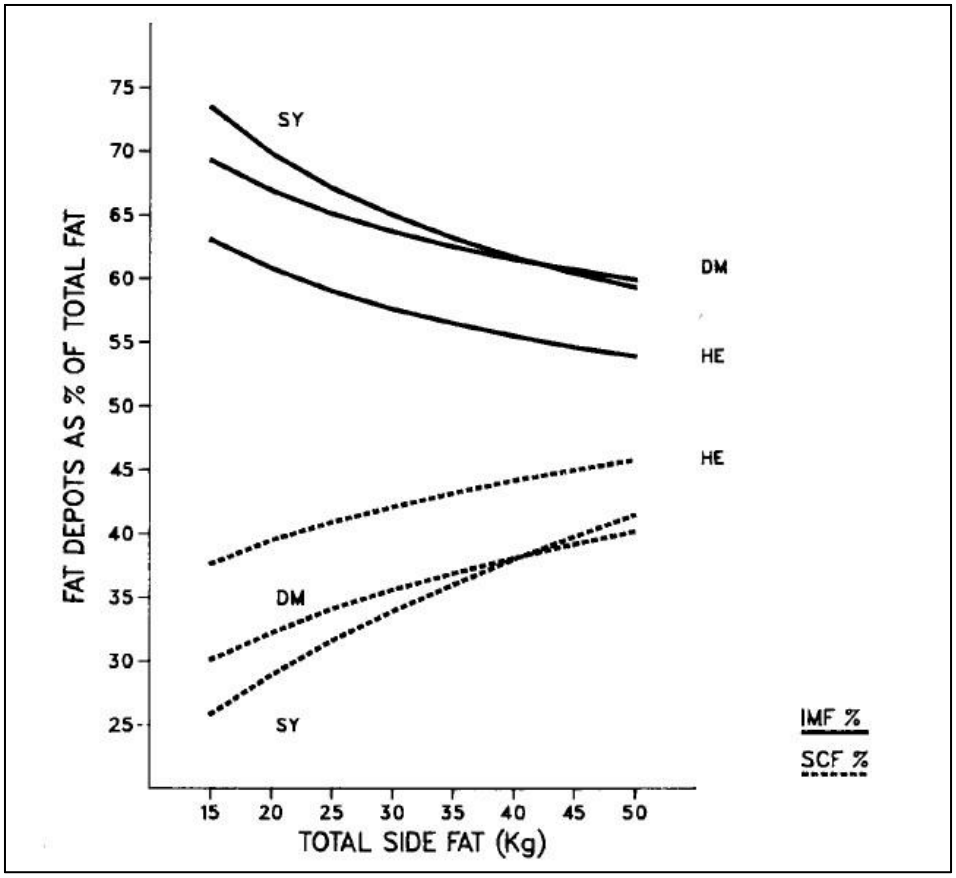
Figure 2: Hindquarter and Forequarter of a cow [19]



From the previous part it appears that DM Animals possess special type of metabolism for their genetic effect. This phenomenon also proved when the research found that DM Animals had very small amount of Subcutaneous Fats and Carcass Cavity Fat on their sides than the HE and SY. Between the HE and SY the HE grew more than the SY. The fat distribution was mainly on the cavities of the carcass and intramuscular regions. Here the HE showed the opposite. They had reserved major amount of fats in their Subcutaneous layer. The lower amount of fat can be explained since DM Animals has lower rate of maturation than the other breeds.

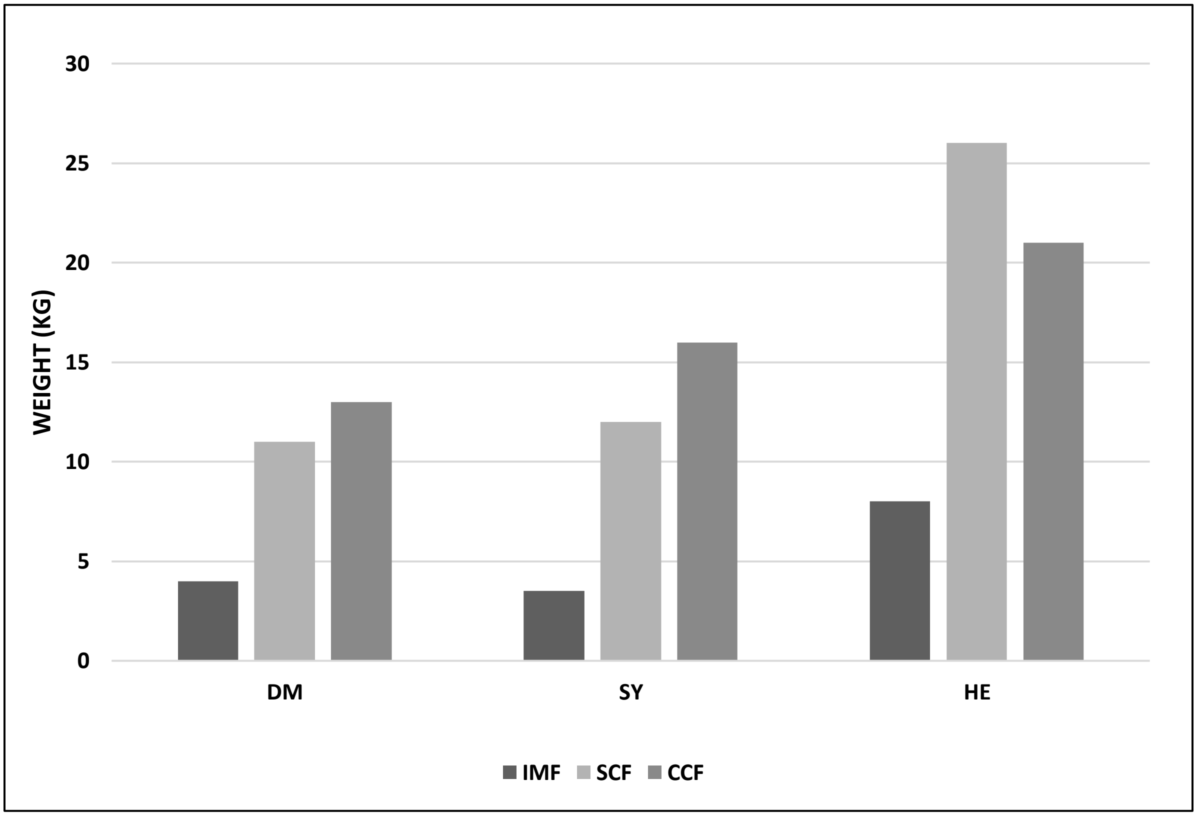
For Forequarter and Hindquarter analysis the DM bulls possessed less hindquarter fat and more in the forequarter part. The DM and SY bulls had similar amount of IMF in the forequarter than the HE bulls. The SY had the highest amount of hindquarter IMF than the other breeds but smaller number of IMF in the forequarter section. For all the three breeds they all had larger

Figure 3:Fat growth and partitioning in cattle [20]



amount of fats in the forequarter than the hindquarter. But for the SCF it was vice versa. For both quarters larger amount of fats was stored in the Subcutaneous layer of the HE, but the SY and DM had developed major parts of their fats in the intramuscular gaps. The growing rates of fat development were varying by the type of breeds through either by Hypertrophy or Hypotrophy. The growth rate for the DM bulls were suggesting that they tend to deposit less CCF and SCF at lower rate than the other two breeds since they possess lower rate of maturation or late maturity. The variation in fat percentages in the forequarter and hind quarter can be liked to the different types of metabolism function in the animals, growth of maturity, their muscle types, and functions. The study also implicated that rather than fat growth rates the commencement of fat growth were impacted more by the breed types [22].

Figure 4: Mean fat weight by depot and breed type [21]



In another study the impact of fat on the meat quality was observed. Bite, lubrication, insurance and strain were the beneficial sides of the intramuscular fat. The removal of bulk density and decreasing strength of the connective tissues can be achieved by the presence of fats in the intramuscular regions, exerted by the theory of strain and bite. The fats usually have lower mass than the muscle tissues of the same volumes. This is how low density can be explained. DM animals always yield in larger butcher cuts since they possess lower amount of fat and hypertrophic muscle formation. Moreover, the presence of fats also ensures that meats are not being rapidly dried out whether they are cooked for longer times or the opposite.

On the other hand, Subcutaneous tissues helps the carcass to absorb slower rate of cooling or chilling in the postmortem stage. As a result, decreased cold-shortening period improves the tenderness of meat. Bulls having potato supplemented diets revealed that increased amount of intramuscular fats augmented the light coloration of meat though the presence, development of pigment compounds was high. DM Animals have more amount of myofiber and pigments in their muscles; this made their meats lighter in color than the normal animals. But the appearance and tenderness of meat can always be affected by the growth rate and age of the animals [23].

2.8. The Future of DM Animals in the Food Production

Future of DM Animals doesn't stand alone on the high amount of yield against invested number of resources. Rather environmental effects of cattle farming, health preservation, method of farming and animal welfare are being the key points in the future of animal farming. Moreover, the ongoing pandemic has put a serious threat to the food production and supply chain management. On the other hand, regional religious views and rise of vigilantes has reduced the access to cheaper animal protein in some part of the world. The later sections will discuss the beforementioned concepts in brief.

A. **Effects of Cattle Farming on the Environment:** According to some research the global production of Methane (CH_4) is around 540 Tera-gram/year. Among this nearly 65 to 85 Tera-gram is coming from grazing cattle and other four-footed animals [24]. The Carbon footprint of the meat production, transportation is the highest in the food production system. The release of Nitrous Oxide (N_2O) and Ammonia (NH_3) is also very high in cattle and other animal livestock production [25]. These emissions are comprising the phenomenon of Greenhouse effect and triggering the radical climate change in negative ways. Brazil is the highest beef exporter of the world according to the United States Department of Agriculture. But Brazil is the mother to the Amazon Rain Forest which is known as "The Lungs of the Planet". Increasing global demand of the beef pushing Brazil to create more grazing field by deforesting the Amazon in the higher rate in the history. The deforestation often carried out by uncontrolled firing. This firing is creating frequently wildfire in higher number and devastating in nature in the history. The longer period and larger area of wildfire is releasing very high number of Carbon in the environment. So, not only the farming procedure is releasing harmful materials in the ecosystem but also the before and aftermath of the cattle farming is putting negative impact on the environment.

B. **Rising Human Health Consciousness:** Red meats are high in calories and Saturated Fatty acids. The consumption of red meats frequently increases the level of Low Density Lipo Protein in the blood which results into rise of Cholesterol. The rise of cholesterol rises the risk of obesity, heart attack and high blood pressure. Moreover, the high of calories need extra activities to burn those. So, by medical research and their publications people around the world are consuming less amount of red meat. For example, in a research it was found that the amount of beef consumption per-capita is declining in the European Union every year since 1985 due to the health preservation [26]. The development of lab meat with Nanotechnology with harmless, necessary nutrients are being produced and increasing at a higher period. This technology will not only solve the public health issue in future it will be the key to preserve environment from harmful climate changes.

C. **Religious Practices and Taboos:** Sacrificing specific animals and not to do so in some religions is an integral part. For the Muslims the annual sacrifice of allowed four-footed animals is essential. This practice also involves distributing the 2/3 of the meats to the neighbors and the poor. So, at least once in year people can have surplus of animal protein. The annual sacrifice created a habit of meat consumption in the Muslim Community. On the other hand, among the Hindus in India slaughtering of cow is strictly prohibited by the religious and local law. Though it was supposed to applicable for the Hindus by religion the law passed by State Governments are being imposed on the Non-Hindu Community as well. As a result, people are not only having restriction on religious practices they are losing access to cheaper animal protein since muttons are more expensive than cow-beef. Unfortunately, the rise of "Cow-vigilantes" has become a cause of unfortunate death. The effects are also inflicting on the Inter-States relation. From 2000 to 2020, 1236 Bangladeshis have been killed by the Border Security Force (BSF) of the and 1145 were injured while smuggling cows from India to Bangladesh [27]. Internally in India people are being killed by the cow-vigilantes in suspicion of slaughtering, carrying, marketing, and eating of cow-beef and while transporting cows for other economical activities rather than slaughtering. The Muslim minority and sometimes people from other faiths are being victim [28]. The high demand of cow-meat in Bangladesh and inadequate supply from India urged the government and private investors to bolster the farming of cattle in the country and it worked within three years. But the cow crisis had become worse in India since farmers can afford to feed the cow that can not be used in the farming or milk production. The exportation of live cattle has also become problem for the farmers surpluses by the local and religious laws they have no way but leaving the cows free to roam. These abandoned cows have little access to food, nutrition, shelter. These deprivations often make the cows hostile resulting to attacking common people in some cases killing them. Moreover, the motorists in the nighttime are facing a greater number of accidents because of these cows uncontrolled movements on the roads [29]. So, from field to fork the situation and future of cattle farming is different from region to region and from religion to religion as well.

D. **Breeding and Reproduction Problem:** Average birth weight of the DM calves is higher than normal breeds [30]. But the pelvic gap of the DM cows is smaller since their bones are strengthened to carry more weights than average cows. This opposite relation creates hinders during birth of calves. It become harder to give birth naturally and requires often surgical procedures. Caesarian cuts require time to heal and the puts restriction on lactating the calve. In addition, the growth of maturity in DM cattle is relatively lower than the normal breeds. This prolonged period requires extra time to enter reproduction period and boost the weight gain rate for the calves [31]. In consequence farming DM animals for all the farmers specifically having no or limited facilities for medical attention and high yield in low time is not easy.

E. **Meat or Milk?** The DM animals are likely to produce more meat but the milk yield is poorer than the other types. After a certain period the weight gaining rate becomes faster than the other breeds but the milk production is still low. In some countries the governments had to make choice over meat vs milk based on the food security, geographical and financial condition of the nation. For example, in Bangladesh the importation and farming DM animals are strictly prohibited [32]. The government has realized that if the farming of DM cattle is allowed most of the farmers will move to it leaving the milk production at risk as well as the food security of the people. Moreover, the government intend to protect the local breed from extinction as it is being used for both meat and milk production. Breeds with milk production specialization are allowed and encouraged to import and farming for maintaining the balance [33]. Many countries around the world are still trying to make a balance or moved to one paradigm based on their needs.

3.1. Conclusion

Despite of the limitations of the DM animals and the side effects of their farming the increasing animal protein demand of the population new avenues must be pursued for a better and sustainable farming of DM animals.

References

1. Darwin, C. (2010). *The origin of species by means of natural selection of the preservation of favoured races in the struggle for life*. Memphis, Tn: General Books, 18.
2. Grobet, L., Royo Martin, L.J., Poncelet, D., Pirottin, D., Brouwers, B., Riquet, J., Schoeberlein, A., Dunner, S., Ménissier, F., Massabanda, J., Fries, R., Hanset, R. and Georges, M. (1997). A deletion in the bovine myostatin gene causes the double–muscled phenotype in cattle. *Nature Genetics*, [online] 17(1), pp.71–74. Available at: https://www.nature.com/articles/ng0997-71 [Accessed 29 Oct. 2019].
3. McPherron, A.C. and Lee, S.-J. (1997). Double muscling in cattle due to mutations in the myostatin gene. *Proceedings of the National Academy of Sciences*, 94(23), pp.12457–12461.
4. Ahmad, S.S., Ahmad, K., Lee, E.J., Shaikh, S. and Choi, I. (2021). Computational Identification of Dithymoquinone as a Potential Inhibitor of Myostatin and Regulator of Muscle Mass. *Molecules*, 26(17), p.5407.
5. McPherron, A.C. and Lee, S.-J. (1997). Double muscling in cattle due to mutations in the myostatin gene. *Proceedings of the National Academy of Sciences*, 94(23), pp.12457–12461.

6. Fiems, L.O. (2012). Double Muscling in Cattle: Genes, Husbandry, Carcasses and Meat. *Animals*, 2(3), pp.472–506.
7. SHAHIN, K.A. and BERG, R.T. (1985). GROWTH AND DISTRIBUTION OF BONE IN DOUBLE MUSCLED AND NORMAL CATTLE. *Canadian Journal of Animal Science*, 65(2), pp.319–332.
8. SHAHIN, K.A. and BERG, R.T. (1985). GROWTH AND DISTRIBUTION OF BONE IN DOUBLE MUSCLED AND NORMAL CATTLE. *Canadian Journal of Animal Science*, 65(2), pp.319–332.
9. Fiems, L.O. (2012). Double Muscling in Cattle: Genes, Husbandry, Carcasses and Meat. *Animals*, 2(3), pp.472–506.
10. Shahin, K.A., Berg, R.T. and Price, M.A. (1991). Muscle and bone distribution in mature normal and double muscled cows. *Livestock Production Science*, 28(4), pp.291–303.
11. Fiems, L.O. (2012). Double Muscling in Cattle: Genes, Husbandry, Carcasses and Meat. *Animals*, 2(3), pp.472–506.
12. SMET, S.D. (2004). DOUBLE-MUSCLED ANIMALS. *ELSEVIER*, pp.398–399.
13. Fiems, L.O. (2012). Double Muscling in Cattle: Genes, Husbandry, Carcasses and Meat. *Animals*, 2(3), pp.472–506.
14. SHAHIN, K.A. and BERG, R.T. (1985). GROWTH AND DISTRIBUTION OF MUSCLE IN DOUBLE MUSCLED AND NORMAL CATTLE. *Canadian Journal of Animal Science*, 65(2), pp.307–318.
15. Coopman, F., Van Zeveren, A., Verhoeven, G. and De Smet, S. (2007). Parameters for the estimation of live weight and for the visual appraisal of the muscular conformation in the (double-muscled) Belgian Blue beef breed. *Archives Animal Breeding*, 50(4), pp.348–355.
16. Fiems, L.O. (2012). Double Muscling in Cattle: Genes, Husbandry, Carcasses and Meat. *Animals*, 2(3), pp.472–506.
17. Fiems, L.O., De Boever, J.L., Vanacker, J.M. and De Campeneere, S. (2015). Maintenance Energy Requirements of Double-Muscled Belgian Blue Beef Cows. *Animals : an Open Access Journal from MDPI*, [online] 5(1), pp.89–100. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4494341/#B9-animals-05-00089 [Accessed 18 Jan. 2021].

18. Fiems, L.O., De Boever, J.L., Vanacker, J.M. and De Campeneere, S. (2015). Maintenance Energy Requirements of Double-Muscled Belgian Blue Beef Cows. *Animals : an Open Access Journal from MDPI*, [online] 5(1), pp.89–100. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4494341/#B9-animals-05-00089 [Accessed 18 Jan. 2021].
19. container36 (2019). *Meat cuts 101*. [online] wheretherivernarrows. Available at: https://container36.wixsite.com/wtrn/post/meat-cuts-101 [Accessed 15 Mar. 2022].
20. SHAHIN, K.A. and BERG, R.T. (1985). FAT GROWTH AND PARTITIONING AMONG THE DEPOTS IN DOUBLE MUSCLED AND NORMAL CATTLE. *Canadian Journal of Animal Science*, 65(2), pp.295–306.
21. SHAHIN, K.A. and BERG, R.T. (1985). FAT GROWTH AND PARTITIONING AMONG THE DEPOTS IN DOUBLE MUSCLED AND NORMAL CATTLE. *Canadian Journal of Animal Science*, 65(2), pp.295–306.
22. SHAHIN, K.A. and BERG, R.T. (1985). FAT GROWTH AND PARTITIONING AMONG THE DEPOTS IN DOUBLE MUSCLED AND NORMAL CATTLE. *Canadian Journal of Animal Science*, 65(2), pp.295–306.
23. Fiems, L.O., Campeneere, S.De., De Smet, S., Van de Voorde, G., Vanacker, J.M. and Boucqué, Ch.V. (2000). Relationship between fat depots in carcasses of beef bulls and effect on meat colour and tenderness. *Meat Science*, 56(1), pp.41–47.
24. Kinsman, R., Sauer, F.D., Jackson, H.A. and Wolynetz, M.S. (1995). Methane and Carbon Dioxide Emissions from Dairy Cows in Full Lactation Monitored over a Six-Month Period. *Journal of Dairy Science*, [online] 78(12), pp.2760–2766. Available at: https://www.journalofdairyscience.org/article/S0022-0302(95)76907-7/pdf [Accessed 13 Mar. 2020].
25. CHADWICK, D. (2005). Emissions of ammonia, nitrous oxide and methane from cattle manure heaps: effect of compaction and covering. *Atmospheric Environment*, 39(4), pp.787–799.
26. Hocquette, J.-F., Ellies-Oury, M.-P., Lherm, M., Pineau, C., Deblitz, C. and Farmer, L. (2018). Current situation and future prospects for beef production in Europe — A review. *Asian-Australasian Journal of Animal Sciences*, 31(7), pp.1017–1035.

27. New Age | The Most Popular Outspoken English Daily in Bangladesh. (n.d.). *18 imported cows seized at Dhaka airport*. [online] Available at: https://www.newagebd.net/article/142961/18-imported-cows-seized-at-dhaka-airport [Accessed 18 Mar. 2022].
28. Human Rights Watch. (2019). *India: Vigilante "Cow Protection" Groups Attack Minorities*. [online] Available at: https://www.hrw.org/news/2019/02/19/india-vigilante-cow-protection-groups-attack-minorities.
29. www.vice.com. (n.d.). *Abandoned Bulls Are Killing Motorists in India*. [online] Available at: https://www.vice.com/en/article/gyazgq/abandoned-bulls-cows-killing-people-india [Accessed 18 Mar. 2022].
30. Dikeman, M. and Devine, C. (2014). *Encyclopedia of meat sciences.* Amsterdam: Elsevier/Academic Press.
31. Dikeman, M. and Devine, C. (2014). *Encyclopedia of meat sciences.* Amsterdam: Elsevier/Academic Press.
32. New Age | The Most Popular Outspoken English Daily in Bangladesh. (n.d.). *18 imported cows seized at Dhaka airport*. [online] Available at: https://www.newagebd.net/article/142961/18-imported-cows-seized-at-dhaka-airport [Accessed 18 Mar. 2022].
33. New Age | The Most Popular Outspoken English Daily in Bangladesh. (n.d.). *18 imported cows seized at Dhaka airport*. [online] Available at: https://www.newagebd.net/article/142961/18-imported-cows-seized-at-dhaka-airport [Accessed 18 Mar. 2022].