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Growth of beef cattle as prediction for meat production: A review

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Increased interest in the breeding of beef cows results from the trends of society, especially in the consumption of quality raw materials of animal origin. Breeding of beef cattle is often encountered as part of a modern rural lifestyle. The good growth ability of calves is a decisive factor in the profitability of breeding of suckling cows and decides on the breeder's satisfaction in setting purchase prices. This quantity is expressed mainly by the average daily gains and the live weight of calves under one year of age. In addition to the achieved weight of beef, is very important shaping of individual body parts representing the most valuable meat parts of animal, to which the body measurements of sires must correspond. Weight gains point to the degree of adaptation of a specific breed to the farming conditions. Equally, the genetic basis of an individual influences the achieved weight of animal. Genetic improvement of meat performance depends on breeding programs that exploit genetic variability between breeds and within the breed. Moreover, the breeding conditions and animal handling could influence the increasing of live weight. Breeding efficiency will always be a summary of factors that determine the own cost and the purchase price of weaned calves. In view of the above, this review is focuses on the main intrinsic and extrinsic factors influencing the growth characteristics of different cattle breeds as well as its relationship with slaughter characteristics.

Keywords: body measurements, body weight, breed, factor, growth characteristics

1 Introduction

Natural way of cattle breeding on pastures is acquiring increased public interest derived from current social trends in consuming safe food of high quality. Beef cattle are most commonly bred this way, which is also linked with a modern rural lifestyle, agro tourism and culture. Mentioned reasons linked to require meat of high nutritional quality with favourable price. Bovine meat satisfies these demanding consumers' requirements, especially for its nutritional composition, juiciness and tenderness. Meat producers effort to quantify variability of parameters conveying the quality of the slaughter product allows breeders usage of feeding systems, which lead to the potential of producing meat of required quality whilst satisfying animal welfare. Beef producers may adjust production systems to better monitoring of meat quality, while breeders can preferably use variability among animals, by choosing animals with higher genetic potential for producing meat of greater quality. It is desirable for the final product to show signs of certain quality during the life of the animal, which means using easily measurable biological components that relate to sensory attributes of quality. Many different biological mechanisms take part in expressing meat quality. These mechanisms show joint effects of different production factors (gender, age, breed, feeding, etc.) on sensory attributes (texture, colour, flavour), as well as biological characteristics of muscles (fibres, collagen, enzymes, lipids, etc.; Renand et al., 2001). Manipulation with beef quality for economic advantages requires understanding how factors as muscle type, sex and breed influence the muscle characteristics of a growing animal (Schreurs et al., 2008).

One of the most important parameters of beef production is the growth ability of animals (Toušová et al., 2014). Growth is fundamental and deciding factor

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in meat utility, especially in categories intended for fattening, growth intensity is of deciding importance. Muscle and fat production of slaughter animals is chiefly the result of growth function, thus the average development of an individual consists of a proportion of functional changes in growth, relative bone, muscle and fat ratio (Owens et al., 1995). The growth scale of animal is given by its genetically defined mature weight. Many characteristics of carcasses develop depending on achieved degree of maturity; the breed effect is often the result of differences at maturity. In the final stage of fattening, growth rate becomes an important economical aspect, since it determines feeding amount and length of fattening (Schreurs et al., 2008). Measuring body weight and composition allows for more accurate estimation of nutrients retention, while measuring weight and quality of carcasses allows for better determining economy of production (Owens et al., 1995). To improve not only the production of beef, but carcasses as well, genetic sources are important included differences among breeds. No single one breed excels in every attribute important for meat production (Bartoň et al., 2006). Increase in adult weight and size of cattle is nowadays aim of modern selection programmes. Furthermore, regional preferences of consumers are considered, especially in terms of the eventual product quality. Therefore, the body size, carcass composition, as well as the indicators of beef quality should be considered for regarding the biological relation between these parameters (Albertí et al., 2008).

In relation to the importance of bovine growth for meat production, the aim of this paper was to bring findings about growth intensity of some substantial beef breeds and factors influenced the growth. Concurrently, the review provides findings about slaughter and meat quality indicators, without which the characteristics of bovine meat production would not be complete.

2 Intrinsic factors influenced the growth of cattle

Growth intensity has decisive meaning, with growth function producing muscle and fat. The average development of an individual is dependent on functional changes in growth and ratio of bones, muscles and fat. Quality carcass is characterized by a large amount of muscle mass, minimal amount of bones and a relative amount of fat (Dikeman and Devine, 2004). Economically and production favourable is growth intensity and carcass composition showing in young animals, although the growth and development of young cattle is unequal. Growth intensity is also influenced by age of animal. With increasing age, the growth intensity is decreasing; the consumption of nutrients for weight gain is increasing as well as individual tissues in the body are changing (Bobček, 2002).

The total muscle weight and mass increases until the end of growth in the process of proteosynthesis, as describe Dikeman and Devine (2004). Proteosynthesis is influenced by three factors: changes in muscle fiber (the ratio of individual muscle components changes), hormone-level control mechanisms (somatomedins, thyroid hormones, sex hormones, insulin) and environmental factors (nutrition, age, gender).

Application of the multiphase function allows detailed explanation of the pattern of live weight growth, body size of groups or individuals (Koops et al., 1989). Growth intensity during the ontogenesis is different, while growth allometry indicates the result. Growth allometry expresses the growth rate of tissue or organ in relation to entire growth. According to Fľak and Antal (1980), the allometric function expressing the relation of the specific growth rate of a part of the organism to the growth of the entire organism has a special position in the evaluation of animal growth. Partial growth rate of organs and tissues vary from birth to adult; this change in growth is marked as differential growth. Since the growth of individual organs and tissues occurs at different times, these differences will be manifested by a change in body shapes and proportions of animals. The point at which the weight changes in the animals' fat content can be defined as the mature size (Dikeman and Devine, 2004). As describes Owens et al. (1995), the average fat content of animals´ body at this stage is approximately 25%. Proportional growth was found to be measured as the weight of tissue, organ or part (individual muscles) relative to the entire or the tissue. Huxley (1993) was able to develop a mathematical method for detection of changes in growth of various tissues relative to an entire animal or tissue, which can compare relative growth of animal or tissue on a log scale using eqn:

$$y = bx^k$$

where:

y – tissue weight
b – represents the y intercept
k – the slope or growth impetus

According to the above equation, the allometric growth of body measurements was also calculated by Pontecorvo (1939). Authors found a linear allometric relationship of withers height to the body weight of 6 cattle breeds at the level $a = 0.675–0.785$. Other authors (Kidwell et al., 1952) reported higher level of heritability of the constants "*a*" and "*b*" of this function at body measurements characterizing skeletal development in comparison with measurements related to fleshiness.

Dikeman and Devine (2004) noted that live weight is the most important and most commonly measured parameter, probably because of the importance of weight for marketing. Weighting is important for breeding documentation, growth control and is closely related to utility and cattle size. There are differences in the live weight of cattle in terms of sexual dimorphism (bulls about 100–300 kg heavier), within the day (according to the filling of the digestive and urinary system up to 10%), during transport (weight loss 10–15% over 300 km). Measurements that are determined by the withers height and the body length of the animal may be expressed by an index. A Dimension – weight index is changing during growth of animal with highest value at birth. In terms of sex of animals, males exhibited a higher dimension – weight index than females (Yapp, 1924). Body measurements are important characteristics in dairy cattle as well as in beef cattle (Bene et al., 2007). They are often using to estimate animals´ maturity and other characteristics, i. e. live weight. Moreover, body dimensions can also serve as important selective factors with a relatively high level of heritability.

Growth is influenced by the neuro-humoral system and the production of hormones with different effects on tissue growth. Hypophysis through somatotropic *growth hormone* affects growth and production of proteins, thyroid gland through thyroxine stimulates bones growth and metabolic activity, insulin affects growth and production of proteins and fat, transport of glucose, acetate and amino acids into cells (Dikeman and Devine, 2004). The adrenal medulla hormones, epinephrine and norepinephrine help to mobilize glycogen to provide muscle energy. In addition, their effects also affect muscle protein metabolism and lipid metabolism. Adrenalin can activate certain tissue receptors known as β-receptors, which shift available nutrients away from fat deposition and towards to muscle accumulation (Irshad et al., 2013).

Sex hormones such as androgens and estrogens can affect growth, especially growth and production of proteins and fats; glucocorticoids (cortisol and corticosterone) affect metabolism of carbohydrates, fats and proteins (Dikeman and Devine, 2004). Different growth rate as well as tissue composition are influenced by the sex of the animals, while males grow faster with later maturation. Compare to females, carcasses of males have higher muscularity and less fat content (Isrhad et al., 2013). Muscle growth is stimulated by androgens as increase of protein synthesis, thereby reducing fat deposition. Higher development of the musculature, especially the forequarter, neck and back can be observed in bulls. In addition, androgen and oestrogen stimulate bone salt deposition, which causes increased growth of bones in males compared to females or castrates. In general, oestrogens have minimal effect on skeletal muscle protein synthesis, but are effective in promoting body fat deposition, with their specific effects dependent on puberty and oestrogen concentration (Irshad et al., 2013). The hormonal state of cattle is directly related to the distribution of fats and proteins in muscles (Blanco et al., 2008).

Growth and reproduction as important economic features should be included in each breeding program. Before implemented a selection program, it is necessary to know not only the genetic parameters but also the relationship between them (Chin-Colli et al., 2016). One of the most important tasks of higher productivity in beef production is genetic improvement of growth. Heritability as a proportion of genetic variability to phenotypic variability is still a topical subject of genetics. Heritability, i.e. the heredity of bovine growth attributes, has been estimated in various breeds and populations, traditionally based on pedigree information. This traditional estimate is called "classical heritability" (Ryu and Lee, 2014). Nowadays, powerful genotyping is currently used, and the use of a commercial DNA microarray chip is already routine in identifying genomic association signals for complex phenotypes (Lu et al., 2013).Identification of molecular markers associated with gene expression and growth properties are under great attention (Dikeman and Devine, 2004). Genetic markers are of great importance for indicators of growth and meat utility. As part of the research on genetic markers, efforts have been made to develop genetic maps that allow the use of chromosomal regions and genes for selection. A number of papers deal with the identification of unknown quantitative traits locus (QTL) affecting economically significant properties (Louda et al., 2009). Indicators of meat utility are controlled by an unknown number of genes. Some of these individual genes have a greater effect on the traits than others. The number of QTLs detected for meat quality was found in pigs 4018, cattle 512 and for meat production in pigs 573 and cattle 973. A number of markers that are associated in relation to meat utility are used in commercial tests targeting for certain traits (Knoll, 2010). Table 1 represents selected markers of nucleotides for quantitative traits of cattle associated with meat quality, carcass composition and growth.

The *LIM-homeobox gene 3* (*LHX3*) plays an essential role in the development of hypophysis and nervous system. The *LHX3* transcription and growth abilities in cattle are influenced by sequence variants in coding and non – coding regions of *LHX3* (Huang et al., 2015). The authors found the association of the SNPs 1-6 genotype

Table 1 Selected markers of QTN (nucleotides for qualitative traits) related to meat quality, growth and carcass composition of cattle

Trait category	Gene name	Gene symbol
Meat quality	fatty acid-binding protein 4	FABP4
	fatty acid synthase	FASN
	pituitary-specific transcription factor	*Pit-1* (POU1F1)
	stearoyl-CoAdesaturase	SCD
	thyroglobulin	TG
	calpastatin	CAST
	micromolar clacium activated neutral protease (calpain 1)	CAPN1
Growth, feed intake	fatty acid-binding protein 4	FABP4
	G-protein-coupled receptor 137	GPCR137
	growth hormone	*GH*
	growth hormone receptor	GHR
	growth hormone-releasing hormone	GHRH
	insulin-like growth factor-1	IGF-1
	neuro peptide Y	NPY
	pituitary-specific transcription factor	*Pit-1* (POU1F1)
Carcass composition	*leptin*	LEP
	myostatin (growth differentiation factor 8)	MSTN (GDF8)

Source: Ibeagha-Awema et al. (2008); modified

with body weight at 6, 12 and 18 months of age in the Nanyang breed (*P* <0.01; *P* <0.05). Analysis by Sun et al. (2015) exhibited a strong linkage of SNP T1694A and C2213 G (r^2 >0.33) in the study of the association of *cofilin2* (*CFL2*) polymorphism with growth abilities in Chinese Quinchuan cattle. For adipogenesis and regulation of the expression of fatty acid biosynthesis genes is responsible the *SREBP1c* gene. The level of its expression increases in parallel with the increase in fattening. Growth attributes analysis of Nanyang breed showed significant effect of SNPs in the *SREBP1c* gene on body weight and average daily gain at birth, 6 and 12 months of age (Huang et al., 2010). In the European Piemontese breed, the *C313Y* mutation in the *myostatin* gene responsible for muscularity and tenderness has been demonstrated. The developed double muscling evolves at the age of 3 months and thus does not affect the calving difficulty (Káčer, 2016). Also, *fibroblast growth factor 21* (*FGF21*) can be used as a gene for marker-assisted selection (MAS). This hepatic hormone regulates peripheral glucose tolerance, energy balance and lipid metabolism (Sun et al., 2013). Transcription of this gene in bovine liver is stimulated by *growth hormone* (*GH*), which is thought to be the major regulator of animal growth, development and metabolism (Yokoo et al., 2010). Sun et al. (2013) found the association of SNPs of bovine *fibroblast growth factor 21* with higher body weight after 18 months of age in Nanyang cattle. In adult cattle, weight change is largely due to a change in fat deposition into tissues. *FGF21* is considered as a mediator of fat storage in cattle due to its function in regulating energy homeostasis and glucose metabolism, explaining its association with body weight control. *Leptin* is considered to be a candidate gene in the management of bovine performance, carcass quality and meat quality. The concentration of *leptin* is associated with adiposity and feed intake, therefore the changes in nutrition caused by a change in weaning period can affect both *IGF-I* and *leptin* concentrations and thus change growth and development (Blanco et al., 2009). Liu et al. (2010) reported *melanocortin-4 receptor* (*MC4R*) as the candidate gene for final body weight and carcass weight.

The heritability of most carcass traits is generally moderately high, while technological measures are more heritable than sensory characteristics (Irshad et al., 2013). Growth inheritance level reaches low values (h^2 = 0.12–0.27). As describe in Table 2, heritability of the live weight ranges between 0.10 in age of 6 months and 0.69 in 21 months of age. According to Szabó et al. (2007), the heritability of average daily gains of calves before weaning is h^2 = 0.27 and h^2 = 0.30 at weaning. While evaluating the direct and maternal effects, Duangjinda et al. (2001) found in the Charolais breed at weaning the value

$h^2 = 0.33$ for direct heritability, and $h^2 = 0.15$ for maternal heritability. There is a different correlation between direct and maternal genetic effects (Szabó et al., 2007). Knowing the dependence and correlation coefficient values makes it possible to determine the characteristics that support a particular production (Szabó et al., 2006). Authors Stålhammar and Philipsson (2008) evaluated components of variance according to gender for gains in weaning time and after weaning time in Swedish beef cattle. They found that genetic relationship between the direct effects observed in bulls and heifers was in most cases moderately to highly positive, on average $r = 0.7$. In terms of maternal effects, genetic and environmental, the correlations between genders was highly positive ($r = 0.7$ to 1.0). Bene et al. (2007) reported correlations between live weight and wither height $r = 0.84$ and between live weight and hip height $r = 0.70$.

The slaughter parameters are characterized by medium to high heritability, so they can be significantly influenced by the breed of animal (Irshad et al., 2013). Crossbreeding appears to be as a convenient alternative to change these characteristics because of wide variability between bovine breeds (Albertí et al., 2008). In contrast, dressing percentage, as a proportion of carcass weight from live weight of animal, achieves low to moderate heritability (Irshad et al., 2013; Coleman, 2016). There are differences in dressing percentage values between animals due to changes in digestive fill and weight, fat content in the carcass and other factors which influence the live weight (Coleman, 2016). In comparison with continental European breeds, traditional British beef breeds (Angus, Hereford, Shorthorn) tend to have lower dressing percentage values, because they are early maturing and they carcasses have higher proportion of fat in non-carcass depots (Irshad et al., 2013). Coleman (2016) mentions that the crossbreeding of British or Dairy breeds with European beef breeds, which mature later, potentially increases growth rate of calves as well as dressing percentage and lean meat yield. Albertí et al. (2008) reported significant genetic variation of fat distribution in different parts of the cattle body. According to Casasús et al. (2000) in cattle it will occur also under similar nutritional conditions. When compare beef breeds which transform the nutrient mainly into proteins, dairy breeds with different hormonal and metabolic profile, deposit more intra-abdominal fat (Albertí et al., 2008). Relative to the deposition of subcutaneous fat, large late-maturing breeds (British beef breeds) have more intermuscular fat compare to continental European – small early maturing breeds, which have higher levels of intramuscular fat (Irshad et al., 2013). On the other hand, the differences in the physiological age of breeds at the same chronological age as well as differences in the growth potential between breeds could affect the variability of fat tissue in the body. The development of fat tissue is influenced by multiple factors; a relationship between fatness and breed type is still not clear (Albertí et al., 2008).

Genetics also plays a key role in determining average daily gains (ADGs). In general, continental cattle breeds achieve the required weight faster than other breeds. The expected differences in progeny within the breeds are based on individual genetics and thus overcome the differences in growth rate. Average daily gains can be enhanced by heterosis, with better offspring manifestations compared to parents (Drovers, 2013). Economic efficiency of beef cattle production systems is associated with the body weight and weight gain of cattle (Caetano et al., 2013). Genetic progress in field of body weight and weight gain can be reached by changes in these attributes explained by the additive action of genes and positive genetic correlation between them (Martínez-González et al., 2010). There also exist publications on a positive genetic correlation between sexual maturity and body weight of animals in both – young and adult ages. Due to the favourable genetic

Table 2 Coefficients of heritability of selected bovine growth indicators

Cattle		Coefficient of determination h^2	Range
ADG (prenatal)		0.38	–
ADG from birth to 7 months of pregnancy		0.29	0.27–0.30
Gains in the field test (85.–365. days of life)			
The live weight	6 months	0.31	0.10–0.53
	12 months	0.37	0.30–0.49
	21 months	0.44	0.22–0.69
Withers height	6 months	0.38	0.22–0.56
	12 months	0.51	0.44–0.64

ADG – average daily gain; Source: Krausslich, 1994 association within different age groups of animals, it is possible to improve body weight and weight gain at sexual maturity and reproductive performance of cows through selection for high body weight in young ages of animals (Caetano et al., 2013).

2.1 Maturation of cattle

By the term of physiological age, we mean the stage of development of the animal. Physiological age can be described by identifiable stages of the body development or body function, such as body height and weight, carcass composition or puberty onset. During growth, the composition and shape (form) of the body change dramatically and continually. Moreover, in genotype-dependent variation in carcass composition is stage of maturity an important factor (Irshad et al., 2013). Since different breeds vary in maturity extent and average weight, standardization of body composition measurement (muscle, fat and bone ratio) to the same level of mature body weight (actual weight to expected maturity) leads to much less variation in carcass composition than standardization to the same age or weight (Irshad et al., 2013). The higher weight of weaned calves coming from the crossing of dairy cows with beef sires is likely to reflect higher milk intake due to the impact of the dairy breed. Coleman (2016) found the faster growth rates after weaning of Hereford-sired cross straight-bred Angus steers, which indicate a tendency of crossbreds to grow to higher final weights and possibility of compensating the growth.

The ability of cattle to grow is correlated with the development of the body and the achievement of physical maturity, the calving ease as well as the maternal characteristics of the cow (Szabó et al., 2007). Several authors evaluated the relationship between calving ease and calf weight; they found that live birth weight as well as sex of the calf significantly influences calving difficulty, mainly in primiparous cows (Krupa et al., 2005; Strapák et al., 2000; Hradecká et al., 2000). Whereas the birth weight of calves influences calving ease in primiparous more than 71% and 61% in second calving, it represents one of the main selection criteria (Toušová et al., 2014). The highly significant influence of the year of birth, herd and sex of calves on the live weight at birth and weaning weight, as well as daily gain up to the weaning in the evaluation of Czech Fleckvieh and Beef Simmental crosses were determined by Vostrý et al. (2008). Calving ease statistically significantly influenced the live weight at the level of significance $P < 0.001$ and daily gains at the level $P < 0.05$. The genotype had a significant effect on birth weight. Paputungan and Makarechian (2000) based on their studies conclude that, calves from heavier cows in general, were heavier at birth and had a higher growth rate before weaning. Calves from dams with average body condition score had faster growth than those born to cows with high scores of body condition.

The extent of growth of the animal is determined by its genetically defined mature weight. Mature weight is consistent with lifetime production. For most animals, a sigmoidal growth model is typical for reaching the maturity. However, animals exclusively used for meat production are often slaughtered before reaching the maturity. The slope of the growth curve indicates the growth rate and is usually expressed as the average daily gain (ADG, kg day^{-1}). The cattle with high weight gains produce more muscle fibres with greater glycolytic activity, which contributes to the meat aging processes and hence the tenderness that is considered as an important factor in consumer preferences (Albertí et al., 2008). Growth rate is an important economic aspect in the final stage of fattening, as it determines fattening time and feed quantity. Cattle with smaller body frame usually mature earlier and show slower growth rate at lower mature weight than later maturing cattle (Menchaca et al., 1996, Schreurs et al., 2008). Breeds with higher body weight need more time to reach puberty, so they can reach higher weight before reaching mature size (Papaelo et al., 2015).

2.2 Carcass characteristics associated with growth of cattle

Many carcass characteristics develop depending on the level of maturity reached; the result of differences in maturity is often the effect of the breed (Schreurs et al., 2008). Compared to later maturing breeds in the same age, earlier maturing breeds with smaller body frame are associated with lower muscularity and higher fat content (Schreurs et al., 2008, Scollan et al., 2006). Typical cattle breeds classified as early maturing are Aberdeen Angus, Hereford or Jersey (Table 3). Late maturing breeds are e.g. Limousin, Holstein, Charolais or Beef Simmental. Cattle of a smaller body frame are typically characterized by early adolescence at lighter mature weight, as described in Table 3 (Freer et al., 2007; Schreurs et al., 2008). According to Papaleo Mazzucco et al. (2016) when we compare breeds with different performance (British breeds, Continental breeds and cross-breeds), animals with a smaller mature size (British breeds) are characterized by lighter carcasses with greater fat thickness, smaller ultrasound rib-eye area and percentage of lean muscle at the same live weight.

According to paper of McMurry (2009) the weight of weaned calves is strongly affected by the influence of European breeds but also by using crossbreeding, complementarity and heterosis (McMurry, 2009). Producing calves for fattening and finishing from

Table 3 Standard values for carcass weight (kg) in different cattle breeds

Cattle breed	Cows	Steers	Bulls	Level of maturity
Jersey	400	480	560	early maturing
Aberdeen Angus, Hereford	500	600	700	early maturing
Limousine, Holstein	550	660	770	late maturing
Charolais, Beef Simmental	650	780	910	late maturing

Source: Freer et al., 2007

crossbreeding is nowadays a common practice due to the benefits of obtaining hybrid vigor (Papaleo Mazzucco et al., 2016). The productivity of beef cattle could be increased by utilising a cattle breed which is suited to the environment, mainly in terms of growth rate and carcass production (Albertí et al., 2008; Keane and Moloney, 2009). By means of carcass and meat quality parameters over different production systems, it is possible to estimate the potential value of a biotype (crossbreeds or pure-bred animals) for profitable beef production. Considering the purchase prices of products, the final weight of cattle is important characteristics for beef producers. There is a strong relationship between mature weight of cows and higher growth potential of calves that could achieve valuable carcass and purchase weight at an earlier age. The time required for preparing animal for sale or slaughter is an important economic attribute, hence the overall growth is the best available measure (Papaleo Mazzucco et al., 2016). On the other hand, the most reliable characteristic of animal growth potential is the live weight measured at the target age (i.e. one year old). Also carcass composition depends on the range of target weight and different growth curves of breeds (Albertí et al., 2008).

A quality product with the desired properties can only be produced in herds with high productivity (Bureš and Bartoň, 2012). Higher musculature is typical for European cattle with larger body frame, British breeds are characterized with marbling in meat; and carcasses of Zebu cattle have higher content of connective tissue (Blanco et al., 2008). Traditionally a selection of beef cattle breed or crossing has been on the basis of performance parameters, carcass market value, adaptability to the climate, availability of feedstuffs and personal preferences. However, the nutritional quality has recently received an increased attention, mainly in terms of health safety (Bartoň et al., 2008). For the consumer are important the quality attributes such as meat colour or fat content, which can be result of the combination of breeds or by the selection of an appropriate production system (Albertí et al., 2008). The beef quality and sensory properties are affected by several factors, such as nutrition, slaughter age and weight, slaughter or sex category and pre-slaughter handling (Nogalski et al., 2017).

The genetic background belongs to the most important factors affecting meat quality (Prado et al., 2009). Meat from fairy breeds has been generally considered of inferior eating quality compared to British and European beef breeds (Muir et al., 2000). Nowadays, when dairy cattle is predominant in the cattle population, it is possible to effectively increase the quantity and quality of beef through commercial crossing of dairy cows with beef bulls in order to create herds for the beef production. Commercial crossing results in offspring which have higher fattening performance and higher slaughter quality (Nogalski et al., 2017). Coleman (2016) noted improved growth rate and meat yield of calves from crossbreeding European breeds over Angus or Hereford when compare to pure-bred Angus or Hereford cattle. For the beef calf production on the base of dairy cows, cattle breeds with a high growth potential such as Charolais are used (Bureš and Bartoň, 2012). Charolais cattle as a late-maturing breed could be fattened intensively to heavy body weights (Bartoň et al., 2008). Castration and beef production from steers are a common practice in beef production leader countries; such meat is in high demand (Vieira et al., 2007). Castration also improves the quality of beef by increasing the intramuscular fat content, which is a key determinant of the sensory properties of beef (Hocquette et al., 2010). In the same line, Nogalski et al. (2017) reported higher fat content in carcasses of steers slaughtered at higher body weights. Intensive fattening of steers until 18 months of age resulted in highest weight of most valuable meat cuts. Moreover, castration of the crossbred offspring is associated with lower slaughter weight and a shorter fattening period (Nogalski et al., 2017). Table 4 describe average values of slaughter age, slaughter weight and daily gain of different cattle breeds by several authors. Average daily gains of different breed ranged between 1.03 kg in Limousin cattle (Chambaz et al., 2003) and 1.97 kg in Angus cattle (Albertí et al., 2008).

The optimal slaughter ages and weights differ widely between breed types of cattle, what is particularly characterized by different fat deposition during the

Table 4 Basic slaughter characteristics of different cattle breeds

Breed	Slaughter age (days)	Slaughter weight (kg)	ADG (kg)	Source
Aberdeen angus	597.7	428.6	1.97	Albertí et al. (2008)
	433.7	562.3	1.17	Bartoň et al. (2006)
	381	–	1.30	Chambaz et al. (2003)
	510	662.5	1.23	Bureš and Bartoň (2018)
Charolais	634	460.6	1.53	Albertí et al. (2008)
	526.3	620.7	1.43	Bartoň et al. (2006)
	513	–	1.22	Chambaz et al. (2003)
	630	682.22	0.620	Vavrišínová et al. (2017)
Simental	621.8	455.9	1.49	Albertí et al. (2008)
	515.5	632.4	1.42	Bartoň et al. (2006)
	499	–	1.18	Chambaz et al. (2003)
Holstein	596.3	458	1.18	Albertí et al. (2008)
	515	655.6	1.32	Bureš and Bartoň (2018)
Holstein calves	–	155.0	0.825	Vavrišínová et al. (2010)
	151.80	150.30	0.740	Vavrišínová et al. (2019)
	198.20	179.00	0.710	Vavrišínová et al. (2019)
	203.40	210.00	0.840	Vavrišínová et al. (2019)
Limousin	594	–	1.03	Chambaz et al. (2003)
Limousin crossbreed	541.5	528.12	0.520	Vavrišínová et al. (2017)
Jersey	378.4	414.7	1.08	Albertí et al. (2008)
Hereford	482.5	540.1	1.32	Bartoň et al. (2006)
Fleckvieh	518.7	629.0	1.34	Bureš and Bartoň (2018)
Parda de montaña	309	447	1.65	Balnco et al. (2009)
Pirenaica	322	451	1.66	Blanco et al. (2009)
Gascon	539.7	659.2	1.29	Bureš and Bartoň (2018)
Charolais × simental	408.8	554.3	1.35	Bureš and Bartoň (2012)
	526	698	1.31	Bureš and Bartoň (2012)
Slovak pinzgau	600	471.00	–	Vavrišínová et al. (2009)

finishing period of fattening (Albertí et al., 2008). The slaughter age influences the beef tenderness in a greater extent than the rate of growth; hence later maturing cattle should be fattened to higher weights (Nogalski et al., 2017). When compare different cattle breeds, Holstein cattle tend to have more tough meat than British or European beef cattle, however, differences can be reduced by comparing animals at the same level of maturity or ageing the meat (Muir et al., 2000; Purchas and Zou, 2008). Increased likelihood of intramuscular fat from Jersey cattle results in tendency of Jersey cattle to have tender beef, often more tender than i.e. Angus or Holstein (Coleman, 2016).

Albertí et al. (2008) evaluated 436 young bulls from fifteen Western European breeds (beef, dairy and local types) to assess variability in live weight, total live weight gains, body measurements and carcass characteristics at different ages. They divided cattle into three groups in relation to their carcass characteristics. High meat producing breeds (Piemontese, Asturiana de los Valles, Pirenaica, Limousin, South Devon, Charolais, Aberdeen Angus) characterized by late maturing, short carcasses and high blockiness; animals with average meat production and intermediate characteristics (local and dairy breeds) Whereas breeds Jersey, Casina and Highland – breeds with low meat production corresponded to early maturing with long carcasses and low blockiness. Carcass blockiness index expresses the relationship between length of carcass and hot carcass weight, while high index values indicate the high development of muscularity. Blockiness is reflected in the carcass conformation, which is an important criterion for carcass classification on the European market. Therefore, the carcass blockiness index can be a complementary tool for the classification of carcasses, especially in classifying of different breeds on the same market (Albertí et al., 2008). As noted in Albertí et al. (2005) the increase of blockiness from low to high meat producres in young bulls is rather constant; for the veal-type can be assessed a clear leap from medium to high meat producers. When comparing cattle of different breeds of similar age and with similar management, there are changes in carcass weight, while carcass composition depends on the range of total weights and differences in growth curves of each breed. According to Blanco et al. (2008), carcasses of animals with compensatory growth contain more fat depending on the length of fattening. Hence, compensatory of the growth could influence the tissue composition, while its variability may be originated in the length and quality of the restriction of the feed but also in the age during at restriction, the severity and the duration of restriction. In the weaning period, as describe Blanco et al. (2009) when is a predominance of muscle and bone tissues development, a nutritional restriction could compromise subsequent growth.

Growth parameters are also associated with the final weight and hip height at the end of fattening in feedlot tests (Morsy et al., 1998). Veal carcass quality and models of growth are influenced by different management and feeding conditions, as describes Domaradzki et al. (2017). To evaluate the growth rate and weight of livestock as well as feed utilization and carcass quality, the linear body measurement are used. These linear measurements better reflect animals body proportions than conventional methods of weighing (Essien and Adesope, 2003). Informations about animal weight and changes in weight are a key management tool; thus they are important for determine responses to genetic selection (Lukuyu et al., 2016). Using body linear measurements could be more reliable and offers advantages over subjective methods – weighing or visual assessment and scoring. These methods can be influenced by short-term effects such as urination, defecation or gut fill (Lukuyu et al., 2016). Lukuyu et al. (2016) reported a strong correlation between live weight and heart girth (r = 0.84) as well as body condition score (r = 0.70). Moderate correlation was found between hear girth and body length (r = 0.66). Body weight of livestock as a good indicator of animal condition is an important factor in selection for slaughter, breeding or determining feeding levels (Ozkaya and Bozkurt, 2009). Many authors describe body measurements of cattle as important selection criteria for growth (Van Marle-Köster et al., 2000). There is a relationship between body measurements and body weight, which is influenced by breed of animal, age, utility type, body frame, body condition score or level of fattening. Body measurements are in close correlation with body weight of animal, while heart girth is often describes as best prediction parameter (Ozkaya and Bozkurt, 2009). Authors reported the highest correlation between body weight and heart girth in Brown Swiss cattle (r = 0.95) and body length (r = 0.89). In the same line correlation coefficients in Holstein cattle were 0.78 and 0.69. Evaluation of relationships between growth characteristics in beef cows were reported in Bene et al. (2007). Correlations between live weight and body measurements were moderate to strong positive (r = 0.40–0.83), between age and body measurements moderate positive (r = 0.01–0.46), between body measurements moderate to high positive (r = 0.22–0.81). According to Maiwashe et al. (2002) strong genetic correlation (0.76 ±0.06) between shoulder width and body length indicates, that selection for measurements in shoulder area could lead to rapid progress in body length.

4 Conclusions

Meat performance is influenced by several factors, it is a function of fertility, is carried out in growth and development processes and is characterized by indicators of fattening, carcass value and meat quality. Among the most important factors influencing the growth of cattle above cited authors include internal properties (neurohumoral system, breed, utility type, sex, body frame) as well as external properties, especially length of fattening, nutrition and management. The most significant correlations of growth, carcass and meat quality characteristics were determined between live weight of cattle and heart girth, body length as well as between body weight and age of animal. Nowadays, the analysis of genes associated with gene expression and growth characteristics are of enormous importance in evaluation of meat performance. In beef production system, genetic improvement of cattle growth is currently one of the most important tasks.In addition, attention of geneticists is directed to identifying unknown QTLs associated with meat quality. In determining this area, number of QTLs for meat quality was detected – 4,018 for pork, 512 for beef, 573 for pork meat production and 973 for beef production.

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