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Review on the relationship of feeding various nutrients like energy, proteins and minerals to the growth of animals

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Abstract: Animal growth performance and quality of meat depend on the interactive effects of meat animal genotype, rearing conditions, pre-slaughter handling, and carcass and meat processing. This paper focuses on the effects of feeding. Feed has effect on growth performance of meat animals, carcass composition and meat qualities of meat animals. The feeding level and protein: energy ratio can be used to manipulate growth rate or composition of weight gain. Restricted feed allowance strongly reduces growth rate and carcass fatness and also intramuscular fat (IMF) level, resulting in decreased meat tenderness or juiciness. Expression of compensatory growth due to restricted followed by ad libitum feeding modifies the composition of weight gain at both carcass and muscle levels, and may improve meat tenderness due to higher in vivo protein turnover. Decreasing the protein: energy ratio of the diet actually increases IMF and improves eating quality but gives fatter carcasses in contrast, a progressive reduction in the protein: energy ratio leads to similar carcass composition at slaughter but with higher IMF. Technological meat traits (pH1, pHu, colour, drip loss) are generally not affected by the level or protein: energy in feed. Modification of fatty acid composition and antioxidant level in meat can be obtained through diet supplementations (e.g. vegetable sources with high n-3 fatty acids), thereby improving the nutritional quality of meat animals.
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Introduction

Nutrition is a powerful component of livestock production system that controls several aspects of meat animal growth and carcass yield and quality. Consumer oriented demands in meat quality has motivated the meat producers to concentrate on the nutritional aspects of livestock rearing. The animal feed mostly affects hygienic, sanitary and nutritional characteristics of meat. Particularly, various meat qualities attributes that are affected by the amount and type of nutrient intake of the animal shall include dressing yield, meat: bone ratio, protein: fat ratio, fatty acid composition, caloric value, colour, physicochemical and processing properties, shelf life and sensory attributes.

The effects of feeding level, composition (protein: energy ratio) and pattern (restriction-realimentation) as tools to manipulate growth rate, composition of weight gain, intramuscular fat (IMF) deposition which is often associated with improved meat sensory traits and thereby improved pork quality, are described. Variations in muscle lipid composition and nutritional value of meat through dietary supplementation (fatty acids, antioxidants) are also presented (Wood *et al.,* 2004).

Restricted feeding (up to 35% compared to *ad libitum* feed intake) can be applied to reduce growth rate and thereby increase age at slaughter at a given body weight (BW). A 25% restriction in feed allowance during the growing-finishing period decreases growth rate by about 27% (Lebret *et al.,* 2001). Since body fat deposition rate highly increases with age, in contrast to protein deposition rate which remains almost constant during the growing-finishing period, feed restriction affects more fat than lean tissue deposition when applied during the finishing period. Therefore, restricted feeding leads to leaner carcasses compared with *ad libitum* feeding (Lebret *et al.,* 2001). IMF deposition is also reduced by up to 25% in the m. *Longissimus* of restricted compared with *ad libitum* fed p. Consequently, eating quality can be adversely affected with lower tenderness and juiciness (Ellis *et al.,* 1996) even though some studies do not report any significant effect of feeding level on loin sensory traits (Wood *et al.,* 1996). Muscle fibre type composition and glycolytic potential as well as technological meat quality traits (pH1, pHu, drip loss, colour) remain generally unaffected by feed restriction (Lebret *et al.,* 2001).

The efficiency of meat animals in converting feed into meat is generally related to the level of feed intake, but the relationship is rather complex. Highest efficiency in converting feed energy into body weight is achieved when animals are fed ad libitum. But, if feed energy intake exceeds the amount needed for lean tissue growth, the excess is used for fat deposition. Thus, animals' full-fed high-concentrate diets usually produce more carcass fat, and consequently, are less efficient in converting feed to lean meat than are animals fed slightly below ad libitum energy intake, even though the ad libitum fed animals would be more efficient in total feed energy retention. This is particularly evident in the later growth stages, as muscles and bone approach their mature sizes. Slight to moderate feed restriction is an effective procedure to modify body or carcass composition. The abdominal fat in broilers chicken can be reduced by a 3 to 5 day period of feed restriction, beginning at 5 to 7 days of age. Slight feed restriction of mono-gastric animals, particularly in the later growth stages, will produce leaner animals at slaughter, but limit feeding requires more labor and housing and animals reach acceptable slaughter weight more slowly. The additional cost associated with restricted feeding may surpass the additional value of leaner carcasses. Dietary energy of ruminant animals may be restricted conveniently by including variable amounts of fiber in the diet (Lawrie, 1998). Therefore the objective of this term paper is:

- To understand the important of various feed for meat animals
- To know the effect of feed on meat quality and carcass yield

2. Literature Review

2.1. The Effect of Feeding like Energy, Proteins and Minerals to the Growth of Animals

Growth performance of meat animals, carcass composition, and quality of meat and products depend on multiple interactive effects of genotype (genetic background, presence of unfavorable alleles at the major genes, rearing conditions (feeding level, housing and environmental conditions, production system), pre-slaughter handling, and carcass and meat processing (Terlouw, 2005). This paper focuses on the influences of feeding system on growth performance, carcass and muscle composition of meat animals. The effects of feeding level, composition (protein : energy ratio) and pattern (restriction–re-alimentation) as tools to manipulate growth rate, composition of weight gain and intramuscular fat (IMF) deposition are described. Indeed, IMF proportion is generally associated with improved meat sensory traits (Wood *et al.,* 2004a), even though some studies report only little influence of IMF on the eating quality (Rincker *et al.,* 2008) or show that this positive relationship depends on the ultimate pH classification of the meat (Lonergan *et al.,* 2007). Variations in muscle lipid composition and nutritional value of meat through dietary supplementation (fatty acids, antioxidants) are also presented.

The feeding level (restriction), pattern (restriction–re-alimentation) and the protein: energy ratio of the diet, together with the genetic growth potential of meat animals, determines the growth rate and the composition of weight gain at both whole-body and muscle levels. These factors are therefore used to modify growth rate and/or carcass and muscle composition at slaughter

Restricted feeding (up to 35% compared to ad libitum feed intake) can be applied to reduce growth rate and thereby increase age at slaughter at a given body weight (BW). A 25% restriction in feed allowance during the growing-finishing period decreases growth rate by about 27% (Quiniou *et al.,* 1995; Lebret et al., 2001). Since body fat deposition rate highly increases with age, in contrast to protein deposition rate, which remains almost constant during the growing-finishing period (Reeds et al., 1993), feed restriction affects more fat tissue deposition than lean tissue deposition when applied during the finishing period. Therefore, restricted feeding leads to leaner carcasses compared with ad libitum feeding (Ellis *et al.,* 1996; Wood *et al.,* 1996; Lebret *et al.,* 2001). IMF deposition is also reduced by up to 25% in the m. Longissimus of restricted compared with ad libitum fed animals (Lebret *et al.,* 2001). Consequently, eating quality of meat can be adversely affected with lower tenderness and juiciness (Ellis *et al.,* 1996), even though some studies do not report any significant effect of feed level on loin sensory traits (Wood *et al.,* 1996). Muscle fibre type composition, glycolytic potential as well as technological meat traits (pH1, pHu, drip loss, colour) remain generally unaffected by feed restriction (Candek-Potokar *et al.,* 1999; Lebret *et al.,* 2001).

An adequate and continuous supply of protein is required in animal diets for growth and maintenance of tissues. Proteins are composed of various amounts and kinds of amino acids, some of which cannot be synthesized in animal body. These are called essential amino acids, and must be present in the diet of animal. Every animal has a daily need for dietary protein. Although animals cannot synthesize tissue proteins beyond their genetic potential by consuming excess protein, the rate of growth is readily reduced by an inadequate dietary protein. Growth rate in mono-gastric animals are reduced by an inadequate total amount of protein, a deficiency of any one of essential amino acids in the diet (Lawrie, 1998). But in ruminant animals, amount and quality of dietary protein are less critical than in mono-gastric animals.

In general, as the energy density of the diet increases, either through the use of high quantity grains that replace forages or by adding fat, the growth rate of the animals increase, animals reach slaughter weight at younger age, the resultant carcass is heavier and higher in overall fatness the Percentage of muscular tissue is lower and that of fat higher, in animals of high plane of nutrition than those on a lower plane. When the proteins: energy ratio is increased, the fastest growing animals may become leaner. The meat is juicier and the fat flavor masks the meat flavor of the species Beef carcasses from grain fed cattle are not as susceptible to cold shortening as these fatter, heavier, more muscular carcasses chill slower. Rapid rates of growth have been shown to have higher amounts of collagen solubility in young cattle fed with high concentrate diet concentrate diets to cattle prior to slaughter has a positive effect on structural components of the muscle and results in improved meat palatability. Concentrate diets Improve beef flavour and juiciness.

The meat is brighter and cherry red in color and the fat is whiter. Beef obtained from cattle fed on corn based diets is more desirable in terms of flavour than pasture-fed beef. Flavour deference is due to fatness variation in meat on high plane of nutrition, a greater proportion of fat is synthesized from carbohydrate; and such fat has consequently a lower iodine number (Webb, 2003). High plane of nutrition increases the percentage of intramuscular fat and decreases the percentage of moisture in sheep. There is a progressive diminution in the percentage in the longissimus dorsi as the plane of nutrition is increased in pigs. Low concentration of tocopherol in grain based diets makes the beesusceptibleto auto-oxidatiooxymyoglobin (brighter metmyoglobin) (brown) and decrease colour stabile feeding of high concentrate diets prior to slaughter improves marbling scores and palatability meat from intensively reared young male bull aloes showed a significantly solubility, sarcomerelength, myobrillar fragmentation index, tenderness and connective tissue residue scores but lower collagen, insoluble collagen and shear force value compared to meat from semi- extensively reared spent male and female buffaloes (Webb, 2003).

Dietary fats are used by the animal for energy, and certain fatty acids are essential for growth. They also may be assimilated and deposited as body fat. Composition of deposited fat varies among species. All meat animals are able to synthesize fatty acids and/ or adipose tissue from carbohydrates and proteins, and the fat which is deposited is characteristic of the species. Fats in the diet of mono-gastric animals may assimilate and deposited in relatively unchanged form; whereas, dietary fats consumed by ruminants undergo degradation and synthesis of more saturated fat by rumen bacteria before assimilation and deposition. Carcasses from mono-gastric animals fed a diet containing a specific type of fat will have fat deposits of similar chemical composition to the dietary fat. For example, pigs or chickens fed a diet high in unsaturated diet will have soft, oily carcass fat. However, the rapid turnover of depot fats permits the replacement of deposited fat by dietary changes (Lawrie, 1998).

Dietary protein level and protein: energy ratio Diet composition, particularly the protein: energy ratio can be used to modify the composition of growth and increase IMF deposition. Indeed, feeding pigs ad libitum with protein or lysine-deficient but adequate energy diets during the growing or finishing phases has been shown to increase IMF proportion and improve meat tenderness and juiciness. Growth rate is reduced as a consequence of limited protein or lysine intake. However, back fat thickness or percentage of dissectible fat is also increased, even though the effect is much lower on carcass than on muscle lipid deposition (Castell *et al.,* 1994).

Minerals are needed to build strong bones and teeth and to make blood, muscle, and nerves. Some minerals may need to be supplemented directly in the ration. Salt, calcium, and phosphorus are minerals needed in larger amounts than other minerals. Cattle should have a salt‐mineral box to supply them with the extra minerals they do not get from their feed. This box should be accessible to cattle at all times. Minerals needed in smaller amounts are called trace minerals. Examples of trace minerals are calcium and phosphorus. We eat cheese and drink milk to get calcium and phosphorus. For meat cattle, grass and hay can be a source of calcium, while grains are high in phosphorus (Ellis *et al.,* 1996).

2.2. Effects of feeding on meat yield and quality

2.2.1. Effects on meat quality

Meat quality and yield can be manipulated through feeding but the effects and the directions of the effects depend on the tissues studied, the composition of the feed and feeding regime, the duration of the feeding treatment and the age, sex and physiological status of the cattle fed or treated. Feeding affects the rate of conditioning and consequently carcass composition, conformation, meat yield and meat and fat quality. The effects of feeding on beef quality are generally studied in terms of the content and composition of the lean and fat tissues, and the subsequent effects on the colour, nutrient content (protein, fat mineral and vitamin content), tenderness, aroma, flavour, acceptability and taste of the final product (Webb, 2003).

The effects of feeding on beef quality are generally more significant in terms of the lean colour, while the effects on the protein content and amino acid profile are almost negligible. By contrast, the effects of feeding on beef fat content and composition, including fatty acid composition, n-6/n-3 ratio and conjugated linoleic acid (CLA) content are generally small but highly significant. The dietary effects on beef fat, although small, are often so important in terms of either the nutritive value, colour of the product or quality or consistency of the fat, that it is worth including the feed components or additives in the diet at relatively high costs, provided that consumers are aware of the intrinsic quality and added benefits of the product. This means that beef contains the complete range of essential nutrients (i.e. essential amino acids and fatty acids), while plant sources are often low in one or more nutrient (Webb, 2003), and that modern feeding practices also provide the opportunity to improve the mineral and vitamin content of beef and subsequently the shelf life, keeping characteristics and sensory attributes.

Nutritional effects on beef quality will also depend on the criteria used to evaluate beef quality and will probably be perceived differently by consumers compared to butchers, retailers and wholesalers (Webb, 2003). In a study conducted in Europe it was found that the quality attributes of beef depend mainly on the tenderness and other sensory characteristics, but that consumers base their evaluation of beef quality (intent to purchase) mainly on fat content and colour (Grunert, 1997). Since the perception of fat is generally negative, the positive effects of fat on taste and tenderness are not perceived. By contrast, butchers generally prefer carcasses with moderate amounts of very firm carcass fat (that generally contains a larger proportion of saturated fatty acids), which improves the "cut-ability" of the carcass because it is easy to trim. Carcasses that contain soft fat are more difficult to cut and often result in a greasy appearance, while the fat may even become rancid and result in off flavours. Although off flavours have been reported in beef, it is not common.

It follows that manipulation of meat quality through feeding should be limited to those attributes that are conceivable by consumers and that will contribute to either the intrinsic or extrinsic attributes of beef. Of course improvements in both the intrinsic or extrinsic attributes should be indicated by means of labeling or a specific brand name e.g. "like it lean", because most of the extrinsic attributes are not conceivable, for example consumers will have no idea if cattle were grain fed or reared on pastures, if this is not indicated on the packaging or brand name (Webb, 2003).

2.2.2. Effects of feeding on muscle content and composition

The effect of feeding on the physical properties of muscle is negligible (Forrest *et al.,* 1975), but the growth of animals can be manipulated through the energy and protein content of the diet, which also results in changes in muscle composition (bone, muscle and fat content)(Lawrie, 1998; Lawrence and Fowler, 2002). It is well known that animal performance is improved by intensive feeding. Simmental cattle fed concentrate diets (Sami *et al.,* 2003) had significantly higher growth rates, average daily gains, final body weights and feed efficiencies compared to their pasture fed counterparts. Improvements are usually associated with better carcass conformation scores and a higher carcass fat content, while shear force values often decrease slightly as the time on feed increase. These results agree with those of Maloney *et al.,* (2003). Vestegaard *et al.,* (2000) also reported differences in muscle fibre types (more Type I, IIA and less Type IIB fibres) and a shift towards slow contracting fibres, with better vascularisation and more oxidative metabolism in muscles of pasture fed bulls compared to concentrate fed bulls of ca. 360 kg body weight. These differences were less noticeable at heavier body weights of about 460 kg.

Although the effects of intensive feeding on the sensory characteristics are variable, the tendency is towards marginally higher flavour scores and sometimes slightly lower acceptability scores due to the higher visible fat content of samples, although the effects of fat thickness is rather controversial. In a comprehensive study on this topic (Luchak *et al.,* 2003), it was found that the external fat trim level exerted almost no effect on the palatability traits of beef. Although a popular perception is that the degree of marbling improves the sensory characteristics of beef, the results are also variable, probably because longer feeding periods are required during which time muscle toughness may increase noticeably.

Feeding may affect meat colour (Lawrie, 1998). Muir *et al.,* (1998) reported darker coloured meat in cattle finished on pastures compared to intensively fed cattle, while French (2000) found no difference in the meat colour of cattle of the same age and energy intake regardless whether they were fed grass or concentrates. These conflicting results are mainly due to the fact that meat colour is more dependent on the process of anaerobic glycolysis post-mortem during the normal conversion of muscle to meat. This involves the conversion of glucose reserves in muscle to lactic acid, which accumulates rapidly because the circulatory system is no longer functional. The acidification of muscle increases and pH decreases below the isoelectric point (pH 6.0) where myo-fibrillar protein molecules have no electrical charge, which eventually affects the muscle enzymes, integrity of cell membranes, decrease in water binding capacity, rigor mortis and normal development of meat colour. The rate at which muscle pH decreases is of the utmost importance in terms of the normal development of meat colour.

Feeding affects the glycolytic potential of muscles and consequently the normal conversion of muscle to meat and the red colouration of meat. Stressed, fasted or undernourished cattle will result in a depletion of muscle glycogen reserves, so that the normal decline in muscle pH does not occur, resulting in dark, firm and dry (DFD) meat. The glycogen content of longissimus muscle samples from pasture fed steers is also lower (ca. 63 µmol/g) compared to those from concentrate fed steers (70 µmol/g) (Vestergaard *et al.,* 2000). DFD meat is more susceptible to spoilage and may reduce consumer acceptability (Viljoen *et al.,* 2002). These researchers confirmed that the general appearance, colour and acceptability of normal steaks are preferred to those of DFD steaks, but found no significant differences in the sensory characteristics of fried normal and fried DFD steaks. The prevalence of DFD meat can be greatly reduced by improved management during the finishing, loading and transportation of livestock, as well as better feeding and feed supplements like antioxidants.

By contrast, stress susceptible animals are more prone to a condition resulting in pale, soft and exudates meat. This condition is not common in cattle, but in certain pig breeds stressful conditions like lairage result in abnormally high concentrations of catecholamine's which trigger a rapid depletion of muscle energy reserves, accumulation of lactic acid, fast pH decline and rapid development of rigor mortis (Lawrence and Fowler, 2002). The meat becomes pale in colour and the sensory characteristics are usually undesirable.

The effect of feeding on meat fat

The findings which suggest that the risk of chronic heart diseases is aggravated by the consumption of sugar-rich foods (excessive energy intake) as well as meat and other animal products rich in saturated fat and dietary cholesterol, resulted in a significant effort by the meat industry worldwide to reduce carcass fat content. Unfortunately conventional wisdom has translated "saturated fatty acid" to mean "saturated fat" and that meat fat is all saturated. Webb *et al.*, (1994a; b, 1998; 2003) showed that the saturation levels of red meats vary between 45 and 55%. This means that a moderate consumption of lean meats should not necessarily give rise to dangerously high blood cholesterol levels. Nevertheless, the drive towards improving the fat in beef focused mainly on the following aspects: 1. Reducing the total carcass and beef fat content, 2. Reducing the saturated fatty acid content in beef, 3. Increasing the poly-unsaturated fatty acid content in beef, 4. Increasing the n-6/n-3 long-chain fatty acid ratio of beef fat, 5. Manipulating the cist / trans fatty acid ratio of beef fat, 6. Increasing the CLA content of beef fat.

It is important to note that feeding does not change the body fat composition in ruminants as much as in monogastric animals, but diet-induced changes in the fat composition of ruminants have been reported in ovine and bovine species (Webb *et al.*, 1997). The quantity, quality and composition of ruminant fat may be affected by nutrition, in particular the kind and nature of the cereals, the mode of presentation of the cereals and the kind and presentation of roughage (Webb *et al.,* 1998).

The effect of feeding on the amount of carcass fat of meat

Feeding significantly affects the amount of fat deposited in the carcass. According to Webb (2003), these fats occur in most tissues in the body, but the bulk of it is localized in four important anatomical locations namely internal (inside the body cavity), subcutaneous (all the fat on the external surface of the carcass underneath the skin or m. cutaneus trunci), intramuscular (between muscles) and intramuscular (within muscles). Although the emphasis of beef production is now on the production of edible lean with a minimum of excess visible fat (Forrest *et al.,* 1975), it is certain that fat in meat contributes to eating quality (Wood, 1990).

It is feared that reducing fat to too low levels may adversely affect eating satisfaction. In this regard the media is often to blame for incorrect generalizations regarding the fat content of meat compared to other foods (Webb, 2003). Unfortunately data on the fat content and composition of meat often refer to the carcass rather than the saleable or edible portion of meat. The trimming of carcasses and the removal of excess fat are standard procedures during meat processing. Consumers often remove the remaining visible subcutaneous fat before consumption. It is safe to say that South African beef compares favourable with that from other countries in terms of the amount of carcass and meat fat.

Cattle are fed to different levels of carcass finish in different countries due to different meat grading or classification systems. Marbling (visible intramuscular fat located in the perimysial connective tissues between muscle fibre bundle) is an important quality attribute of beef carcasses in the USA and the best grades are obtained in heavy feedlot cattle (ca. 400 kg carcass weight) with a high carcass fat content (ca. 25 to 30%). South African beef carcasses weigh appreciably less (ca. 220 kg) and therefore contain less fat (ca. 18%) compared to their American counterparts (Webb, 2003).

An increase in carcass fat content often results in a lower polyunsaturated to saturated fatty acid (P/S) ratio, in other words a greater proportion of saturated fatty acids accumulate in the fat depots with fattening (De Smet *et al.,* 2000). When excessive amounts of fat accumulate, the consistency of the subcutaneous fat may decrease again (Wood *et al.,* 2003) due to the accumulation of greater proportions of oleic acid (C18:1). Webb et al. (1997) found that the pelleting of high-maize diets alleviate this excessive accumulation of carcass fat and improves the consistency and colour of subcutaneous fat in sheep, and may also be applicable to beef cattle. These effects are mainly due to improved animal performance and shorter finishing periods in the feedlot. It is therefore possible to manipulate both the amount of carcass fat and also the proportion of polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) simply by feeding animals to a predetermined degree of fatness. This is an important tool available to the beef industry to meet consumers' demands for lean healthy meat.

2.2.5. The effect of feeding on the meat fatty acids

Meat fat quality is determined by the fatty acid composition, which affects the degree of saturation of the fat, the shelf stability and flavour. The chemical and physical properties of fat influence the eating and keeping qualities of meat (Kempster *et al.,* 1982). The interest in fatty acids in relation to consumer health lies in the content of essential fatty acids (EFA's), polyunsaturated/saturated fatty acids ratio (P/S), n-6/n-3 ratio and conjugated linolenic acid (CLA) and cholesterol. The basic EFA's are linoleic (C18:2n-6) and linolenic (C18:3n-3) acids. These fatty acids cannot be synthesized in human tissues but are required for the synthesis of prostaglandins, prostacyclins and thromboxenes. An intake of 1-2% of total calories as EFA is recommended (Mead *et al.,* 1986).

The successful manipulation of EFA's, PUFA's and n-6/n-3 ratio in beef by dietary means has been confirmed in various studies (Wood *et al.,* 2003). Dietary manipulation of PUFA's, eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and CLA's in monogastric animals are quantitatively more significant and practical compared to ruminants, because of the extensive biohydrogenation in the rumen and formation of saturated fatty acids. The disadvantage of meat from monogastric animals is that it contains appreciable amounts of n-6 fatty acids (e.g. high n-6/n-3 ratio, which impact negatively on human health) because they are fed high grain diets rich in linoleic acid.

The proportion and ratio of n-3 long-chain fatty acids in meat have been increased (up to 1g/100g of total fat) by including fish oil (ca. 0,5-2%), fish meal (ca. 150-200 g DM / animal / day) and linsead oil (ca. 0,5-2%) in the diets of cattle and sheep. Vegetable oils may provide a good source of linolenic acid (C18:3n3) like rapeseed oil (7% C18:3n3), canola oil (11% C18:3n3), soybean oil (7% C18:3n3), wheat germ oil (7% C18:3n3), while corn and saflour oils are poor sources of linolenic acid (Raes *et al.,* 2003). Grains contain appreciable amounts of linoleic acid (C18:2n6) which may again increase the n-6/n-3 ratio, which is less acceptable from a health point of view.

Fish oil and fish meal contain high concentrations of EPA and DHA, while linsead oil and forages contain high concentrations of linolenic acid (C18:3n3) compared to other feed sources. Dietary inclusion of these components invariable results in small but significant improvements in the n-3 long-chain fatty acid content of meat the effects of these supplements on the P/S ratio, particularly in the muscle appear to be more variable. PUFA's may be further increased by feeding protected dietary oils by means of the formaldehyde treatment of dietary proteins which protects the PUFA's (Scott *et al.,* 1971). PUFA's may also be increased in ruminant fats by including a mixture of soya oil and linseed oil (2:1 ratio) in the feed (Enser *et al.,* 2001), but this also increased the n-6/n-3 ratio which is not desirable. Unfortunately ruminants are sensitive to the inclusion of high concentrations of unprotected polyunsaturated oils (>5% of diet), which obviously limits the extent to which beef fats can be manipulated. The results of Webb et al. (1998) also suggest that the composition of the subcutaneous fat of feedlot steers is affected by β-agonist treatment.

2.2.6. The effect of feeding on the mineral content of meat

Selenium, iodine, chromium, zinc and copper have been supplemented in the diets of ruminants to improve meat quality. Although the concentrations of these minerals included in the diets may be reflected at a tissue level, the effects on beef quality are variable. This is probably due to the fact that the form (organic vs. inorganic) in which minerals are supplemented affect their biological activity.

The most important effect in terms of meat quality have been observed by supplementing diets with selenium which acts as an antioxidant and generally yields similar results compared to vitamin E supplementation. Again, the effects depend on the animal's nutritional status, type of diet fed, and presence of natural antioxidants like β-carotenes and xanthophylls pigments, as well as interactions with other minerals. Animals with mineral deficiencies like selenium, which result in white muscle disease, often respond well to supplementation. Supplementation of zinc to cattle feeds in either an organic form (Zn proteinate, Zn polysaccharide) or inorganic form (Zn oxide) was evaluated in beef steers, but the effects on meat quality were negligible (Kessler *et al.,* 2003).

2.2.7. The effect of feeding on the sensory characteristics meat

The sensory characteristics of meat are usually described in terms of the aroma, flavour, juiciness, tenderness and acceptability of a specific cut or portion. Different muscles differ in terms of all the above characteristics, but samples of the longissimus muscle are usually used as reference in meat science research. Tenderness is probably the most important quality attributes of beef, but consumers base their evaluation of beef quality mainly on fat content as well as fat and lean colour (Grunert, 1997). Consumers prefer beef with white or creamy fat. Yellow fat is often perceived as indicative of an old, diseased or a dairy type animal (Webb, 2003), which may create serious marketing problems due to consumer resistance. It is interesting to note that these yellow fat pigments may contribute to the typical flavour of meats (Webb, 2003).

As far as meat fat content is concerned, there is definitely more emphasis on the production of lean beef with a minimum amount of excess fat. This noticeable trend continues despite the fact that the fat content in edible lean beef in South Africa is relatively low compared to the USA. Wood, (1990) warned that reducing fat to too low levels might adversely affect eating satisfaction. It appears to be quite difficult to meet the consumer's demands for lean and healthy beef, whilst at the same time provide a consistently tasty product and acceptable eating experience.

Changes in the composition of ruminant fat may contribute substantially to the sensory properties of meat, by mainly affecting the degree of saturation of the fats and the proportion of specific long-chain fatty acids. Kemp *et al.,* (1981) for example, found no definite relationship between the fatty acid content and organoleptic scores of lamb. Westerling and Hendrick, (1979) reported a negative correlation between saturated fatty acids in both the subcutaneous and intramuscular fat with the flavour of beef. However, the fatty acids were not associated with either the juiciness or tenderness of beef.

Oleic acid improved the flavour while both stearic and palmitic acid reduced the flavour of beef M. longissimus muscle. Dryden and Marchello, (1970) reported a negative relationship between palmitic acid and the overall palatability of bovine m. longissimus. The proportion of C18:1 in the subcutaneous fat correlated positively with both the aroma and initial juiciness, while fatty acids of the trans-configuration do not contribute to the sensory properties of lamb (Webb *et al.,* 1994b). These researchers also reported a negative correlation between the aroma of lamb and the ratio of saturated to unsaturated fatty acids. Similar correlations were obtained by Field et al. (1978) and Miller *et al.,* (1980). Wood *et al.,* (2003) found that the concentration of C18:3 (which occurs predominantly in grass lipids), improves the odour and flavour intensity of beef. It is evident that the long-chain fatty acids affect beef quality and that these components can be manipulated through feeding.

Conclusion

This presentation provides an overview of meat quality and quantity and the relationship effect through feeding. Nutrition significantly affects the rate of conditioning and consequently carcass composition, conformation, meat yield and meat and fat quality. In addition to tenderness, the importance of fat quality has increased because it contributes towards the appearance, palatability, nutritive value, processibility, shelf life and ultimately the acceptability of meat. The meat quality attributes are affected by the amount and type of nutrient intake by the animal. Increased energy density of the diet results in heavier carcass, higher fatness and marbling. Feeding lipids rich in polyunsaturated fatty acids enhances conjugated linolenic acid in beef, polyunsaturated: saturated fatty acids and n-6: n-3 ratio in meat animals. Supplemental feeding of nutrients produces heavier carcass, higher dressing percentage, slight increase in fat deposition and desirable organoleptic traits. Feeding of vitamin E improves colour, tenderness, juiciness, oxidative stability and extends shelf life of meat. Feed supplemented with selenium and zinc fairly improves the acceptability and decreases the oxidative rancidity of the meat product. Probiotic feeding in broilers improves protein, water holding capacity, emulsion stability, emulsifying capacity, organoleptic scores and shelf life of the meat products. The meat obtained from β-adrenergic agonists administered animals showed decrease in tenderness due to a lower percentage of heat soluble collagen and rapid maturation of connective tissues. Organic nutrition did not affect the growth performance and carcass quality of meat animals. Thus, animal diet greatly contributes for the quality of meat. Emphasis is increasingly placed on the production of edible lean with a minimum of excess fat, but reducing fat to too low levels may adversely affect eating satisfaction. Beef quality can be manipulated by a variety of nutritional interventions, many of which have been implemented successfully in feedlots world-

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