Consumer Preferences in Meat

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Abstract

This paper addresses some of the requirements of modern consumers for fresh and processed meats. A focus is placed on the sensory quality attributes of meat tenderness, juiciness, flavour and odour and how these relate to the needs of the consumer. At the same time, cognizance is taken of the currentrequirements for healthy and nutritious food products, especially as pertaining to the lipid composition and the salt in the diet.Consumer desires for convenient and ready-to-eat meat products are discussed, as are some important issues surrounding process and/or production characteristics and their relation to animal welfare.

Keywords: meat, preference

Introduction

Animal producers around the world are currently faced with the common challenge of trying to feed the seven billion people on earth with an ever-diminishing supply of natural resources. Not only are there global decreases in the amount of suitable land available for farming, butthere are also a number of other universal hardships being faced, such as extreme weather patterns, degradation of land due to unsound farming practices and increases in zoonotic diseases. The only manner by which the production of meat protein can be increased is for animal producers to become more scientific in their production methodologies. This will almost certainly necessitate an increase in the intensification of animal production systems. Nonetheless, modern consumers are frequently expressing aversions to consuming meat that is derived from an intensive 'factory-like' production system.

The intensification of animal production invariably leads to theprovision of balanced feeds to the animals. This brings the needs of the animals into direct opposition with those of humans, where both would be competing for protein and energy resources such as those typically supplied by cereals and other crops. Additionally, a strong contender for these energy resources is the bio-fuel industry. This has caused many of the feedlot industries to use metabolic enhancers (Dikeman, 2007; Hansen, Frylinck& Strydom, 2012) so as to improve the food conversion

efficiency of the system. On the other hand, the use of antibiotics in feed are a common practice in the poultry industries, and to a lesser extent in the pork industries(Sofos, 2008). The use of stimulants and antibiotics, however, once again leads to mixed perceptions among consumers, primarily since different countries may permit or ban the use thereof.

Another major challenge faced by food producers is to ensure that highly perishable products reach the market in a'safe' manner, with a minimal decrease in quality. A large proportion of the meat production in the world is from regions that are situated far from the market, such as is the case in the South Americas. Such situationsdepend critically on the maintenance of the cold chain throughout transportation so as to minimise post-harvest waste. The transportation of meat across the globe also has implications in terms of the costs and the carbon footprint. The latter, in particular, has led to consumer movements in some first-world countries that promote the purchasing of"locally produced"foods sincethese are perceived to be more sustainable or environmentally-friendly.

Another major socio-economic challenge currently being faced relates to the fact that a large proportion of the world's people do not possess sufficient financial means to purchase high-quality protein sources, such as those produced from animals. In stark contrast, another portion of the world population may have a great surplus of financial resources and these individuals can often be highly critical in their food choices. In the latter case, extrinsic cues such as the carbon footprint and animal welfare issues associated with the production process become increasingly important purchasing drivers (Grunert, 2006) and the more affluent consumers are frequently willing to pay a price premium for their choices (Bennett, Anderson &Blaney, 2002). Although many producers have a strong social responsibility towards feeding the world's population, they are also faced with the reality of having to be economically viable. In other words, farmers will not produce food unless it is economically feasible for them to do so. According to the United Nations Food and Agricultural Organization (FAO), agricultural output will need to increase by 70% by 2050 in order to feed the world's population. Such a forecast will require the production of another billion tonnes of food grain and 200 million tonnes of livestock meat. The key to increasing food production from animals will rely on the improvement of productivity through selectively using genetic technologies to breed for increased animal production criteria (Gao, Zhang, Hu & Li, 2007; Allan & Smith, 2008). These breeding objectives should simultaneously also address welfare-friendly objectives, such as enhanced disease resistance (Thomas, Scollan& Moran, 2011). Other means of fulfilling the predicted requirementsmay include the breeding of animals that are appropriate or well-suited to their environments (Silanikove, 2000;Gregory, 2010; Craine, Elmore, Olsen &Tolleson, 2010; Bell, Charmley, Hunter & Archer, 2011).

Although all indications are that the price of meat as a protein source will continue to increase in the future, the demand for this commodity is also set to increase.

The increase in demand is strongly linked to the huge increase in buying power from China and India. The wealthier consumer, who can afford red meat, is frequently also a well-educated and travelled person who places value on the quality aspects of the meat (Martelli, 2009). However, this perceived quality is multi-dimensional and includes sensory quality, healthiness, convenience and process characteristics like animal welfare and production (frequently 'organic') systems (Grunert, 2006). The pressure on red meat sales due to the worldwide economic recession has caused a reappraisal of the factors which influence its appeal to consumers, which ultimately all comes back down to the quality of the meat. According to Wood, Enser, Fisher, Nute, Richardson &Sheard (1999), some of the factors determining meat quality include the absence of microbial hazards, the prevention of animal exploitation, the sensory appeal of the meat and the perceived healthiness, especially in relation to the amount and type of fat.

Sensory Quality

Irrespective of the purchasing ability of the consumer, each individual inevitably wants to have the best eating experience for their money. In the lower income groups, meat is eaten for its nutritional value, while in the higher income groups it is often consumed for the eating experience itself. In fact, the consumption of meat is seen as a sign of prosperity and wealth. Thus, as the wealth of a community increases, sodoes their meat consumption (Aaslyng, 2009). However, the type and amount of meat consumed is influenced byother factors, such as gender, age and marital status. Men eat more meat in general and a greater proportion of red meat than women (reviewed by Aaslyng, 2009). Additionally, older people typically eat more meat in general and a greater proportion of red meat than children. Families also tend to eat more meat than single people. Interestingly, Aaslyng (2009) notes that less-educated, adult men exhibit one of the highest levels of meat consumption, while young, well-educated women show one of the lowest levels of consumption.

It is self-evident that the traditional manner in which meat is prepared will influence the quality descriptors. A consumer eating a fresh steak will have different quality cues compared to one eating a traditionally dry/smoked or stewed meat product. Although a large amount of research has focused on the quality attributes of fresh meat (typically consumed as steaks), the desire for greater convenience in meal preparation has also resulted in an increase in the consumption of ready-to-eat meat products. The quality attributes of these would also differ and be more focused on perceived healthiness (fat levels, cholesterol, salt concentrations) and ease of preparation and consumption, with time-saving being of essence.

Ultimately, meat is consumed for pleasure. For fresh meats such as steaks, chops and roasts, three sensory attributes are of major importance for the hedonic value of the meat: tenderness, juiciness and flavour (both in the presence of fried flavour and

the absence of off-flavours) (Aaslyng, 2009). These three attributes have received a huge research focus in the past and will continue to receive attention in the future. The value of each characteristic also differs within each situation. For instance, when meat is very tender, then the value placed on juiciness and flavour becomes more important. However, tenderness is the most important of the three. It is now well established that no single factor influences these characteristics, but that it is rather a cumulative effect of a large number of factors that are extrinsic and intrinsic to the animal itself. The modern scientific animal producer will use a number of technologies (such as DNA markers for meat quality traits) and production systems (intensive feedlot that restrict movement thereby minimising the effect of exercise on muscle colour and toughness) to ensure that a fresh product is produced that meets the expected hedonic value deemed appropriate by the consumer. However, it is also known that a number of negative activities along the supply chain could negate these technologies.Of special interest to the modern discerning consumer is the welfare status of the animals in transit to the abattoir (see section 6).

The aforementioned quality characteristics are all applicable to cooked meat. Prior to cooking, the meat has to be purchased and the primary quality characteristic at this time is the visual appearance (colour of the meat). The colour of the meat is determined by numerous extrinsic and intrinsic factors such as the age of the animal, the environment in which the animal was raised (i.e. whether it was exposed to a high level of physical activity), the muscle type, the concentration of myoglobin pigments and then the chemical state of the myoglobin (Mancini, 2009; Mancini &Hunt, 2005). Other factors such as *ante mortem* stress also lead to abnormal colour developments, such as dark, firm and dry (DFD) or pale soft and exudative (PSE) meat. The former is typically associated with the meatfrom ruminants, whilst the latter is more frequent with that from monogastric animals. The stressor that causes these abnormal phenomenon are typically induced by human-animal interactions (Coleman & Hemsworth, 2012), but can also be caused by other factors such as extreme weather fluctuations (King, Wheeler, Shackelford &Koohmaraie, 2009).

After the meat has been purchased and cooked, the next important quality characteristic is the tenderness. This characteristic also plays a very important role in the consumer's willingness to repurchase the same product (Aaslyng, 2009). Although it is well recognised that the age of the animal plays an important role in determining the tenderness of meat (older animals have more heat stable collagen), most animals slaughtered in intensive production units are young adults, of which a large proportion are intact males. Age-induced toughness is thus generally of lessor importance. Other factors such as *ante mortem* stress also play an important role (King *et al*., 2009; Terlouw, Bourguet&Deiss, 2012) in terms of tenderness. When animals experience stress, they frequently try and move away from the stressor,which results in the metabolism of glycogen reserves prior to death. The entire aerobic/ anaerobic metabolism is influenced, causing the*post mortem* lactic acid production

(measured as pH) to deviate from the norm and resulting in either DFD or PSE. This in turnimpactson the activity of the proteolytic enzymes that are responsible for tenderising the meat (Devine *et al*., 2006). Numerous strategies may be applied in an attempt tonegate the decrease in tenderness, includingelectrical stimulation, carcass suspension, chilling regime, aging, use of external enzymes, mechanical, hydrodynamic shock, pressure and *pre-rigor* stretching (Thompson, 2002; Farouk, Wiklund &Rosenvold, 2009). Nonetheless, all of these methods are costly, and the quality of the end product still frequently differs considerably from that expected of the fresh meat product. Of special note in this regardare the *Bosindicus* breeds that are known to have higher levels of calpastatin, the inhibitor for the calpain enzymes, causing the meat from these breeds to be tougher (Shackelford, Koohmaraie, Miller, Crouse & Reagan, 1991; Strydom, 2006).

Juiciness is an important factor in the eating quality of meat, although its importance is determined by the specific meat product being consumed.For instance, juiciness is more important when consuming a steak than it is when consuming that meat which has been cut into small strips for a stew. Whereas *ante mortem* stress plays an important factor in determining the water-binding capacity of fresh muscle (by influencing the rate of decrease of muscle pH as well as the final pH), the main factor determining the juiciness of meat is the end-point temperature during the cooking (Aaslyng, 2009).Increased amounts of intermuscular fat also increases juiciness, especially when the meat is cooked at a high temperature. Aaslyng (2009) noted that the most important factor to increase the juiciness of meat is to educate the consumer on not over-cooking the meat. However, ethnic differences in food preparation also have to be taken into account when addressing this parameter.

The flavour of any meat is a combination of its taste and aroma, which are strongly influenced by additional factors such as mouthfeel and juiciness. Raw meat has hardly any aroma and only a blood-like flavour. During the application of heat, a complex series of thermally-induced reactions occur between the non-volatile components of the lean and fatty tissues (Elmore &Mottram, 2009). Over 1000 volatile compounds have been identified in meat. Elmore &Mottram (2009) reviewed the two main reactions that result in flavour development as meat is cooked. The first is the Maillard reaction, occurring between the reducing sugars and amino acids, and which is responsible for the typical meaty flavour and savoury, roast and boiled character. The second factor is lipid degradation that results in fatty aromas typically found in cooked meat. Inevitably, it is also the fat composition that is responsible for the flavour and aroma differences between species (Wasserman & Talley, 1968).

The diet has a strong influence on the fatty acid composition of animals, especially when considering monogastric animals. In ruminants, the rumen microorganisms in the digestive system have a major impact on the composition of fatty acids leaving the rumen for absorption in the small intestine (Jenkins, 1993; Doreau&Chilliard,

1997). Microbial enzymes derived from *Butyrivibriofibrisolvens*are responsible for the isomerisation and hydrolysis of dietary lipids and the conversion of unsaturated fatty acids (UFA) to various partially and fully saturated derivatives, including conjugated linoleic acid (CLA: C18:2 cis-9, t-11) (c), trans vaccenic acid (C18:1 t-11) (VA) and stearic acid (C18:0). Althoughlinoleic (C18:2 n−6) (LA) and linolenic (C18:3 n−3) (ALA) acids are the main UFA in the diet of ruminants, the processes occurring within the rumen ensure that the major fatty acid leaving the rumen is C18:0. The uptake of UFA into the small intestine by ruminants is similar to that in non-ruminant animals, but differs in the case of saturated fatty acids (SFA) (Bauchart, 1993). The intestinal absorption co-efficient of individual fatty acids is higher in ruminants than in non-ruminants, ranging from 80% for SFA to 92% for polyunsaturated fatty acids (PUFA) in conventional low fat diets. The higher absorption efficiency of SFA by ruminants has been attributed to the greater capacity of the bile salt and lysophospholipidmicellar system to solubilise fatty acids, as well as the acid conditions within the duodenum and jejunum (pH 3.0–6.0). The low pH is due to a low concentration of pancreatic hydrogen carbonate which reduces the conversion of SFA into insoluble calcium salts (which cannot be absorbed by the enterocytes). However, triacylglycerol resynthesis in ruminants takes place via the glycerol-6-phosphate pathway due to the virtual absence of 2-monoacylglycerol. The resynthesized lipid is carried as lipoproteins, chylomicrons and very low density lipoproteins (VLDLP) in the blood stream for uptake by the lipoprotein lipase enzyme and incorporation into the tissues. An important difference between non-ruminant and ruminant animals is that in the latter, the long chain PUFA, C20 and C22, are not incorporated to any great extent into triacylglycerols, but instead are incorporated into the membrane phospholipids and will be deposited in significant amounts in the intramuscular tissue (Enser, Hallett, Hewett, Fursey& Wood,1996; Offer, Marsden, Dixon, Speake& Thacker,1999).

Healthiness

The past number of years has been characterized by an increase in consumer interest in their nutrition and health, which has resulted in the development of health directives by governments for some food components, especially fats (Simopoulos, 2001).

Beef, Lamb and mutton contain high concentrations of SFA, so much so that their PUFA:SFA ratio is lower than the recommended minimum value of 0.45 for human diets. The excessiveconsumption of food with a high proportion of SFA is a major predisposing factor to the risk of coronary heart diseases (CHD), hypertension, stroke, diabetes and obesity in humans, which has led to a worldwide decline in red meat consumption (Webb, Casey & Van Niekerk,1994; Moloney, Mooney, Kerry & Troy, 2001). Although the relationship between dietary fat and the in-

cidence of diseases associated with the modern lifestyle are widely documented, especially CHD (Kritchevsky, 1998, 2000) and various cancers (Wood et al., 2003), this has also been challenged in the past few years (McAfee et al., 2010). As an example, in a meta-analysis and review of epidemiological cohort studies, no independent association could be found between the consumption of animal fat and breast cancer (Alexander, Morimoto, Mink & Lowe, 2010). The low PUFA:SFA ratio of ruminants is a consequence of the extensive biohydrogenation of ingested PUFA by the rumen microorganisms, leading to the formation of trans-MUFAs and SFA, which are then incorporated into the lipids in the muscle (Jenkins, 1993).

The degree of saturation of animal fats is influenced by its fatty acid composition (Webb & Casey, 1995). Accordingly, the quality of fat is determined by the fatty acid composition, which affects the palatability and shelf life. As mentioned, a shift in fatty acid composition can be induced by means of dietary manipulation, which will subsequently enhance the nutritional quality of red meat and fat quality. Dietary manipulation strategies are also available that minimise biohydrogenation of ingested PUFA in the rumen (Chikunya, Demirel, Enser, Wood, Wilkinson & Sinclair, 2004).

Another aspect that has been the focus of consumer attention as pertaining to red meat is the level of sodium (Na), due to its correlation with high blood pressure. Epidemiological studies indicate a positive association between excessive intake of Na, blood pressure and prevalence of hypertension (Appel et al., 2006). However, the Na levels in fresh meat are low. Rather, it is frequently the high levels of salt (NaCl) that are added to many processed meats consumed in the western diet that leads to an elevation in the Na levels. However, consumers are generally not always able to distinguish between the Na in fresh meat and that in processed meat.

Convenience

Within the current sophisticated world, the purchasing behaviour of the consumer has changed. Typically in an economically vibrant society, time isofpremium value and the modern consumer prefers the purchasing of a convenient product. This product should either be a ready-to-eat (RTE) one or it shouldbe packaged in such a manner that it requires minimal preparation time.The food industry has largely addressed this consumer desire by developing and producing a variety of RTE products which are now widely marketed in retail outlets across the globe. Since RTE products generally require minimal processing on the part of the consumer, the safety standards for these are normally stringent and are most often addressed by the implementation ofa strong HACCP (Hazard Analysis Critical Control Points) plan in most manufacturing facilities. In addition, a number of novel packaging strategies have been developed to extend the shelf-life of RTE products, such as modified atmospheric packaging (McMillin, 2008).

With food safety and transparency in mind, most countries have nowenactedfood labelling regulations that require that certain information be displayed on packaging, which includes (but is not limited to) a full ingredient list, nutritional composition data,recommended daily allowances (RDAs), as well as the declaration of certain common allergens.A great deal of research, however, has shown that consumers frequently experience difficulty in understanding much of the information presented on food labels (Shannon, 1993; Sadler, 1999; Kempden, 2011). When individuals do not understand labelling or information overload arises, they tend to avoid the presented information altogether (Kaswell&Padberg, 1992) and food labels become an ineffective information source and do not serve as successful purchasing drivers (Kempden, 2011).

New innovative mobile phone technology now allows consumers to selectively acquire additional information on certain characteristics of food products, and in so doing, assists with their interpretation of food labels. Using such applications, individuals are able to scan food product barcodes in store using their cellular phones and they can thereafter browse information relating to the nutritional composition of the product, the farm of origin, the carbon footprint and other pertinent content relating to animal treatment and environmental sustainability. Another technological trend geared towards convenience is shopping on-line, which permits consumers to choose which products they wish to purchase without going into the store.

Although there has undoubtedlybeen an increased preference for convenience foods, there has also been a recent consumer trend towards the purchasing of 'home-grown'or 'locally-produced' products, typically from weekend markets or farm-stalls. The driving ideology behind this trend is that'home-grown' and 'local' is best, with all attributes linked to the modern concepts of organically-produced, carbon foot print and so forth, which encompasses not only the production system but also the value chain as pertaining to transport and packaging. Underlying the purchasing of these products is a belief that they are healthy and safe to consume (Gellynck, Verbeke&Vermeire (2006), which may not always be the case, especially where there are no authorities to ensure that the necessary regulations are adhered to.

Process/production characteristics

The response to animal welfare is largely a citizen response based on extrinsic and intrinsic cues (Grunert, 2006). However, there are an increasing number of consumers who are willing to pay more for a product that is perceived to have been produced in an ethical manner, that includes accepted standards and norms as pertaining to animal welfare (Bennett *et al*., 2002; Napolitano, Girolami&Braghieri, 2010). Of course, the credibility of the authentication authority is of utmost importance as pertaining to the consumer's willingness to pay for the product being endorsed (Martelli, 2009; Van Loo *et al*., 2011). Animal scientists, food scientists and consumers all have different

ideas and perceptions onthe definitions ofmeat quality.There are unquestionably certain congruencies and divergences between producers and consumers (Sepúlveda, Maza&Pardos, 2011), indicating that the flow of information between these two ends of the value chain requires further development. To an animal scientist, quality would be linked to production performance, wherethe welfare aspects would be underwritten by the following five basic principles: adequate air, water, and feed; safe housing and sufficient space; appropriate complexity of the environment; regular supervision and effective health care; sensible handling. On the other hand, for a food scientist, quality would be linked to aspects measurable in the product, such as pH, colour, chemical composition as well as sensory characteristics. For the consumer, the following major dimensions have been identified which are considered as being relevant to the quality of animal products: sensory characteristics, including taste, odour, appearance, texture; healthiness, as animal-based foods are associated with their composition; intake of essential nutrients but these are also frequently deemed as potentially impairing human health (e.g. source of saturated fatty acids, vector of infections or pollutants); convenience, concerning the ease of preparation; and process characteristics, dealing with the way food products of animal origin are obtained, including farming systems, even though these aspects may have no effects on the other quality dimensions (Grunert, Beach-Larsen &Bredal, 2000). Each dimension aims to satisfy consumer purchase motives or values within the corresponding context (Grunert, 2006).

The animal producer is well aware that if they were to abide by the basic principles of animal welfare, the production performance of the animals would be improved. In dairy cattle, for instance, close human interaction with the animal will result in better milk yield (Hemsworth, Coleman, Barnett, Borg & Dowling, 2002). In young gilts, a positive experience with the stockperson will result in larger litter sizes (Hemsworth, Barnett, Coleman & Hansen, 1989), however, an important aspect in this regard would be the animal-stockperson interaction and the attitude of the latter to animals (Hemsworth, 2003).It is therefore in the best interest of the producer to ensure that the animal is comfortable and has all its needs addressed. It is also well known that the animal welfare, especially as relating to the *ante mortem* stress experienced by an animal, will result in a decline in meat quality (Mach, Bach, Velarde& Devant, 2008). However, in the developing world in particular, producers frequently have no inputs into the value chain of the animal leaving the farm *en route* to the abattoir, nor do they have any input on the activities associated during the offloading, lairage and ultimately stunning and killing of the animal.Hoffman and Lühl(2012), for instance,noted that there were numerous factors contributing to the stress (bruising) of cattle during theirtransportation in Namibia that were outside the control of the producer. Additionally, Hoffman and Fisher (2010) found that the condition of the roads influenced the stress experienced by pigs *en route* to the abattoir. Similarly, Huertas*et al*. (2010) also reported that the conditions of the

road influenced the level of bruising and thus the welfare of cattle transported to slaughterhouses in Uruguay. Alam*et al*. (2010) found that the treatment of cattle and spent water buffalos in Bangladesh at the point of sale and during the transport to the abattoir did not adhere to animal welfare guidelines. Most of the welfare malpractices noted was caused by others along the process/value chain and not the producer.It is of further interest to note that as from 1 January 2013, all countries exporting meat into the EU will have to meet the requirements of Council Regulation (EC) No 1099/2009 (2009), which includes requirements in the following areas: the layout, construction and equipment of slaughterhouses, handling and restraining of animals and stunning and slaughter (Cassidy, 2012).

In some cases, the modern marketplace itself places requirements on the producers that are actually detrimental to the animal's welfare, for example, the regulations found in most countriesrequiring that cattle be identified prior to being slaughtered. This practice results in the excessive handling of cattle during mustering in Namibia where the animals need to be hot branded for ownership identification (Hoffman &Lühl, 2012). In the review by Gregory (2008), it was concluded that the additional handling imposed by checking livestock passports needs to be reconsidered and that the use of remote animal identification methods may help solve animal welfare problems associated with the reading of ear tags. For the modern consumer, the idea of a wet market where live animals are kept and slaughtered in public is abhorrent, not only from the perceived inhumane treatment of the animals, but also from the beastiality response invoked when the animal is butchered in public. Gregory (2008) expands on the welfare issues related to wet markets such as excess handling and rudimentary care.

Conclusion

It is clear that as the profile of the modern consumer changes, their requirements for fresh meat and meat products are concurrently modified. Today, more emphasis is being placed on the ethical production of meat and it effect on the environment. Fortunately for the animal producer, ethical production and treatment for animals is positively correlated with good welfare practices. To meet the increasing global demand for animal protein, producers will need to become more scientific in their production systems – even when farming extensively. An area where there will be a rapid increase in the near future will be the genetic selection of animals to ensure that their performance meets the requirements of the consumer.

References

Aaslyng, M.D., 2009. Trends in meat consumption and the need for fresh meat and meat products of improved quality. In: Improving the Sensory and nutritional

quality of fresh meat. (eds) Kerry, J.P. & Ledward, D. Woodhead publishing Limited, CRC Press, Cambridge, England. pp. 3-18.

Alam, M.R., Gregory, N.G., Uddin, M.S., Jabbar, M.A., Chowdhury, S. &Debnath, N.C., 2010. Frequency of nose and tail injuries in cattle and water buffalo at livestock markets in Bangladesh. *Anim.Welf*.,19, 295-300.

Allan, M.F. & Smith, T.P.L., 2008.Present and future applications of DNA technologies to improve beef production.*Meat Sci.*, 80, 79-85.

Alexander, D.A., Morimoto, L.M., Mink, P.J. & Lowe, K.A., 2010.Summary and meta-analysis of prospective studies of animal fat intake and breast cancer. *Nutr. Res. Rev.* 23, 169-179.

Appel, L.J., Brands, M.W., Daniels, S.R., Karanja, N., Elmer, P.J. & Sacks, F.M.,2006. Dietary approaches to prevent and treat hypertension: A scientific statement from the American Heart Association. *Hypertension*, 47, 296-308.

Bauchart, D., 1993. Lipid absorption and transport in ruminants. *J. Dairy Sci.,* 76, 3864–3881.

Bell, A.W., Charmley, E., Hunter, R.A. & Archer, J.A., 2011.The Australasian beef industries - Challenges and opportunities in the 21st century.*Anim. Front*., 1(2), 10-19.

Bennett, R.M., Anderson, J. &Blaney, R.J.P., 2002. Moral intensity and willingness to pay concerning farm animal welfare issues and the implications for agricultural policy.*J. Agric. Environ. Ethics*, 15, 187-202.

Cassidy, T., 2012.Equivalency between EU and non-EU countries regarding animal welfare at slaughter.*Anim. Welf*. 21(S2), 147-148.

Caswell, J.A. &Padberg, D.I., 1992.Toward a more comprehensive theory of food labels.*Am. J. Agr. Econ.*, **74**, 460–468.

Chikunya, S., Demirel, G., Enser, M., Wood, J.D., Wilkinson, R.G. & Sinclair, L.A., 2004. Biohydrogenation of dietary n-3 PUFA and stability of ingested vitamen E in the rumen, and their effects on microbial activity in sheep.*Brit. J. Nutr.* 91, 539-550.

Coleman, G.J. &Hemswortjh, P.H., 2012.Human-animal relationship at sheep and cattle abattoirs.*Anim. Welf.*, 21(S2), 15-21.

Craine, J.M., Elmore, A.J., Olsen, K.C. &Tolleson, D., 2010.Climate change and cattle nutritional stress.*Glob. Change Biol*., 16, 2901-2911.

Devine, C.E., Lowe, T.E., Wells, R.W., Edwards, N.J., Edwards, J.E.H., Starbuck, T.J. & Speck, P.A., 2006. Pre-slaughter tress arising from on-farm handling and its interactions with electrical stimulation on tenderness of lamb.*Meat Sci*., 73, 30-312.

Dikeman, M.E., 2007. Effects of metabolic modifiers on carcass traits and meat quality.*Meat Sci*., 77, 121-135.

Doreau, M. &Chilliard, Y., 1997.Digestion and metabolism of dietary fat in farm animals.*Brit. J. Nutr.*78 (Suppl. 1), 15S-35S.

Enser, M., Hallett, K.G., Hewett, B., Fursey, G.A.J. & Wood, J.D., 1996.Fatty acid content and composition of English beef, lamb and pork at retail.*Meat Sci.* 44, 443-458.

Elmore, J.S. &Mottram, D.S., 2009.Flavour development in meat. In: Improving the Sensory and nutritional quality of fresh meat. (eds) Kerry, J.P. & Ledward, D. Woodhead publishing Limited, CRC Press, Cambridge, England. pp. 111-146.

Farouk, M.M., Wiklund, E, &Rosenvold, K., 2009. Carcass intervention and meat tenderness. In: Improving the Sensory and nutritional quality of fresh meat. (eds) Kerry, J.P. & Ledward, D. Woodhead publishing Limited, CRC Press, Cambridge, England. pp. 561-604.

Gao, Y., Zhang, R., Hu, X. & Li, N., 2007. Application of genomic technologies to the improvement of meat quality of farm animals.*Meat Sci.,* 77, 36-45.

Gellynck, X., Verbeke, W. &Vermeire, B., 2006. Pathways to increase consumer trust in meat as a safe and wholesome food. *Meat Sci.,* 74, 161-167.

Gregory, N.G., 2010. How climatic changes could affect meat quality. *Fd Res. Int*., 43, 1866-1873.

Gregory, N.G., 2008. Animal welfare at markets and during transport and slaughter. *Meat Sci.,* 80, 2-11.

Grunert, K. G., Beach-Larsen, T.&Bredal, L., 2000. Three issues in consumer quality perception and acceptance of dairy products.*Int. Dairy J*., 10, 575-584.

Grunert, K.G., 2006. Future trends and consumer lifestyles with regard to meat consumption.*Meat Sci.,* 74, 149-160.

Hansen, S., Frylinck, L. & Strydom, P.E., 2012. The effect of vitamin D3 supplementation on texture and oxidative stability of beef loins from steers treated with zilpaterol hydrochloride. *Meat Sci.,* 90, 145-151.

Hemsworth, P.H. ,2003. Human-animal interactions in livestock production.*Appl. Anim. Behav. Sci.*, 81, 185-198.

Hemsworth, P.H., Barnett, J.L., Coleman, G.J. & Hansen, C., 1989.A study of the relationship between the attitudinal and behavioural profiles of stockpersons and the level of fear of humans and reproductive performance of commercial pigs.*Appl. Anim.Behav. Sci*., 23, 301-314.

Hemsworth, P.H., Coleman, G.J., Barnett, J.L., Borg, S.& Dowling, S.,2002.The effects of cognitive behavioral intervention on the attitude and behaviour of stockpersons and the bahavior and productivity of dairy cows.*J. Anim. Sci*., 80, 68-78.

Hoffman, L.C. & Fisher, P., 2010.Comparison of the effects of different transport conditions and lairage times in a Mediterranean climate on the meat quality of commercially crossbred Large White x Landrace pigs. Journal of the South African Veterinary Association, 81, 225-227.

Hoffman, L.C. &Lühl, J., 2012. Causes of cattle bruising during handling and trans-

port in Namibia. *Meat Sci.,* 92,115-124.
Huertas, S.M., Gil, A.D., Piaggio, J.M. & van Eerdenburg, F.J.C.M., 2010. Transportation of beef cattle to slaughterhouses and how this relates to animal welfare and carcase bruising in an extensive production system.*Anim.Welf*., 19, 281-285.
Jenkins, T.C., 1993. Lipid metabolism in the rumen.*J. Dairy Sci.* 76, 3851-3863.
Kempden, E., Bosman, M., Bouwer, C., Klein, R. & van der Merwe, D., 2011.An exploration of the influence of food labels on South African consumers' purchasing behaviour. *Int. J. Consum. Stud.*, 35, 69–78.
King, D.A., Wheeler, T.L., Shackelford, S.D. &Koohmaraie, M., 2009.Fresh meat texture and tenderness. In: Improving the Sensory and nutritional quality of fresh meat. (eds) Kerry, J.P. & Ledward, D. Woodhead publishing Limited, CRC Press, Cambridge, England. pp.61-88.
Kritchevsky, D., 1998. History of recommendations to the public about dietary fats. *J. Nutr.*128, 449S-452S.
Kritchevsky, D., 2000. Antimutagenic and some other effects of conjugated linoleic acid.*Brit. J. Nutr.* 83, 459-465.
McAfee, A.J., McSorley, E.M., Cuskelly, G.J., Moss, B.W., Wallace, J.M.W., Bonham, M.P. &Fearon, A.M., 2010. Red meat consumption: An overview of the risks and benefits. *Meat Sci.* 84, 1–13.
McMillin, K.W., 2008. Where is MAP going? A review and future potential of modified atmospheric packaging for meat. *Meat Sci*., 80, 43-65.
Mach, N., Bach, A., Velarde, A. & Devant, M., 2008.Association between animal, transportation, slaughterhouse practices, and meat pH in beef.*Meat Sci.,* 78, 232-238.
Mancini, R.A., 2009. Meat Colour. In: Improving the Sensory and nutritional quality of fresh meat. (eds) Kerry, J.P. & Ledward, D. Woodhead publishing Limited, CRC Press, Cambridge, England. pp. 89-110.
Mancini, R.A. & Hunt, M.C., 2005.Current research in meat colour.*Meat Sci*., 71, 100-121
Martelli, G., 2009. Consumers' perception of farm animal welfare: an Italian and European perspective. *It. J. Anim. Sci*., 8 (S1), 31-41.
Moloney, A.P., Mooney, M.T., Kerry, J.P. & Troy, D.J., 2001. Producing tender and flavoursome beef with enhanced nutritional characteristics. *Proc. Nutr. Soc.* 60, 221-229.
Napolitano, F., Girolami, A. &Braghieri, A., 2010. Consumer liking and willingness to pay for high welfare animal based products. *Trends Fd Sci.&Techn*., 21, 537-543.
Offer, N.W., Marsden, M., Dixon, J., Speake, B.K. & Thacker, F.E., 1999. Effect of dietary fat supplements on levels of n−3 polyunsaturated fatty acids, trans acids and conjugated linoleic acid in bovine milk. *Anim. Sci*., 69, 613–625.

Sadler, M., 1999.UK industry guidelines on nutrition labelling to benefit the consumer.*Nutr. Food Sci.*, 1, 24–28.

Sepúlveda, W.S., Maza, M.T. &Pardos, L., 2011. Aspects of quality related to the consumption and production of lamb meat. Consumers versus producers.*Meat Sci.,* 87, 366-372.

Shackelford, S.D., Koohmaraie, M., Miller, M.F., Crouse, J.D. & Reagan, J.O., 1991. An evaluation of tenderness of the longissimus muscle of Angus by Hereford versus Brahman crossbred heifers.*J. Anim. Sci*., 69, 171-177.

Shannon, B., 1993. Nutrition labelling: putting the consumer first. *Brit. Food J.*, 96, 40–44.

Silanikove, N., 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livest. Prod. Sci*., 67, 1-18.

Simopoulos, A.P., 2001. n-3 fatty acids and human health: defining strategies for public policy. *Lipids* 36, S83-S89.

Sofos, J.N., 2008. Challenges to meat safety in the 21st century.*Meat Sci.,* 78, 3-13.

Strydom, P.E., 2006. Do indigenous South African cattle breeds have the right genetics for commercial production of quality meat? *Meat Sci*., 80, 86-93.

Terlouw, E.M.C., Bourguet, C. &Deiss, V., 2012.Stess at slaughter in cattle: role of reactivity profile and environmental factors. *Anim. Welf.*, 21(S2), 43-49.

Thomas, C., Scollan, N. & Moran, D., 2011. A road map for the beef industry to meet the challenge of climate change—A discussion document. *Anim. Front.*, 1(2), 6-9.

Thompson, J.M., 2002. Managing meat tenderness.*Meat sci*., 62, 295-308.

Van Loo, E.J., Caputo, V., Nayga Jr., R.M., Meullenet, J-F. &Ricke, S.C. 2011. Consumers' willingness to pay for organic chicken breast: Evidence from choice experiment. *Fd Qual. Pref*., 22, 603-613.

Wasserman, A.E. & Talley, F., 1968.Organoleptic identification of roasted beef, veal, lamb and pork as affected by fat.*J. Food Sci.,* 33, 219-223.

Webb, E.C., Casey, N.H. & Van Niekerk, W.A., 1994.Fatty acids in the subcutaneous adipose tissue of intensively fed SA Mutton Merino and Dorper wethers. *Meat Sci.* 38, 123-131.

Webb, E.C. & Casey, N.H., 1995.Genetic differences in fatty acid composition of subcutaneous adipose tissue in Dorper and SA Mutton Merino wethers at different live weights.*Small Rum. Res.* 18, 81-88.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Richardson, R.I. &Sheard, P.R., 1999.Manipulating meat quality and composition.*Proc. Nutr. Soc.* 58, 363-370.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R. &Enser, M., 2003. Effects of fatty acids on meat quality: a review. *Meat Sci.* 66, 21-32.