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Organic meat quality

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Abstract: The present chapter briefly describes the international basic standards in use for the organic farming of meat animals. The situation of the two main organic meat markets (viz. oversupplies in EU and fast growth in USA), where demand and supply are both developed, and the potential development in other countries, where the internal demand is limited and the production is export-oriented, is then examined in terms of commercial value, number of meat animals, price premiums for farmers, and price to consumers. Consumer price represents the main limit to the expansion of organic meat purchasing; possible strategies to overcome this constraint are also discussed. An ample discussion is dedicated to the effects of organic farming (e.g. extensive rearing system, appropriate breed and feeding based on pasture) on meat quality (e.g. pH, colour, instrumental texture, sensory tenderness and flavour) and on differentiation from conventional products. Finally, we describe safety problems possibly arising in conventional meat (e.g. hormone, antibiotics and other growth promotants administration), and in organic products (limited use of conventional medicine to prevent and cure bacterial and parasitic infections). The reasons for possible increased healthiness of organic meat are also illustrated.

Key words: organic farming; organic meat quality; organic meat market; organic meat safety; organic meat healthiness.

17.1 Introduction

17.1.1 Organic standards

Intensive systems allow the production of meat at relatively low prices. However, for consumers from western countries price is not the only determinant behind animal-food purchases as they are acquiring an increasing interest in other aspects concerning farming practices and related to product safety (Verbeke and Viane, 1999), animal welfare (McInerney, 2004) and environmental pollution (McCarthy *et al*., 2003). Currently, public concern is particularly centered on factory-farm methods of raising and slaughtering animals for meat production, which represent the main production system in Europe and North America, and are also accounting for most of the market in the developing countries, including Brazil, Malaysia, the Philippines, Thailand, etc. These methods are considered responsible for public health threats, such as avian flu, mad cow disease and dioxin contamination, ecological problems concerning air and water pollution, loss of livestock genetic diversity, and massive instrumentalisation of animals into short-lived production machines (Verhoog *et al*., 2004).

As a response to the increasing demand for products responding to these new societal needs, the International Federation of Organic Agriculture Movements (IFOAM) was founded with the aim to coordinate the international network of organic agriculture organizations. IFOAM in 1980 developed the first basic standard for organic agriculture, which has been repeatedly revised and updated. Such standards have the broad objective of bringing agricultural and animal production practices back to the principles of sustainability. In particular, farming should not rely on external feeds, and manure production should not exceed the absorption capability of the agricultural ecosystem. In addition, the ethological needs of the organically farmed animals should be respected in order to allow the expression of their natural behaviour.

Considerable variation among organic standards of different European countries induced EU to promulgate a common Council Regulation (EC 1804/1999) on organic farming (European Communities, 1999) which implemented the general Regulation EEC 2092/91 on organic agriculture (European Communities, 1991). The EU Regulation had an important impact on the harmonization of international organic standards within and outside Europe, as all countries willing to export to EU need to meet the European standards. However, an analysis of different national and international standards shows that, although many aspects are similar (limits on non-organic feed, prohibition of growth promoters, prohibition of drugs in absence of disease), there are still a number of areas where harmonization is needed (housing, grazing areas, withholding periods for drugs, conversion time, age at weaning, nose ringing of pigs, etc.). In general, EU standards are more detailed than standards from the USA, developed within the National Organic Program (NOP) in 2002, or from Australia. In addition, the EU Regulation pays more attention to the animal ethological needs as compared to other international standards (Schmid, 2000). Variation among different standards can also be observed on general principles. IFOAM standards focus more on management, with the aim to promote health and welfare of the animals by respecting their physiological and ethological needs (IFOAM, 2002). Conversely, Codex Alimentarius, as issued by Food and Agriculture Organization (FAO), is more environmental oriented and gives the animals a role in closing the nutrient cycle, improving soil fertility through their manure, and controlling weeds through grazing (FAO, 2001). These differences may result in variations in specific aspects, which may limit the trade of organic meat.

17.1.2 Organic meat market

North America and Western Europe account for 95% of the world retail sales of organic food products, at US$ 13 and 10.4 billion, respectively. Although consumer interest is growing in other regions, the demand is confined to the industrialised world largely because of the price premium of organic products. Many developing countries have large sections of their populations below the poverty line, and this makes it difficult for a market of organic products to develop (Willer and Yussefi, 2004). Rapid economic growth in countries such as China, Brazil, and South Africa is causing the upper social classes to expand, and this is creating a market for organic food. Most production in Asian and African countries will be for export markets, although regional markets are also developing.

The Western European market for organic meat was traditionally the largest in the world; however, it has now been equalled by North America. The European market has faced rapid expansion since the mid 1990s and is now reporting slowing growth rates as certain sectors approach maturity.

The average European expenditure rate on organic products is US$ 27.2 per annum, ranging from US$ 7.3 (Spain) to US$ 105 (Switzerland) *per capita*.

In 2003, EU, including 15 countries, certified non-dairy cattle (mainly suckler cows) amounting to about 1 million heads, corresponding to 1.7% of total non-dairy cattle herd (European Commission, 2005). Austria ranked first with 25% of EU, followed by Italy with 15%. Certified pigs amounted to 450 000 heads, mainly located in Germany and France, while organic broilers were more than 9 million (France ranked first). Organic sheep and goats amounted to 2.4 million. They were located mainly in the United Kingdom and in Italy. According to Hamm *et al.* (2002), beef had the highest market share (1.7%) followed by sheep and goat meat (0.7%), pork (0.3%) and poultry (0.3%).

Only little and partial information is available on prices for organic meat and meat products as prices diverge depending on the country and on the product. For instance, farmer price for organic pork in 2002 was about 2.46 €/kg on EU-15 average. Price premiums for organic pork in EU were about 62%. Consumer price for organic pork cutlet was about 13.17 €/kg but differed considerably between the 15 member states. The high divergence in consumer prices and price premiums often reflects the different sale chains used, e.g. consumer prices usually are much higher in organic food shops than in supermarket chains. Similarly, there was a considerable variability among the 15 Member States in farm gate prices for beef as well as in consumer prices for minced beef (European Commission, 2005).

The North American market for organic products is reporting the highest growth worldwide. The meat sector is the fastest growing organic food industry, with sales expanding by 51% in 2005 (Organic Monitor Ltd., 2006). High market growth rates have led to organic meat supply shortages, with producers unable to meet growing demand from retailers. The organic beef and pork markets are the most affected because of low production levels. Although production has increased since 2004, supply is expected to lag behind demand for a number of years. As a consequence, prices are rising for a range of organic meat products and an increasing number of North American processors are looking overseas for supplies, particularly from Latin America, Australasia and Canada. Although organic beef has the fastest growing market, organic poultry, and broilers in particular, is the most widely available in North America (nearly two-thirds of this sector). The relatively short production cycle and low price premium are responsible for organic chicken being the most popular organic meat with consumers. USA retail sales of organic poultry were US$ 161 million in 2005, well under 1% of conventional poultry sales. However, retail sales of organic poultry are rapidly growing (Nutrition Business Journal, 2006). Prices for organic broilers from July 2004 through early 2006 ranged from US$ 1.89 to US$ 2.45, while average prices for conventional broilers varied from US$ 0.59 to US$ 0.82 per pound (Oberholtzer *et al*., 2006). Organic beef, in comparison, is more rarely found in retailers because of small-scale production, and inadequate distribution infrastructure, although the success of competing products such as 'natural' beef is decreasing. USDA (United States Department of Agriculture) rules for 'natural' beef are less strict than those for organic products: antibiotics, hormones and animal by-products are banned but conventional feedstuffs are allowed. In USA the number of certified animals in 2005 was over 36 000 beef cows, 10 000 hogs and pigs, 4400 sheep and lambs, and over 10 000 000 broilers.

The Argentine government has established national standards for organic products. These are at least as stringent as those of IFOAM and the European Union. The organic industry in Argentina is mainly export oriented (85% by value is exported, with an estimated value of US$ 32 million). The European Union is the principal destination of Argentina's organic beef exports. Meat exporting began in the mid 90s with beef, and more recently Patagonian lamb became the predominant export for international markets. In 2002, there were 754 000 and 122 000 certified sheep and cattle, respectively, in Argentina. However, a domestic market is being developed in Buenos Aires (Willer and Yussefi, 2004).

Elsewhere, both Brazil and Uruguay are seeking to develop exports of organically produced meat (Willer and Yussefi, 2004). In the case of Brazil, organic beef production systems are being developed in the centre of the country. The authorities in Brazil see the organic production system as a way of boosting local cattle producers' income, while reducing the environmental damage that traditional methods of cattle raising have caused. While 90% of Brazil's overall organic production is exported, Brazil's internal market for organic foods is growing at around 25% a year.

Although the Australasian continent comprises almost 40% of global organic farmland, with 12.1 million hectares, the market represents a fraction of the global total (Willer and Yussefi, 2004). Sales of organic products were estimated at about US$ 200 million in 2002, with Australia comprising the most. Beef cattle farmers use much of the organic farmland in Australia as pastureland. The Australian and New Zealand organic food industry is export-oriented, with significant quantities of primary products, including beef and lamb, going to other northern hemisphere countries and relatively low amounts sold in the domestic market. However, sales of organic products within Australia are growing at about 15 to 20% per annum.

Although trade liberalisation may be removing tariff barriers, exporters are finding it increasingly difficult to meet supply gaps because of the differences in organic standards between regions.

17.1.3 Willingness to buy organic meat

Food quality is not an objective feature of the products as it is affected by consumer perception, and it is often referred to as perceived quality. Many aspects can be used by consumers to make their food choices. Intrinsic (e.g. cut, colour, fat rim) and extrinsic cues (price, origin, stamp of quality, production and nutritional information) are used to form expectations about product quality attributes. The latter can be classified in two categories: those experienced before or during consumption (experience quality attributes, e.g. price and sensory properties) and those not experienced directly, such as healthiness, naturalness and ethical aspects, which have to be communicated in order to be perceived as they are credence characteristics that cannot be confirmed either before or after purchase (Grunert *et al*., 2004).

According to a recent on-line survey (ACNielsen, 2005), organic alternatives are purchased mainly for health reasons (respondents thought that organic foods were healthier for them and their children). European people seemed to be more conscious of the wider benefits of organic foods, such as protecting the environment and animals. As to the barriers to purchasing organic alternatives, availability and credibility were considered a problem. However, the general sense among consumers who would not buy organic products was that they were usually more costly.

Meeting organic certification requirements usually implies higher production costs. For example, it is reported that the cost of producing organic beef in the United Kingdom is 20% higher than that for conventional methods. In some cases, the high cost of converting to organic meat and dairy production has led to subsidies being paid to the farmer. However, this is not the case in many countries (e.g. USA and developing countries). Thus, the extra production costs have to be paid by consumers.

Provision of information about the manufacturing process (e.g. organic v OGM) can affect acceptability (Caporale and Monteleone, 2004) and consumer willingness to pay (Lange *et al*., 2002), thus providing a means to cover the extra production costs sustained by organic farmers. The price that people are willing to pay is the major determinant of the market share of organic meat. Although intent to purchase depends upon the interactions of quality attributes such as appearance and colour (Brewer and McKeith, 1999), organic labelling has been found to have a more consistent effect as compared to some sensory characteristics on the price offered by consumers for organic pork (Dransfield *et al*., 2005). Using questionnaires on organic foods in Spain, consumers appeared to be prepared to pay about 12% more for organic red meats and chicken (Gil *et al*., 2000). In France and The Netherlands, questionnaire responses suggested that almost half of consumers would pay 20% more for pork from pigs raised outdoors (Carpentier *et al*., 2004), whereas Dranfield *et al*. (2005) suggested that people from different European countries would offer 5% extra for organic pork.

Meat is usually commercialised as undifferentiated product. Food differentiation can be based on both product and process characteristics. For animal-based products, such as meat, the process characteristics may be represented by the farming practices and the related organic standards. However, these characteristics are not easily evaluated or experienced by consumers, which indicates the need for a special, constant and reliable quality signalling system, given to consumers through appropriate information in order to motivate them and increase their willingness to buy and pay for organic meat (Bredahl, 2004; Grunert *et al*., 2004).

Another element favouring the spread of organic meat into the general retail sector is that purchasers of organic food tend to be in the higher income segment (FAO, 2002). Consequently, supermarkets seek to attract such customers by providing a wide range of food, including organic meats. The increased involvement of supermarkets, with their centralised systems of purchasing and distribution, may result in pressure to reduce the current price differential between organic and conventional products.

17.2 The quality of organic meats as compared to conventional products

Organic rules markedly affect farming practices, which in turn can influence meat quality. This section will provide information about the effects of the main aspects covered by organic standards on the quality of meat obtained from the major farmed animal species (Table 17.1), in relation to the corresponding conventional products. However, in many studies, the overall production system was considered; thus the effects of single factors, such as rearing system, diet or genetic type, could not be precisely separated. For instance, Walshe *et al*. (2006) compared organic and conventional beef samples gathered from the retail market; thus the effect of the entire organic chain was evaluated. These authors found similar sensory characteristics in the two products. Combes *et al*. (2003a) compared rabbit meat obtained from organic and conventional production systems which were different for several aspects including housing, feeding and breed. In this study, trained panel members were able to distinguish the organic product from the conventional one, indicating that the former was more tender.

17.2.1 Rearing system

Organic rules promote the use of pasture and outdoor areas, while indoor space allowance is, in general, higher as compared to conventional/intensive systems.

Organic broilers housed in an indoor pen with access to a grass paddock show lower growth performance and lower amounts of abdominal fat compared with conventional birds housed in indoor pens (Castellini *et al*., 2002a). This is

Table 17.1 Effects of the main aspects covered by the organic standards on meat quality characteristics

Property	Animal		Outdoor/Grazing		Forage based diet		Rustic breed
IMF	Pigs	–	Olsson *et al*., 2003; Millet *et al*., 2004	–	Hansen et al., 2006		
	Broilers					+/–	Fanatico *et al*., 2005
	Cattle	–	Vestergaard *et al*., 2000a; Realini *et al*., 2004	+/–	Marino *et al*., 2006		
L*	Pigs	–	Bridi *et al*., 1998	+	Millet *et al*., 2004	+/–	Oliver *et al*., 1994; Enfalt *et al*., 1997
	Broilers	+	Castellini *et al*., 2002			–	Fanatico *et al*., 2005
	Cattle			+/–	French *et al*., 2000		
WHC	Pigs	–	Olsson *et al*., 2003			+/–	Oliver *et al*., 1994; Enfalt *et al*., 1997
	Broilers	–	Castellini *et al*., 2002			–	Fanatico *et al*., 2005
	Cattle	+/–	Realini *et al*., 2004	+/–	Marino *et al*., 2006		
pHu	Pigs	–	Enfalt *et al*., 1997; Olsson *et al*., 2003	–	Millet *et al*., 2004		
	Broilers	–	Castellini *et al*., 2002			+	Castellini *et al*., 2002
	Cattle			+/–	Marino *et al*., 2006	+/–	Campo *et al*., 1999
Flavour	Broilers					+	Fanatico *et al*., 2006
	Cattle	+/–	Realini *et al*., 2004	+/–	Marino *et al*., 2006	+	Braghieri *et al*., 2005
WBS	Pigs	+	Olsson *et al*., 2003				
	Broilers	+	Castellini *et al*., 2002			+	Fanatico *et al*., 2005
Tenderness	Cattle			+/–	Marino *et al*., 2006	–	Braghieri *et al*., 2005
	Pigs			–	Hansen *et al*., 2006		
	Broilers					–	Fanatico *et al*., 2005
Crude protein content	Cattle			+/–	Marino *et al*., 2006		
	Pigs	+	Olsson *et al*., 2003				
	Broilers	+/–	Fanatico *et al*., 2005				
	Cattle			+/–	Marino *et al*., 2006	+/–	Fanatico *et al*., 2005
Mineral content	Pigs	+	Olsson *et al*., 2003				
	Broilers	+	Castellini *et al*., 2002			–	Fanatico *et al*., 2005
	Cattle	+	Nielsen and Thamsborg, 2005	+	Marino *et al*., 2006; Nielsen and Thamsborg, 2005	+	Braghieri *et al*., 2005
PUFA/CLA	Pigs	+	Nilzen *et al*., 2001	+	Nilzen *et al*., 2001; Oksbjerg *et al*., 2005		
	Broilers		Castellini *et al*., 2002	+	Castellini *et al*., 2002		
	Cattle	+	Yang *et al*., 2002; Descalzo *et al*., 2005	+	Yang *et al*., 2002; Descalzo *et al*., 2005		
Antioxidents	Pigs	+	Nilzen *et al*., 2001	+	Nilzen *et al*., 2001; Hogberg *et al*., 2002		

+: increase; –: decrease; +/–: no effect.

probably due to increased activity (Lewis *et al*., 1997), which also makes animals calmer and less sensitive to environmental stressors.

In general, free-range pigs display increased carcass lean meat contents (Enfalt *et al*., 1997; Sather *et al*., 1997) and decreased back fat thickness (Warriss *et al*., 1983) because of both higher energy requirements to maintain body temperature and higher levels of exercise performed in outdoor areas. However, different results were obtained by other authors: although organic pigs were kept in ample outdoor areas, their carcasses had lower lean meat percentages and thicker back fat than the corresponding conventionally grown animals (van der Wal *et al*., 1993; Bridi *et al*., 1998; Olsson *et al*., 2003). Such different results are not necessarily in conflict as in the latter experiments the higher fatness may be explained on the basis of the higher energy content of the feed formulated according to organic standards, in combination with a rather mild climate during the production period. Enhanced physical activity may also cause shorter carcasses in organically grown pigs (Enfalt *et al*., 1993; Millet *et al*. 2004).

The organic production system may result in a decreased technological meat quality. Meat of organically raised broilers (Castellini *et al*., 2002a) and pigs (Sather *et al*., 1997; Enfalt *et al*., 1997; Olsson *et al*., 2003; Millet *et al*., 2004) had lower ultimate pH (pHu), higher drip and cooking losses and higher shear force values than conventionally grown animals. Exercise may also negatively affect beef, with higher shear values and reduced taste (Vestergaard *et al*., 2000b).

The lower pHu of the organic chickens could be due to a lower consumption of glycogen as a consequence of reduced sensitivity to pre-slaughter stress of animal kept in good housing conditions (Castellini *et al*., 2002a). The same effect was observed in outdoor reared pigs. Enfält *et al*. (1997) attributed this result to the capacity to utilise substrates other than glycogen during transport to the slaughterhouse. Increasing the pig physical fitness by spontaneous activity performed in ample outdoor rearing areas may determine adaptations of muscle metabolism, leading to increased aerobic capacity (Petersen *et al*., 1998). These adaptations are glycogen sparing (Henckel *et al*., 2000; Petersen *et al*., 1997). In fact, it has been shown that moderate physical activity during growth can increase the pre-slaughter glycogen content of muscle (Essen-Gustavsson *et al*., 1988). Accordingly, other studies displayed higher energy levels in the *Longissimus dorsi* of outdoor raised pigs at slaughter (Barton-Gade and Blaabjerg, 1989; Enfält *et al*., 1997). In addition, it has been shown that very high levels of vitamin E in the fresh grass that is frequently associated with outdoor rearing, may increase muscle glycogen stores (Lauridsen *et al*., 1999). Lower pHu can shrink myofibrils, reducing their water-binding ability and increasing light scattering (Castellini *et al*., 2002a). Furthermore, this condition can reduce the importance of myoglobin in selectively absorbing green light, resulting in less red and more yellow meat. However, other studies found no differences in the rate and extent of pH decrease post mortem (Dufey, 1995), while the changes observed in water-holding capacity were explained by the slightly changed muscle characteristics and early post mortem metabolic events of the exercised outdoor animals (Nilzen *et al*., 2001). In fact, recent studies suggest that pHu accounts for a small part of the ability of meat to retain water

(Schafer *et al*., 2002), while a high glycogen content in itself may negatively affect water-holding capacity by the ability to bind water released during post mortem glycolysis (Fernandez, 1991). Conversely, in outdoor organically raised rabbits, higher pHu and improved loin tenderness in comparison with conventionally reared indoor animals were observed (Combes *et al*., 2003b).

Outdoor raising may have diverging effects on meat colour and haem pigment levels, as some authors found no influence of exercise (van der Wal *et al*., 1993; Enfalt *et al*., 1993), whereas in more recent studies, increased space allowance and grazing induced a darker meat colour in young bulls (Vestergaard *et al*., 2000a) and pigs (Bridi *et al*., 1998). Nuernberg *et al*. (2005) also observed that bulls fed on grass-based systems, including pasture, showed a colour of muscle darker than concentrate-fed animals. These latter results are generally attributed to the increased activity of grazing animals (Millet *et al*., 2004; Priolo *et al*., 2001) leading either to high levels of myoglobin in the muscle (Shorthose and Harris, 1991) or to a greater frequency of Type II A than Type II B fibres or to an increased mean fibre cross-sectional area (Petersen *et al*., 1998). Occasionally, the meat from free-range pigs has been found slightly paler or less red than that from conventionally raised animals (Sather *et al*., 1997).

The higher shear and bite resistance value as well as the lower sensory tenderness observed in organic pig meat (Danielsen *et al*., 2000) either with (Enfalt *et al*., 1997; Sather *et al*., 1997) or without (van der Wal *et al*., 1993) lower intramuscular fat can be due to the higher physical activity of the animals. The same effect has been observed in broilers as a consequence of a lower stocking density (Farmer *et al*., 1997). The higher shear force values of organically produced meat may be due to the slower daily growth rate, which can cause a slower protein turnover in the muscle of more extensively raised animals, making their muscular tissue more difficult to tenderize during post-mortem storage (Nielsen and Thamsborg, 2005). In addition, collagen can adapt to functional demands such as physical activity, and a tendency towards increased amounts of heat stable collagen has been reported in the *Longissimus dorsi* of pigs performing physical exercise (Petersen *et al*., 1997). Combes *et al*. (2003a) documented that collagen content is similar or slightly higher in organic outdoor rabbits than in confined animals, while the heat-solubility of collagen is not modified by the rearing system. However, differences in tenderness between organic and conventional meat may be very subtle as neither a descriptive sensory panel, nor a consumer preference test, could discriminate organic from conventional pig meat (Olsson *et al*., 2003; Millet *et al*., 2005). These results suggest that other factors, such as genetics, and slaughter age and procedures might interfere and prevail in determining the final product tenderness.

High space allowances and grazing are deemed to be related to high energy expenditure and low fatness (Enfalt *et al*., 1997; Sather *et al*., 1997). Accordingly, Olsson *et al*. (2003) and Millett *et al*. (2004) observed that, despite a higher energy content in the feed and a lower estimated lean meat percentage for organically raised pigs, intramuscular fat was lower in this product than in that obtained from conventionally raised animals. Nevertheless, no general rule concerning the influence of the outdoor rearing system on intramuscular fat content can be proposed because of confounding factors such as climatic conditions, level of space allowance, genotype, feeding level and diet composition offered to the animals. For instance, the meat of free-range or organic pigs may contain less intramuscular fat levels (Enfalt *et al.*, 1997; Olsson *et al.*, 2003) than the meat of indoor animals, while increased (Lebret *et al.*, 2004) or similar (van der Wal *et al.*, 1993) intramuscular fat levels may be observed in pigs from semi-outdoor housing systems as compared to indoor rearing. An increase in intramuscular fat level can enhance consumer acceptability of pork (Fernandez *et al.*, 1999b), as several studies suggest a favourable relationship between intramuscular fat, juiciness and tenderness (Hodgson *et al.*, 1991; Fernandez *et al.*, 1999a).

A higher crude protein content and lower water/protein ratio seems to be one of the more consistent characteristics of meat from pigs raised in a more extensive way (Dworschak *et al.*, 1995; Enfalt *et al.*, 1997; Olsson *et al.*, 2003). Another consequence of alternative production systems on meat chemical composition is the higher ash (Olsson *et al.*, 2003) and mineral (zinc, copper and iron) contents (Dworschak *et al.*, 1995), as the metal binding capacity of proteins may be higher in the muscles of pigs kept outdoors as compared to conventionally raised animals. In addition, higher iron content may be associated with the higher myoglobin levels often observed in the muscles of exercised and organically reared animals (Shorthose and Harris, 1991).

17.2.2 Feeding

Major differences with conventional/intensive systems include the assumption of spontaneous or cultivated fresh forages at the pasture, higher forag- to-concentrate ratio, the prevalent use of organically-produced ingredients, and the ban of synthetic amino acids, antibiotics and growth promoters as feed ingredients. The effects of these latter two aspects will be discussed in the subsequent paragraph.

A higher nutrient content in organic crops has been observed in comparison with conventional feed. The latter may contain more water, thus causing nutrient dilution (Worthington, 1998). A higher crude protein content in organically produced feed may determine reduced intramuscular fat contents in organic pigs (Olsson *et al.*, 2003; Essen-Gustavsson *et al.*, 1994).

When animals can benefit from an outdoor area, energy requirements for activity and thermoregulation will increase. Hence, they may require a feed with a higher energy-to-amino acid ratio. However, the main problem in non-ruminant nutrition is the difficulty in finding protein sources with a well-balanced amino acid pattern. The exclusion of synthetic amino acids has to be compensated for by other protein sources; for instance, the use of grain legumes has been suggested (faba beans, peas and lupines) for pigs (Sundrum *et al.*, 2000). Although weight gain and feeding efficiency may be reduced, no amino acid supplementation (Sundrum *et al.*, 2000) or the consumption of diets with low protein-to-energy ratios (Blanchard *et al.*, 1999) favour the production of meat with high intramuscular fat, which is an important positive aspect of eating quality characteristics (Fernandez *et al*., 1999a). According to Millet *et al*. (2006), in the diet of finishing pigs protein content has limited effects on meat characteristics. Thus, in this phase, reduced lysine levels, compared with those used in conventional pig diets, may be fed to organic pigs without relevant consequences on meat quality (Millet *et al*., 2006).

In ruminant nutrition, protein sources alternative to soya bean (faba beans, peas and lupines) are being studied in order to minimise the risk of GMO contamination. Preliminary results indicate that faba beans did not change colour, water-holding capacity (Sodo *et al*., 2007), chemical composition, tenderness and cooking loss (Ragni *et al*., 2006) of beef, whereas the use of lupin induced a lower intramuscular fat as compared to soya bean based diets (Ragni *et al*., 2007).

A restricted concentrate feeding plus *ad libitum* roughages resulted in lower intramuscular fat and slight lower tenderness in pig meat (Danielsen *et al*., 2000; Hansen *et al*., 2006). The decreased tenderness of meat from the restricted-fed pigs may be due to a reduced daily gain, which results in slower muscle growth, slower protein turnover and lower meat proteolytic potential (Therkildsen *et al*., 2002).

Higher levels of roughage and larger intakes of fresh grass can determine changes in the fatty acid profile of intramuscular and depot fat, resulting in higher ratios of unsaturated to saturated fat. A marked effect of grass-based diets was observed in organic beef cattle (Nielsen and Thamsborg, 2005), lambs (Enser *et al*., 1998), free-range reared pigs (Dufey, 1995; Nilzen *et al*., 2001; Oksbjerg *et al*., 2005; Hansen *et al*., 2006), broilers (Castellini *et al*., 2002a) and rabbits (Pla *et al*., 2007). These effects on fatty acid composition could depend either on high roughage intake or on restricted feeding leading to leaner carcasses (Oksbjerg *et al*., 2005). A leaner meat, in fact, has a higher proportion of phospholipids that are richer in polyunsaturated fatty acids (PUFA) and particularly in C20 and C22 fatty acids (Elmor *et al*., 1999). An improvement in fatty acid composition of bovine muscles, with a higher polyunsaturated to saturated ratio, was also found in Podolian young bulls fed with a higher forage-to-concentrate ratio in the diet according to EC-Regulation 1804/1999 (Marino *et al*., 2006). In addition, meats from cattle (French *et al*., 2000; Yang *et al*., 2002; Realini *et al*., 2004; Nielsen and Thamsborg, 2005) and lambs (Santos *et al*., 2002) fed large amounts of roughage, or fed on pasture, have a higher content of conjugated linoleic acid (CLA), an intermediate product of ruminal biohydrogenation, with beneficial effects on human health (Pariza *et al*., 2001).

However, an increased amount of PUFA in muscles can make meat more susceptible to lipid oxidation. Meat from organic broilers shows higher 2-thiobarbituric acid reactive substances (TBARS) values in comparison with conventional products (Castellini *et al*., 2002a; Lawlor *et al*., 2003).

Thermal and oxidative degradation of unsaturated fatty acids yield a number of carbonyl compounds that influence flavour (Griebenow *et al*., 1997). Carcasses from beef slaughtered directly from pasture can have a grassy flavour that may derive from the action of ruminal microorganisms breaking down chlorophyll (Griebenow *et al*., 1997). However, finishing of steers with large amounts of roughage had only minor detrimental effects on eating quality as compared to finishing with barley *ad libitum*, so it is questionable if the consumer can taste any differences (Andersen *et al.*, 2002).

The lower lipid stability of the meat from organic animals may be also due to the higher content of metallic ions (total and haem Fe) catalysing peroxidation (Fukozawa and Fuji, 1992). Physical exercise can increase the amount of haem-iron (Hoffmann, 1995), particularly in the more oxidative muscles (Petersen *et al.*, 1997).

In cattle, Walshe *et al.* (2006) found that organic and conventional beef had similar levels of natural antioxidants, but organic samples were higher in fat content and were therefore more susceptible to lipid oxidation and less colour stable. However, in general, beef produced on pasture could have lower TBARS levels than meat from grain-fed animals, due to the protection conferred by natural products present in grass (Descalzo *et al.*, 2005; 2007). Feeding cattle on pasture, in fact, confers higher levels of vitamin E, β-carotene (Yang *et al.*, 2002; Descalzo *et al.*, 2005) and vitamin C (Descalzo *et al.*, 2005). In addition, feeding grass silage causes a higher vitamin E concentration in beef compared to maize silage (O'Sullivan *et al.*, 2003). Higher levels of α-tocopherol were also found in the meat from free-range pigs with access to pasture (Nilzen *et al.*, 2001). In pigs, the feed formulated according to the European regulation contained more vitamin E than the conventional feed (25.3 compared with 19.9 mg α-tocopherol/100 g feed), which led to higher vitamin E levels in the meat of organically raised animals (Hogberg *et al.*, 2002).

Grazing and high amounts of roughage can result in yellow fat, due to the high levels of carotene in the feedstuff that is not totally degraded to vitamin A in the intestinal mucosa (Therkildsen *et al.*, 1995): the longer cattle graze on pasture, the higher are β-carotene levels (up to 50% higher than those finished on grain) in plasma, muscle, and adipose tissues (Yang *et al.*, 2002).

Forage effects on tenderness are controversial as in some cases their consumption produces an improvement as compared to concentrate (Oltjen *et al.*, 1971), whereas in other studies no differences in tenderness between grain- and forage-finishing beef (French *et al.*, 2000, 2001) or higher tenderness in grain-fed cattle (Bennett *et al.*, 1995) was observed.

Flavour is highly dependent on diet, and, in general, high-energy grain diets induce a more acceptable intense flavour than low-energy forage or grass diets (Melton, 1990; Kerth *et al.*, 2007).

17.2.3 Genotype

Organic farming should be based on the use of indigenous genotypes, well adapted to extensive rearing conditions and the difficulty of the surrounding environment.

In Europe, organic poultry systems frequently employ slow-growing meat birds, which have a growing period of at least 81 d. Most USDA organic production, on the other hand, relies on the same fast-growing genotype used in conventional systems. According to Castellini *et al.* (2002b), slow-growing genotypes show a good adaptation to extensive rearing conditions, whereas fast-growing genotypes show unbalanced muscle response to the greater activity and reduced oxidative stability of the meat.

The effect of genotype often interacts with age: for instance, slow-growing chickens require a longer rearing period (Farmer *et al.* 1997), but also local and rustic cattle and pig breeds may need a longer finishing period due to their lower weight gains which are a consequence of either a lower genetic selection or a more fibrous diet. Obviously, meat quality is affected by the degree of maturity of the animals at slaughter (Castellini *et al.*, 2002b).

Genotype effect on poultry meat colour is not directly manifest. Slow-growing genotypes usually show redder and darker meat compared with fast growing birds (Le Bihan-Duval *et al.*, 1999; Berri *et al.*, 2001). This is probably due the higher content of myoglobin in the muscles of slow-growing animals (Gordon and Charles, 2002), which achieve their slaughter weight at an older age (Fanatico *et al.*, 2006). Other authors ascribe differences in redness among genotypes to differences in the type of muscle fibre (Lonergan *et al.*, 2003). In addition, the longer period spent foraging by slow growing birds may determine a more yellow meat (Fanatico *et al.*, 2005). In general, the meat from fast growing broilers has more fat, lower pHu and iron, and is paler (Castellini *et al.*, 2002b).

Genotype effects on broiler meat quality are also evident on water holding capacity (Fanatico *et al.*, 2005; Lonergan *et al.*, 2003; Rizzi *et al.*, 2007) and tenderness (Fanatico *et al.*, 2005): both are lower in alternative genotypes. Texture differences may be due to the higher slaughter age of slow-growing genotypes and, consequently, to the higher content of mature collagen crosslinks (Fletcher, 2002). Differences in tenderness may be also ascribed to the fact that fast growing genotypes have larger muscle fibers with different proteolytic potentials (Dransfield and Sosnicki, 1999).

The higher drip and cooking losses found for the muscles of slow growing genotypes can affect sensory profile of meat, which may be dryer than in fast growing birds (Fanatico *et al.*, 2006). Although a trained panel perceived some differences in texture and flavour between the meats from conventional and alternative genotypes, the consumer panel did not detect differences in liking (Fanatico *et al.*, 2006). The capacity of a panel to discriminate meat from slow- v fast-growing genotypes is largely debated (Richardson and Mead, 1999).

Organic pigs are required to eat large amounts of roughage. Thus it is necessary to find suitable genotypes in order to convert this roughage into useful nutrients (Nielsen and Thamsborg, 2001). In addition, animals should be pigmented and adapted to outdoor conditions. As a consequence, many organic farms rely either on commercial hybrids presenting large proportions of Duroc, or on the pure Duroc breed or on local pigmented breeds. The Duroc genotype has a positive influence on taste and juiciness in comparison with Landrace (Oliver *et al.*, 1994) or with Yorkshire (Enfalt *et al.*, 1997), whereas no effect on colour or water holding capacity was observed (Oliver *et al.*, 1994; Enfalt *et al.*, 1997). However, this breed may give rise to an increased amount of inter-muscular fat with detrimental effects on meat products such as ham (Wood *et al.*, 2004). Pork from local breeds is often characterised by higher fat percentage, which is detrimental for human health (Zullo *et al*., 2003). However, breeds of high fat production potential and high levels of subcutaneous fat tend to produce more saturated meat, which makes the product more suitable for transformation (Wood *et al*., 1989).

In cattle, some Spanish rustic breeds (Avileña-Negra Ibérica, Morucha and Retinta) do not differ from double muscled, dual-purpose or fast growth rate genotypes in terms of juiciness, fibrosity or overall flavour intensity (Campo *et al*., 1999), whereas other native bovine genotypes, such as Podolian cattle, showed significant differences in comparison with Limousine × Podolian crossbred with an improved fatty acid profile in terms of PUFA content and a lower tenderness (Braghieri *et al*., 2005). Differences in shear force and sensory tenderness were found between Hereford, Hereford × Friesian, and Friesian steer grazed at pasture when compared immediately after slaughter. Such differences were possibly associated to a higher calpastatin to μ-calpain ratio in the meat from Friesian steers, which was less tender. However, after an appropriate period of ageing (6–9 days) these differences disappeared (Muir *et al*., 2000). Ageing time, in fact, seems to reduce toughness differences among breeds (Campo *et al*., 1999).

17.2.4 Mutilations

A central concern in organic husbandry is the welfare of the farmed animals. This does not mean that it is important only to keep the animals healthy and to prevent anxiety, pain and suffering, but that it is also important to respect the integrity of the animals (Verhoog *et al*., 2004). One aspect of the nature of cattle is that they use horns in the expression of social behaviour. Therefore, in organic husbandry, dehorning should be avoided. The EU regulation states that these operations should be not carried out systematically, although for reasons of safety they may be authorised by the inspection authority. Many farmers see problems of working safely with horned cattle. In addition, the risk of injuries for the animals increases, with possible negative effects on carcass quality (higher incidence of bruised muscles), while demands regarding housing design, space allowances and management are higher. In organic farms, the use of tie stalls is limited in time; therefore, the percentage of herds with dehorned animals is increasing with the introduction of loose housing systems.

As for de-horning, the production of entire animals may be more in line with the organic principles of naturalness. However, many organic dairy farmers do not consider castration unethical as they prefer not to engage in outdoor young bull production due to handling and fencing problems, particularly when there are heifers nearby (Nielsen and Thamsborg, 2002). Security of the farmer and the public may be also at risk, when bulls are on pasture. Bulls are well suited to intensive feeding systems as they have a greater potential for muscle growth, with higher live-weight gains (about 20%), better feed efficiency (about 15%), and leaner carcasses (Jarrige and Auriol, 1992) than steers. Conversely, the latter tend to accumulate fat, thus they may be preferred in organic systems where the amount of roughage administered to the animals is higher and the grazing period longer (Nielsen and Thamsborg, 2005). Steer meat generally shows a better eating quality in terms of tenderness, juiciness and taste (Andersen and Ingvartsen, 1984; Steen and Kilpatrick, 1995), as it is higher in marbling (intramuscular fat), lower in collagen content, and higher in collagen solubility (Temisan, 1989).

Castration is extensively performed also in heavy pig organic farming, when the objective is transformation into meat products such as cured ham, and boar taint may become a problem, as the animals are slaughtered after they are sexually mature.

17.2.5 Conclusive remarks

Differences between organic and conventional meats may vary markedly according to the interpretation of organic rules by farmers. The diversity can be very small if the systems differ only in terms of origin of feed (organic v. conventional) administered to the animals, or very large when a comprehensive organic approach, including breed, components of diet, percentage of forage in the ration, grazing and space allowance, is adopted. However, the higher quality of organic meats is related to process characteristics rather than to subtle differences in sensory attributes or nutritional characteristics: product safety, animal welfare, biodiversity and environment safeguard can provide an ethical value to the organic product, which may become even higher if associated to traditional farming systems and typical meat productions.

17.3 Safety and healthiness of organic meat

The IFOAM's principle of health states that 'Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible'. Health is the wholeness and integrity of living systems. In view of this the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects should be avoided. Based on this principle, consumers usually perceive organic meat as safer and healthier compared to conventional product and this is the main reason for purchasing organic food. Organic processing and banning animal flour, GMO food and chemicals in animal feeding, gives consumers the assurance to avoid many diseases (bovine spongiform encephalopathy *Escherichia coli* O157 infections, dioxin toxicity, foot and mouth disease) affecting modern livestock (Magkos *et al*., 2006).

17.3.1 Chemical residues

Organic regulations require that animals have to be fed on organically produced feedstuffs; thus the potential for contamination with pesticide residues and other agricultural chemicals is greatly reduced compared to conventional farming methods. However, organic agriculture, albeit reducing the global level of pollution, cannot avoid contaminations from persistent environmental pollutants, which can potentially be present in organic feedstuffs and hence in organic meat.

For instance, Smith *et al.* (1997) detected levels of pesticide residues above American threshold limits in liver from beef cattle produced under natural and organic conditions, although muscle and fat were not affected. However, the same authors recorded a much higher number of detectable, but non-violative, chlorinated-hydrocarbon and organophosphate residues in conventional samples as compared to organic meat, while natural beef showed intermediate levels. In another study, pesticides and polychlorinated biphenyl residues in both organic and conventional meat were lower than legal limits, while lead and cadmium residues were very low and did not differ between organic and conventional meat (Ghidini *et al.*, 2005).

17.3.2 Growth promotants

Organic rules do not allow the use of growth promotants, such as antibiotics and hormones, for growing and fattening animals. If antibiotics are used to restore an animal to health, that animal cannot be used for organic production or be sold as organic.

The practice of administering growth promoters to livestock has been an issue of scientific debate and public concern for many years. European Union banned anabolic steroids in 1986 and did not authorise the use of alternative substances such as β-agonists, the physiological analogue of adrenalin, for repartitioning purposes (increase lean meat to fat ratio) and feed conversion efficiency improvement (Allen *et al.*, 1987). In contrast, the USA beef cattle industry has adopted the use of anabolic implants as a routine management practice because of market incentives to increase growth rates and reduce costs of live weight gain. Approved anabolic implants are either estrogenic, or androgenic, or both (Morgan, 1997).

The risk associated with the use of hormones, in particular oestradiol, is the carcinogenic effect exerted in their both initiating and promoting tumours (Devanesan *et al.*, 2001). Little information is available on hormone residues in conventional meat as compared to the organic product. Smith *et al.* (1997) detected no residues of anabolic steroids (testosterone, oestradiol, progesterone) and xenobiotics (zeranol, trenbolone acetate) in conventional, natural and organic beef samples. However, a dose-dependent increase in residue levels of various hormones, particularly at the implantation sites, has been observed (Hageleit *et al.*, 2000). Thus, misplaced implants and repeated implanting, which seem to occur frequently, represent a considerable risk that contaminated meats could enter the food chain.

The term 'antibiotic growth promoter' is used to describe any medicine that destroys or inhibits bacteria and is administered at a low, sub-therapeutic dose. The use of antibiotics for growth promotion rose with the intensification of livestock farming. Infectious agents reduce the yield of farmed food animals and, to control these, the administration of sub-therapeutic antibiotics and antimicrobial agents has been shown to be effective. There is controversy surrounding the administration of growth promoters to animals used for meat production, as overuse of any antibiotic over a period of time leads to the local bacterial populations becoming resistant to the antibiotic. In 2006, the European Union banned the feeding of all antibiotics and related drugs to livestock for growth promotion purposes, whereas in the USA a wide range of antibiotics is used as growth promoters for pigs, including some substances (penicillins, lincosamides and macrolides, including erythromycin and tetracyclines) considered to be 'medically important' (JETACAR, 1999). In addition, in USA pigs are exposed to a range of other antibiotic growth promoters compounds such as bacitracin, flavophospholipol, pleuromutilins, quinoxalines, virginiamycin and arsenical compounds. Compounds used as antibiotic growth promoters for cattle and poultry include flavophospholipol and virginiamycin. Cattle are also exposed to ionophores such as monensin, while poultry are given arsenical compounds.

Human health can be affected directly through residues of antibiotic in meat, which can cause side-effects. However, the major concern connected to the administration of low levels of antimicrobial drugs to food-producing animals is the potential selection of antibiotic resistance determinants that may spread to a human pathogen (Hamer and Gill, 2002). The analyses of conventional, natural and organic beef detected no antibiotic residues (penicillin, tylosin, erythromycin, tetracycline) in the three product categories (Smith *et al*., 1997).

Despite the improved carcass conformation and the larger *Longissimus* muscle areas induced by anabolic growth promotants and β-agonists, these compounds can compromise carcass (Roeber *et al*., 2000) and meat eating quality (Lowman *et al*., 1991). Although in a recent study Berthiaume *et al*. (2006) did not observe differences in marbling and lean colour between 'natural' beef cattle (i.e. produced without the use of ionophores and hormonal implants) and steers with hormone implants, generally hormonal growth promotants and β-agonists can reduce marbling and increase dark cutting incidence (Roeber *et al*., 2000). Similar results were obtained by Woodward and Fernandez (1999) using ionophore treated steer and organic steers. According to Duckett *et al*. (1999), implanting alters intramuscular lipid amount and composition through a dilution effect with the increase in muscle size. In other studies, these treatments induced lower sensory tenderness (Roeber *et al*., 2000) and higher shear force, possibly associated to lower marbling levels (Roeber *et al*., 2000; Platter *et al*., 2003; Smith *et al*., 2007). Through inhibition of the calpain/calpastatin proteolytic system (Simmons *et al*., 1997), in fact, β-agonists can increase the shear-force of meat in a dose-related manner by up to threefold (Vestergaard *et al*., 1994).

17.3.3 Parasite and bacterial contaminations

The growth of the organic food market has been supported by consumers' perception of organic products as safer (Sundrum, 2001). In fact, in organic farms, animals are generally kept in more appropriate environments where animal resistance to infections is promoted and risk of microbial contamination of meat is reduced. However, organic livestock production is not designed to reduce pathogen loads in food animals (Engvall, 2001; Thamsborg, 2001). The limited use of curative and preventive conventional medicines, the ban of antimicrobial compounds, as well as the outdoor rearing, the incorporation of biological cycles within the farm (use of organic manure within a farm, may carry the risk of recirculating infectious pathogens) and the use of very small slaughtering facilities involve potentially higher microbiological safety risks.

Providing chickens with access to an outdoor area may increase the risk of poultry becoming infected with *Salmonella* and *Campylobacter* due to contact with wild birds and other animals and their faeces. *Campylobacter* is the most common cause of gastroenteritis in the United States, (Altekruse *et al*., 1999), the UK (Frost, 2000) and worldwide. The prevalent route of transmission to humans is the ingestion of raw or undercooked poultry meat (Javid and Ahmed, 2002). Engvall (2001) stated that almost 100% of the organically farmed flocks in Sweden might be infected with *Campylobacter*, compared with only 10% of the conventionally reared flocks. These findings were confirmed in recent Danish and Dutch studies (Heuer *et al*., 2001; Rodenburg *et al*., 2004). Organic poultry are at particular risk from *Campylobacter* probably because they are more likely to pick up the pathogen from the environment, than flocks in conventional housing systems (Engvall, 2001; Heuer *et al*., 2001). A difference was found in *Campylobacter* strains between organic and conventional broiler farms. *C. coli* appeared to be the predominant species on organic farms, whereas in conventional broilers 70% of the strains were *C. jejuni*. However, only 7% of the cases of *Campylobacter*-related illness in humans are caused by the former species (Tam *et al*., 2003; Rodenburg *et al*., 2004). The Dutch data on *Campylobacter* are different from the Danish ones, where no difference in strains was found between organic and conventional systems (Heuer *et al*., 2001).

Prevalence of Salmonella in organic poultry systems has been recently investigated in the Netherlands (Rodenburg *et al*., 2004). The incidence of Salmonella infections in organic broilers was 13% in 2003, a percentage similar to that found in conventionally reared broilers. In addition a high incidence of *Toxoplasma* infections has been reported in free-ranging chickens but no data are available on the presence of *Toxoplasma* infections in organic chickens (Dubey *et al*., 2004). *Toxoplasma* does not pose a direct health problem to chickens but is an important food safety issue (Mead *et al*., 1999).

Outdoor rearing may imply an increased exposure to microbiological agents in pigs. A comparison of the *Salmonella*-seroprevalence in Danish organic, free-range, conventional and breeding pig herds (Wingstrand *et al*., 1999) showed that the risk of meat juice samples being seropositive was higher for organic and free-range than for conventional herds (Jensen and Baggesen, 2005).

On the other hand, research carried out at Cornell University demonstrated that organic farming of cattle and sheep can reduce the risk of *Escherichia coli* infection. The main source for human infection with *E. coli* is meat contaminated during slaughter. Virulent strains of *E. coli*, such as *E. coli* 0157:H7, seem to develop in the digestive tract of ruminants when they are fed mainly with starchy grain, whereas ruminants fed grass, silage and hay generate less than 1% of the *E. coli* found in the faeces of grain-fed animals (Couzin, 1998).

Outdoor rearing has been related to high rates of endoparasite infections such as several helminth and ascaris species in organic pigs (Carstensen *et al*., 2002). Similar results have been documented for sheep, cattle, laying hens, and poultry. The prevalence and intensity of parasitic infections were higher in organically than in conventionally raised animals; helminth species diversity was also much higher (Thamsborg *et al*., 1999; Permin *et al*., 1999). In addition, there are parasites which are almost exclusively transmitted outdoors. *Hyostrongylus rubidus* belong to this category together with parasites with indirect life cycles such as *Metastrongylus* spp., *Ascarops strongylina* and *Physocephalus sexalatus*. In organic pig farms, species with a wide host spectrum, such as *Fasciola hepatica*, *Dicrocoelium dendriticum* and *Trichostrongylus axei,* can be more frequently found (Nansen and Roepstorff, 1999). It has been shown that pigs' fibre-rich diets favour helminth infections, particularly *Oesophagostomum* spp., not only in experimental studies (Petkevicius *et al*., 1999) but also at farm level (Pearce, 1999). This is an extremely important observation in relation to organic farming, as roughage/forage has to be offered to pigs on a daily basis in most countries.

Even if these parasites do not represent a real risk for human health, because they are destroyed either when the digestive tract is removed or by cooking, their single presence in animals is perceived negatively by consumers (Kouba, 2003).

Comparing organic and conventional carcass quality in terms of pathological effectss, Hansson *et al*. (2000) observed that 28% of conventional and 17% of organic pig carcass showed abnormalities, while *eosinophilic miositis* was more prevalent in organically reared cattle.

17.3.4 Alternative strategies for animal medication

According to the European regulation, animals must be treated, when possible, with alternative remedies, such as homeopathic and phytotherapeutic treatments, rather than conventional veterinary medicines. Organic farming and homeopathy have similar views on health and disease, aiming to create a more balanced environment in and around the animal and to improve animal resistance to infections. The complementary medicine approach is growing in organic livestock farming practice as there are empirical evidences for the efficacy of alternative treatments (Baars *et al*., 2003). Limited conventional scientific investigation has been conducted on this topic. However, it is important that the research is not simply carried out in conformity with currently valid scientific standards: it has to be also in line with philosophy of homeopathy. Even less is known on the effect of homeopathic treatment on meat quality.

There is very little literature on the use of herbal veterinary remedies and their possible effects on meat quality. The administration of officinal herbs induced a higher cellular immune response and a lower incidence of puerpuerium pathologies in buffalo cows (Pacelli *et al*., 2003), while Bodowski *et al*. (1992) reported the effect of a herbal mixture on muscle composition.

The consumption of forages containing compounds with a high content of condensed tannins (CT), such as *Hedysarum coronarium* and the trefoils (*Lotus* spp.), is able to reduce the impact of intestinal nematodes and nematode larvae in lambs (Iqbal *et al.*, 2007). In the latter species, CT can also prevent bloated rumen (Waghorn and Jones, 1989). However, high concentrations of CT can have deleterious effects on animal performance (Pritchard *et al.*, 1992). These substances bind with and precipitate proteins in the rumen, reduce protein degradation (McNabb *et al.*, 1996), and reduce the fractional absorption of amino acids reaching the small intestine, resulting in low digestibility and low voluntary intakes (Waghorn *et al.*, 1999). The effects of CT on product quality has been poorly investigated. A lighter colour of meat has been obtained with lambs given CT-rich diets (Priolo *et al.*, 2000). The mechanism of action of is not clear. It is likely that tannins do not affect ruminant Fe absorption while inhibiting the successive utilisation of the iron for synthesis, as suggested by Garg *et al.* (1992).

17.3.5 Nutritional properties

From a nutritional point of view, organic meat seems to have healthier properties compared with conventional product. As already mentioned in Section 17.2.2, owing to the frequent grazing, organic animals, and ruminants in particular, often produce a meat with high contents of PUFA, including omega 3 and CLA, that are known to have positive effect on human health (Nielsen and Thamsborg, 2005). In a recent study in the Netherlands (Rist *et al.*, 2007), the content of rumenic acid (the main CLA) and the level of trans-vaccenic acid (a precursor of vaccenic acid) in human breast milk increased, significantly moving in-line with a complete consumption of conventional meat to a moderately organic and to a strict organic meat intake. Since the fat from human breast milk is likely to be of dietary origin, the larger amounts of rumenic acid and trans-vaccenic acid (TVA) in breast milk from the organic groups may be due to the corresponding intake of organic meat products with higher levels of rumenic acid and trans-vaccenic acid. The authors assumed that the levels of CLA and TVA in human milk may be modulated if breastfeeding mothers replace conventional meat products by organic ones.

17.4 Future trends

The global organic meat market will soon face impediments to free trade as a consequence of differences in organic standards between countries. As conventional products tariff barriers are being removed, an effort is needed to make organic standards from different regions more alike in order to promote trade liberalization and allow further development of the organic meat market. However, the main limit to purchasing organic meat remains price because of high production costs, which are affected by organic rules (higher space allowance, origin of feedstuffs, etc.) and small-scale production systems. Two strategies to overcome this constraint have been identified: the spread of organic meat in supermarkets, which is likely to induce a reduction of current price (this approach may be suitable for meat which is organic but is otherwise undifferentiated from conventional products); and the induction of increased willingness to pay by constant and reliable quality-signalling systems, capable of providing ethical value to the product, which may become even higher if associated with traditional farming systems and typical meat productions. The small-scale production, which often characterises organic meat enterprises, highlights the need for structures collecting and distributing the organic meat aiming to organize and standardize the supply.

As to product quality, the main constraints to the fulfilment of high standards are dark colour and toughness, both due to the physical exercise of extensively reared animals and the particular characteristics of local breeds. The most rapid strategies available for improving these aspects would be an adequately extended post mortem ageing and the crossbreeding of cows exceeding replacement needs with bulls of other breeds producing more tender and less dark meat. Research is also studying protein sources alternative to soya bean in order to minimize the risk of GMO contamination. At least for ruminants raised in the Mediterranean regions, faba bean seems to be a valid substitute.

Increased microbiological and parasitic risks in organic meat are associated with the limited use of conventional medicine, outdoor raising of the animals and incorporation of biological cycles within the farm.

We conclude that, in general, the quality of organic meat may be considered higher than conventional products in terms of fatty acid profile, mineral and antioxidant contents, and risk of chemical and growth promotant residuals. Negative aspects such as toughness and colour can be improved using appropriate techniques, while the risk of bacterial and parasitic infections should be carefully monitored, if possible prevented, keeping the animals in a proper environment, and, when necessary, treated using herbal and/or homeopathic remedies. However, the higher quality of organic meats is related to process characteristics rather than to differences in the end product. Meat safety, animal welfare, biodiversity and environment safeguard are the specific aspects supporting the differentiation of organic meats.

17.5 Sources of further information and advice

Organic standards for meat producing animals

IFOAM provides a worldwide common system of standards, verification and market identity: http://www.ifoam.org/.

European regulations on organic agriculture and farming: http://eur-lex.europa.eu/en/index.htm and http://ec.europa.eu/agriculture/qual/organic. Further information on laws, research and market development at European level can be obtained at http://www.organic-europe.net/.

USA organic rules have been issued by USDA within the National Organic Program: http://www.ams.usda.gov/nop/indexIE.htm.

Organic meat market

The World of Organic Agriculture 2007 – Statistics and Emerging Trends 2007 – International Federation of Organic Agriculture Movements (IFOAM), Bonn, Germany: http://www.organic-world.net/default.asp.

Basic data on organic agriculture in Europe: www.europa.eu.int/comm/eurostat/ and http://www.organic-market.info.

Data on North American production and supply of organic products: http://www.ers.usda.gov/Briefing/Organic and http://www.ota.com/index.html.

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Quality and safety of organic meat

The proceedings of the four thematic Workshops organised by the NAHWOA (Network for Animal Health and Welfare in Organic Agriculture) are published on: http://www.veeru.reading.ac.uk/organic/proceedings.htm

The proceedings of the four thematic Workshops organised by the SAFO (Sustaining Animal Health and Food Safety in Organic Farming are published on: http://www.safonetwork.org/

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Animal Health and Welfare in Organic Agriculture (2004), M. Vaarst, S. Roderick, V. Lund, W. Lockeretz (eds), Wallingford, UK, CABI Publishing.

Organizations promoting the research on organic production

CORE Organic: http://www.coreorganic.org/

The International Research Association for Organic Food Quality and Health (FQH)**:** www.organicfqhresearch.org.

The International Society of Organic Agriculture Research (ISOFAR): http://www.isofar.org/

Institutions involved in research on organic production

Research Institute of Organic Agriculture (FiBL): www.fibl.org.

University of Kassel: http://www.uni-kassel.de/agrar/

Danish Research Centre for Organic Farming (DARCOF): http://www.darcof.dk/.

Archive of papers related to research in organic agriculture (Organic Eprints): http://www.orgprints.org/

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