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## MAIN LECTURE

# Advances in research on poultry and rabbit meat quality

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**ABSTRACT** – Main force and weakness points of poultry and rabbit production chains are presented and meat quality discussed in relation to nutritional and technological issues. An analysis of the most important poultry and rabbit meat quality traits and their major relationships with production factors (genotype, feeding, housing, pre-slaughter handling, slaughtering, and processing) is provided. Most recent research advancements are presented in view of the consumer's demand for healthy and safe products obtained respecting animal welfare.

*Key words:* Poultry, Rabbit, Meat quality.

**Introduction** – Over the past few years, meat production and market have undergone several negative events that have impaired the image of this essential food product from the consumer's standpoint. The prospected correlation between high meat intake and human health problems, such as obesity, cardio-vascular and cancer diseases, has led to a reduction in meat consumption (Schönfeldt and Gibson, 2008). This trend has been accentuated by a series of scandals and animal health problems which have hit livestock production, such as BSE, dioxins in meat and avian influenza. Within this context, the poultry and rabbit chains have maintained their identity and a higher value compared to other species because of several reasons. Regarding nutritional aspects, poultry and rabbit meat well

Table 1. Composition and nutritional value of different poultry and rabbit cut-up expressed on a 100 g portion of meat (adapted from Cavani and Petracci, 2008; USDA, 2008).

	Chicken		Turkey		Rabbit	
	Breast <sup>1</sup>	Leg <sup>1</sup>	Breast <sup>1</sup>	Leg <sup>1</sup>	Loin	Hind leg
Water, g	74.8	76.1	74.2	76.2	75.0	73.5
Protein, g	23.1	20.1	24.6	20.5	22.4	21.3
Fat, g	1.2	3.8	0.7	2.7	1.4	3.7
Energy, kcal <sup>2</sup>	104	115	104	106	102	119
Cholesterol, mg	62	80	62	81	48	60
Iron, mg	0.72	1.02	1.17	1.66	1.13	1.34
Sodium, mg	65	86	49	69	37	47

<sup>1</sup>Without skin; <sup>2</sup>Calculated according to Greenfield and Southgate (1992) as recommended by Istituto Nazionale di Nutrizione (1997).

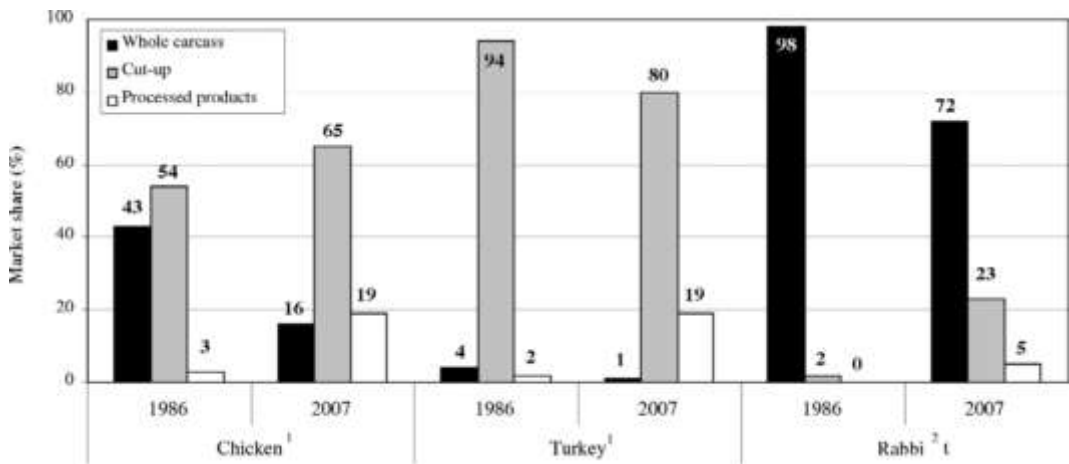
human health problems, such as obesity, cardio-vascular and cancer diseases, has led to a reduction in meat consumption (Schönfeldt and Gibson, 2008). This trend has been accentuated by a series of scandals and animal health problems which have hit livestock production, such as BSE, dioxins in meat and avian influenza. Within this context, the poultry and rabbit chains have maintained their identity and a higher value compared to other species because of several reasons. Regarding nutritional aspects, poultry and rabbit meat well

fit the current consumer demand for a low-fat meat with a high unsaturation degree of fatty acids (FA) and low sodium and cholesterol levels (Hernández and Gondret, 2006; Cavani and Petracci, 2008) (Table 1).

Poultry and rabbit meat may also be considered as “functional foods”, which provide bioactive substances with favourable effects on human health, like conjugated linoleic acid (CLA), vitamins and antioxidants, and a balanced n-6 to n-3 polyunsaturated FA (PUFA) ratio (Barroeta, 2006; Hernández, 2008).

During last years, the changes in consumer’s lifestyle in developed countries have led to a meat market more and more addressed towards easy-handled and processed products (“convenience food”). This trend has been exploited since long time by the poultry industry, which made strong investments in the processing area, and more recently by rabbit industry too. Nowadays, in Italy, the processed poultry meat products account for almost 20% of overall sold products, largely contributing to the creation of the added value of the production chain (Figure 1). On the contrary, most rabbit meat is still sold as whole carcass or some main cut-up, but the processing industry is pushing more and more towards the introduction of more attractive products for consumers having few time for meal preparation (Cavani and Petracci, 2004; Xiccato and Trocino, 2007). Further processed products are demanded due to their convenience, high food safety and quality standards, which stimulate the poultry and rabbit chains to adopt more strict protocols for the production of raw meat.

Figure 1. Evolution of poultry and rabbit meat consumption type in Italy (<sup>1</sup>UNA, 2009; <sup>2</sup>Our estimation from unofficial data).



Beside nutritional and sensorial properties, as well as food convenience level, consumers nowadays wish to have further information about the origin and method of production of meat based food. Further factors contribute to the complexity of food market: on one side, there is an ever growing pressure towards more and more competitive production systems due to the globalization process while, on the other side, there is an increasing demand to move back towards more extensive, traditional, and even organic production systems (Tri-chopolou *et al.*, 2007).

Overall, quality traits of both poultry and rabbit carcass and meat comprise hygienic aspects in relation to safety and toxicology (presence of undesirable microorganisms or residues such as antibiotics, hormones or chemical contaminants), nutritional value and technological and sensory attributes (Table 2). Meat complex properties are influenced by multiple interacting factors that include genotype, feeding, housing, pre-slaughter handling, slaughtering, and processing.

This review provides an analysis of the main poultry and rabbit meat quality traits and their major relationships with production and processing factors. Meat hygiene and safety like chemical residues, emerging pathogens, although of noteworthy interest, are not dealt with this paper.

Table 2. Quality traits of carcass and meat in poultry and rabbit.

Type	Quality trait
Carcass	Hygienic quality (microbial load and chemical residues)
	Slaughtering yield
	Weight of carcass and main cut-up
	Appearance (colour and conformation)
	Adipose tissue depot (consistency and colour)
	Meat yield
	Presence of defects (bruises, bone fractures, etc.)
Meat	Hygienic quality (microbial load and chemical residues)
	Appearance (colour, shape and size)
	Nutritional value (chemical composition and quality of proteins and lipids)
	Technological traits (pH, water holding capacity, texture, susceptibility to oxidation, etc.)
	Sensory attributes (tenderness, juiciness and flavour)

**Advances in research: factors affecting poultry meat quality** - Through the years, meat-type birds have been subjected to intense **genetic selection** for body weight and muscle development which have induced histological and biochemical modifications of the muscle tissue (Barbut *et al.*, 2008). Several studies evidenced that fast growing strains exhibit a high incidence of spontaneous or idiopathic myopathies (e.g. deep pectoral muscle disease) and an increased susceptibility to stress-induced myopathies which may have great implications for meat quality and incidence of abnormal conditions such as pale, soft and exudative (PSE)-like meat (Anthony, 1998; Bianchi *et al.*, 2006c; MacRae *et al.*, 2007; Petracci *et al.*, 2009). This condition is associated with the increase of the meat paleness, poor water holding capacity and impaired texture in fresh meat and processed products (Duclos *et al.*, 2007; Barbut *et al.*, 2008).

The manipulation of poultry **feeding** has been proposed as a tool to modify FA composition by mainly increasing the amount of n-3 PUFA. Algae extracts, linseed oil, hemp oil, or rapeseed oil are suitable sources for n-3 PUFA enrichment (Grashorn, 2007). In relation to

different tissues, FA composition of intramuscular fat can vary less than that of separable fat depots such as abdominal and subcutaneous fat (Cortinas *et al.*, 2004; Villaverde *et al.*, 2006). The minimum feeding time required to achieve substantial FA modification in thigh and breast meat is one or two weeks before slaughtering, respectively (Barroeta, 2006). According to Sirri *et al.* (2003), the enrichment of CLA in poultry meat is not as effective as the enrichment of n-3 PUFA. The increasing of meat PUFA raises the lipid susceptibility to oxidation during storage and cooking. Lipid oxidation causes loss of nutritional and sensory values as well as the formation of potentially toxic compounds (Barroeta, 2006). In order to improve the oxidative stability, different substances such as carotenoids, vitamin E, vitamin C and selenium have been tested in several experiments in order to verify their potential antioxidant effect on poultry meat (King *et al.*, 2006; Fisinin *et al.*, 2008). Vitamin E appears as the most effective antioxidant in meat (Barroeta, 2006); however the interest of using vegetable extracts from fruits, spices, seeds, grains and herbs as substitutes of synthetic compounds is currently growing (Rababah *et al.*, 2004; Brannan, 2008; Vandendriessche, 2008). There is also an increasing interest to emphasize the presence in poultry meat of attractive meat-based bioactive components such as carnosine, anserine, L-carnitine, glutathione, taurine and creatine in order to enhance the health image of meat and developing functional meat products. Poultry meat is particularly rich in anserine which is an endogenous antioxidant by chelating transition metals such as copper (Arihara, 2006).

The majority of poultry meat reaching food market is produced using intensively-reared birds by **housing** them indoors under close environmental control (photoperiod, light intensity, temperature, relative humidity, etc.). Following the multiple and growing demand of European consumers who are more and more sensitive to the ethical and cultural aspects of food consumption, however, there is an increasing interest towards alternative rearing and animal-friendly production systems which can improve animal welfare as well as guarantee higher qualitative standards concerning food safety, nutritional and sensory properties (Magdelaine *et al.*, 2008). Overall recent studies conducted under alternative housing systems evidenced that reduced stocking densities increased the possibility of movement and different feed sources from vegetation in outdoor areas modified the product quality (Fanatico *et al.*, 2005; Castellini *et al.*, 2008). Indeed, birds kept under alternative housing systems showed lower carcass fat depots and higher PUFA content which enhanced the nutritional value of meat but reduced its oxidative stability (Ponte *et al.*, 2008). Moreover the use of slow growing breeds and strains increased the rearing period producing meat with stronger flavour (Fanatico *et al.*, 2005).

The influence exerted by **pre-slaughter handling** on final product quality may be greater than those attributable to variation in husbandry practises. High environmental temperatures, transportation, and handling contribute to the pre-slaughter stress that can determine yield losses, reduced product uniformity, and decreased carcass and meat quality. A more careful bird handling has been reported as crucial factor to reduce carcass defects as haemorrhages, bruises and broken bones (Nijdam *et al.*, 2004). Catching is still mainly operated by hand, but in the last years mechanical systems have been introduced in order to reduce labour costs and animal trauma and mortality. Contradictory results have been found when comparing the results on injury prevalence in birds harvested by manual or mechanical catching (Schilling *et al.*, 2008). Moreover pre-slaughter heat stress has been reported to accelerate *rigor mortis* development and to increase paleness

in poultry meat (Bianchi *et al.*, 2004; Barbut *et al.*, 2008). Petracchi *et al.* (2004), when studying the seasonal effect on the incidence of PSE-like meat, found that this condition was more frequent in summer than in winter (15.5 vs. 2.7%).

Among **slaughter** and **processing** factors, stunning and early deboning exert the most important effects on carcass and meat quality. The animal welfare issues and product quality problems due to the employment of high current electrical stunning in Europe have promoted the use of gas stunning. The main advantage of some automated gas stunning systems is represented by keeping birds in transport crates until they are slaughtered, reducing animal handling and wing flapping and subsequent carcass defects (broken bones, haemorrhages, etc.) (Raj, 2006). Bianchi *et al.* (2006b), comparing electrical stunning with gas stunning in turkeys, observed a lower incidence of engorged wing veins and a tendency to a lower prevalence of breast with blood spots. As for early deboning issue, if the breast meat is removed from the carcass prior to the completion of *rigor mortis* (at least 4-6 h of ageing), the muscle fibres contract and shorten the muscle, and the resulting meat is less tender. Extensive research has been done to develop slaughter methods which allow for acceleration of *rigor mortis* (Fletcher, 2002). The application of electrical stimulation to broiler carcasses seeks to reduce the toughness of meat that is deboned prior to the normal ageing period (Sams, 2002). An emerging processing techniques to improve sensory traits of poultry meat is marination which is capable of ameliorating flavour and tenderness, and increasing product shelf life. The most common marination ingredient is sodium chloride, but there are strong pressures to reduce its use, because of the relationship between increased sodium intake in consumer diets and hypertension. Sodium content in meat products can be lowered by sodium chloride reduction and/or substitution with other ingredients like potassium chloride or magnesium chloride (Alvarado and McKee, 2007).

**Advances in research: factors affecting rabbit meat quality** - Rabbit meat quality is rather stable: differently from other species, no specific alterations of meat texture and physical properties, such as PSE-like condition, are observed and both carcass and meat traits are hardly modifiable by production factors (see recent reviews by Hernández and Gondret, 2006; Hernández, 2008).

Despite in the intensive production systems hybrid rabbits selected for growth rate have been used since a long time (Khalil and Al-Saef, 2008), the effects of **genetic selection** on carcass and meat properties have been little investigated until last years. When comparing lines with different growth rate at the same market weight, meat quality is not affected by the different degree of maturity reached by animals: dressing percentage, carcass composition and colour, chemical composition of muscles or meat parts or texture and sensory properties are similar among lines (Gondret *et al.*, 2005; Pascual and Pla, 2008). Gondret *et al.* (2005) suggested that even if rabbits selected for slow growth rate exhibited superior carcass conformation and higher muscle to bone ratio, these genetic progresses are of relatively little practical importance as a consequence of noteworthy worsening of feed conversion in respect with lines selected for fast growth rate. Around maturity, higher fat content and higher lipolytic activity are detectable in the hind leg meat of animals selected for high growth rate rather than for litter size at weaning, while free FA and oxidative parameters are little influenced by the genetic origin (Hernández *et al.*, 2008).

Like in poultry, the effects of **feeding** on rabbit carcass and meat quality are widely and well assessed. Research is now more interested to develop feeding strategies aiming to increase the value of rabbit meat as *i*) a “**functional food**”, including in rabbit diets n-3 PUFA, CLA, vitamins and antioxidants and assessing the effects on both raw and stored/processed meat; *ii*) a **safe food** produced from healthy animals not treated with antibiotics and other drugs. The first group of studies starts from the well-assessed statement that FA profile of rabbit meat may be favourably modified by the inclusion in the diet of raw materials rich in n-3 PUFA (Dal Bosco *et al.*, 2004; Kouba *et al.*, 2008; Peiretti and Meineri, 2008). The late administration of n-3 enriched diets during the last two weeks of fattening is sufficient to increase the PUFA meat content to requested values, thus reducing the cost in comparison with a longer treatment (Bianchi *et al.*, 2006a; Gigaud and Combes, 2008; Maertens *et al.*, 2008). Meat CLA concentration may be increased too: 0.5% dietary CLA supplementation increased CLA isomers, fat and oxidative stability in *longissimus lumborum* muscle as well as adipocytes size in scapular and perirenal fat (Corino *et al.*, 2007). Even if n-3 PUFA enriched meat and meat based products show high nutritional quality after short-term storage or cooking, the highest dietary PUFA inclusion levels favour meat lipid oxidation (Castellini *et al.*, 1998; Bianchi *et al.*, 2006a; Kouba *et al.*, 2008). Vitamin E supplementation at above-nutritional levels contrasts this effect by increasing meat oxidative stability and shelf life (for a review see Hernández, 2008).

The second group of studies is related to the recent European regulation that bans a-xinic antibiotics and has stimulated research on new feeding strategies or the use of feed additives capable of guaranteeing animal health (Gidenne and García, 2006; Maertens *et al.*, 2006). In particular, a positive role is recognized to digestible or soluble fibre supply in modulating intestinal microbiota and preventing the occurrence of digestive pathologies (García *et al.*, 2009). Apart from the carcass yield changes related to the different gut incidence (Xiccato, 1999; Xiccato *et al.*, 2008), the effects of different fibre fraction on carcass characteristics and meat technological traits have been few investigated until now (Margüenda *et al.*, 2008). Among feed additives, natural antioxidants may be used both to preserve meat nutritional value and FA stability, and to give safer meat products. Vegetable extracts with antioxidant activity exert several effects on animal health and growth performance but also on meat quality; these additives have been largely tested in swine and poultry, while less information is available in rabbits (Hernández, 2008). Supplementing rabbit diets with oregano essential oil (up to 200 mg/kg diet) increased carcass shelf life by reducing average microbial counts on carcasses throughout 12-d refrigerated storage, and increasing the number of days necessary to detect putrid odour and the formation of slime (Soultois *et al.*, 2009).

As **housing** systems are concerned, rabbit meat has a special place in the consumer's mind, as a product coming from small farms and traditional rearing systems. Differently, most of Italian rabbit production comes from intensive commercial farms equipped with bi-cellular cages, which limit social relationships and a normal behavioural pattern and may favour the appearance of stereotypes (EFSA, 2005). First data on alternative collective housing systems showed some weakness in comparison to standard cages: higher diffusion of diseases, increased competition and aggressiveness among animals, impairment of growth performances as well as carcass and meat quality. However, when group size and available individual surface were correctly assessed and hygienic conditions safeguarded, group hou-

sing of rabbits permitted suitable behavioural expression, comparable growth performance without negative effects on meat quality (Trocino and Xiccato, 2006; Trocino *et al.*, 2008; Luzi *et al.*, 2009). Moreover, Gondret *et al.* (2009) found that intense physical activity of rabbits determined an increase of muscle oxidative metabolism and activity of 3-hydroxyacyl-CoA dehydrogenase and citrate synthetase enzymes, an improvement of the hind part proportion of carcass and higher a\* and b\* colour coordinate values of *biceps femoris*.

A further critical point of the rabbit production chain is represented by animal **slaughtering**, including both pre-slaughter and post-slaughter phases, which can affect animal welfare as well as carcass and meat safety and quality. The low degree of integration of the rabbit chain represents a weakness point in comparison with poultry when pre-slaughter handling of animals and consequences on carcass and meat quality are concerned. Long transport and lairage duration and heat stress have been found to affect negatively mortality rate, slaughter yield and carcass and meat quality, besides animal welfare (Trocino *et al.*, 2003; Lambertini *et al.*, 2006; María *et al.*, 2006). However, Petracci *et al.* (2008) showed that, in a commercial integrated chain, pre-slaughter conditions of rabbits are rather satisfying, when transport and lairage are well coordinated and based on slaughtering daily programmes.

**Conclusions** – Both poultry and rabbit meat are foods with high relevance for human nutrition and health and their nutritional value can be further improved by suitable animal feeding strategies. In poultry, the shift towards further processed products has underscored the necessity for higher standards in meat traits in order to improve sensory characteristics and functional properties, while in rabbits carcass traits have still great importance, due to the low proportion of meat marketed as processed products. Moreover the intense selection for muscle growth of meat-type birds has resulted in a higher incidence of abnormal conditions (e.g. PSE-like meat), while evidence of these abnormalities has been not found in rabbit meat. As a consequence, researches are differently addressed and results show a greater variability of appearance, technological and sensory traits in poultry rather than in rabbit meat. In the near future research will focus on animal-friendly production systems with the aim of enhancing animal welfare and guaranteeing for safe meat and meat-based products in both poultry and rabbit sectors.

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