TRENDS IN RABBIT MEAT PROCESSING

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ABSTRACT

Further processed products are currently demanded due to their convenience, high food safety and quality standards. However, even if processing industry is pushing more and more towards the introduction of more attractive products for consumers having few time for meal preparation, worldwide most rabbit meat is still sold as whole carcass or cut-up parts. This review will analyses the historical evolution of rabbit meat consumption and main force and weakness factors in relation to the use of rabbit meat to manufacture further processed products. Bearing in mind these considerations, it then describes the more promising technologies to process raw meat materials in order to obtain added-value products by exploiting rabbit meat intrinsic characteristics. Major trends in meat product formulation are also discussed by highlighting strategies to provide healthier meat products meeting current nutritional needs. Finally, main solutions in rabbit meat and meat products packaging are discussed.

Key words: Rabbit meat, further processing, technologies, ingredients, packaging.

INTRODUCTION

Nutritional and technological properties of rabbit meat and its relationship with *ante-mortem* and *post-mortem* factors have been extensively investigated and many exhaustive review articles have been published through the last 10 years (Dalle Zotte, 2002; Cavani & Petracci, 2004; Hernandez, 2008; Dalle Zotte & Szendro, 2011). Currently rabbit meat is worldwide still sold as whole carcass or at least as cut-up parts, while very low quantities are marketed in form of processed products (i.e. ready-to-cook, ready-to-eat meals, etc.). As a consequence, food scientists have poorly investigated this area and published studies are fairly absent. However, in societies where people tend to live and work in urban areas by taking most of meals out of home and spending less and less time to home meal preparation together with increasing culinary ignorance (Swatland, 2010), rabbit meat consumption can be grown only by introducing rabbit meat as ingredient in processed food products (i.e. ready meals, ready-to-cook, etc.). Otherwise consumption will become even more marginal also in major rabbit meat consuming countries. As a consequence, by starting from historical evolution of rabbit meat consumption, the present review will deal with more promising technological, formulation and packaging solutions to which are potentially suitable to exploit rabbit meat characteristics.

EVOLUTION OF RABBIT MEAT CONSUMPTION

Numerous rabbit-based food products have traditionally been prepared and consumed since the first domestication of European rabbit which occurred in the southern Iberian Peninsula (Andalusia) and dated back to the middle Pleistocene (Lebas *et al.*, 1997; Queney *et al.*, 2002). Because rabbits are relatively small, animals slaughtered for consumption were generally eaten immediately. However, since a single rabbit would offer little more product than could be consumed at one sitting, little effort was devoted to developing preserved rabbit products (such as salted or dried meat, sausages, etc.). For

this reason, although there is a rich history of recipes that utilize rabbit meat in Mediterranean area, there are few traditional further-processed products. Red meat and fish often demanded some form of further processed processing to preserve excess quantities arising from the size of the animal (beef and pork), or because of a large fish harvest (Fletcher, 2004).

In rural societies, many families kept at least few rabbits for meat production to be used for occasional feasts. Even today, rabbit meats are often associated with special festival meals in many Mediterranean countries. The farmers may then have taken rabbits to a traditional market or sold them directly to a processor, who slaughtered and prepared the rabbits for sale to consumers. As industrial cities began to grow, the production of many foodstuffs become more concentrated with the sole purpose of supplying high-population centres with food. The shift from primarily agrarian to industrial societies depended on the intensification of food production, in which farms began to look more to the production of specific foods, as opposed to being self-contained units. The processor would have sold directly to the public or to wholesalers, who then sent the carcasses to a number of small meat markets, meat shops or restaurants in towns and cities. In the early 1970s, rabbit farming become intensive in the main European producer countries such as Italy, Spain and France by means of the application of intensive breeding programmes, better nutrition, disease control, management improvements and vertical integration. A major consequence of that intensification has been the increase in size of rabbit companies and concomitant decrease in the number of rabbit producers (Lebas *et al*., 1997). With the advent of large scale retailing following concentration of population in urban centres, also rabbit meat become sold as pre-packed still in the form of whole carcass, but also main cut-up (i.e. loin and hind legs) become available. However even today the majority of rabbit meat is sold in form of whole carcass and cut-up by strictly remaining a commodity in which almost all consumption was based on home preparation. On the contrary, market share of processed poultry meat products have been a tremendous increase during the last decades (Cavani *et al*., 2009). Because consumers were also not used to buying poultry meat in forms of processed products (i.e. sausages, salami, ham, etc.) and it took many years for these products to gain consumer acceptance. Only when "white meat" (i.e. poultry and rabbit) as opposite to "red meat" (i.e. beef, pork and mutton) began to be perceived as healthy (i.e. high protein/low fat content coupled with a balanced n-6 to n-3 PUFA ratio, low cholesterol and heme-iron content) there was the development of marketing of further processed products made by white poultry meat (Fletcher, 2004). This trend has been exploited since long time by the poultry industry which made strong investments in the processing area. The huge worldwide success of furthered processed products made by poultry meat is due to, besides its dietary and nutritional properties, relatively very low and competitive prices compared to red meats, absence of cultural or religious obstacles, and fitness for processed products development because of its bland flavour and soft texture which allow producers to impart desired flavour profiles (e.g. spicy *vs*. mild flavour) and textures according to market/marketing needs and consumers targeting (e.g. adult *vs*. children) (Petracci & Bianchi, 2012). In recent years, rabbit industries have tried to push more and more towards the introduction of more attractive products for consumers having few time for meal preparation (Cavani *et al*., 2009). Further processed products are currently demanded due to their convenience, but also high food safety and quality standards which can be more effectively guaranteed through proper traceability systems within vertically integrated production chains (Cavani & Petracci, 2006). This market change would imply also in rabbit sector demand of some degree of extended shelf-life and product diversification to allow reasonable time for distribution and marketing of more consumer-oriented foods, as opposed to mass quantities of basic commodities. There are not real technical limitations to manufacture processed products using rabbit meat, but technical ability has always taken second place to the realities of the marketing and economic viability. Today, only very few marketed processed meat products manufactured by rabbit meat such as hamburgers, stuffed rolls and baby foods are marketed. This because even if rabbit meat presents a nutritional profile which is similar to poultry, there are crucial limits impeding the diffusion of rabbit processed products diffusion (Table 1). First of all, rabbit meat cost/price is not competitive in respect to poultry because of much higher production costs. In poultry processing, there are also a huge supply of very inexpensive raw material such as mechanical deboned meat (MDM) which is very attractive for incorporation into further-processed products, while MDM production from rabbit carcass is very difficult because skeleton easily tended to produce bone fragments. Moreover, in many countries there are obstacles to its human consumption because rabbits are considered as pets.

Despite these limiting factors, certainly the only way to increase or at least hold current levels of rabbit meat consumption is to develop rabbit meat-based processed foods tailoring customer needs at various levels (i.e. retailing, catering, final consumer). This can allow to exploit positive nutritional aspects of rabbit meat which well fits the current consumer demand for a low-fat meat with a high unsaturation degree of fatty acids and low sodium, cholesterol and heme-iron levels (Dalle Zotte & Szendro, 2011) by contributing to have ‘‘balanced diet’’ with possible preventive effects on chronic nondeficiency diseases (e.g. obesity, type 2 diabetes, cancer and cardiovascular diseases) (Demeyer, 2010; Corpet, 2011). Moreover consumption of rabbit meat in form of processed foods will also allow to limit ethical implications of using animals as food consumption which are particularly relevant for rabbits which are largely considered pets in many countries. Moreover the use of common flavouring agents used in meat industry can cover typical wild flavour of rabbit meat which negatively impact attitudes of young and unfamiliar consumers.

Table 1: Main strengths and weaknesses of rabbit meat to be introduced in processed products.

STRENGHTS	WEAKNESSES
Nutritional profile	High production cost
Good health image	Defragmentation of production chain
Culinary tradition in Mediterranean countries	Difficulties to produce mechanically deboned meat
	Image as pet animal

MAIN PROCESSING TECHNOLOGIES TO MANIFACTURE RABBIT MEAT PRODUCTS

The first steps in modern processing are slaughtering, evisceration and chilling of carcasses (Cavani & Petracci, 2004). Further processing can be referred to as the operations going from cutting of the carcass into parts, packaging of raw consumer products, deboning and portioning to formulation of specific products (shaping, marination, coating, etc.), cooking and packaging. However it should be mentioned that these definitions are arbitrary and can change over the time and will be used differently by different companies and in different countries. It is also important to underline that processing is referred to an industrial and centralized approach to the creation of “pre-prepared” products, instead of a item prepared for immediate food consumption (Fletcher, 2004). More promising technologies to be adopted in rabbit meat further processing are described as follows.

Cutting, deboning and portioning

The majority of processed rabbit meat is sold as cut-up for direct consumer sale or use in restaurants or institutional markets. Both of them required a highly uniform rabbit-size and specialized cutting operations for portion control. The uniformity of size was critical for cooking protocols, inventory control and consumer expectations. Because of the highly specialized nature of the cuts involved, many of these processors still rely on manual cutting. Consumers often preferred to buy only whole carcass or one specific cut (i.e. loin, hind leg) and such demand was not as specific as that of large dinner customer, so generic cutting was acceptable and more appropriated for mechanical cut-up systems. These machines have been available by many years, but are still subjected to research and development. Because of relatively small volume of rabbit meat sold as cut-up, there are few specialized and integrated in-line machines designed for specific cuts, but more frequently a cut-up separation of entire carcass is realized in a single step (i.e. hind legs, loin region, half front and head). Dinner and restaurant customers often demand specific and highly uniform products in relation to size, shape and weight.

If cut-up parts are hand deboned, edible tissues may be recovered from bones and skeletal frames by using belt-and-drum deboners and this meat is classified as “mechanically deboned meat” (McNitt *et al*., 2003; Negatu *et al*., 2006). MDM from poultry are widely used to manufacture sausages (bologna, salami, and frankfurters) and nuggets and it has the texture of a fine paste and is high in fat and heme pigments from the bone marrow, which give the product a pink/red colour. MDM must comply with requirements concerning residual bone particles and calcium, protein and fat content (Froning and

McKee, 2010). Some studies conducted in United States have been evidenced that mechanically deboned rabbit meat can satisfy the requirements for calcium, protein and fat, but there were too many large bone fragments (McNitt *et al*., 2003; Negatu *et al*., 2006). This issue originated because rabbit bones tended to produce fragments more easily if compared with pork and beef, but also with poultry and this limits very much the production and the utilization of MDM in rabbit industry.

Marination

Marination, the addition of liquids to meat before cooking, is an old process, used in preparing meat, either for immediate consumption or as a preliminary step in preservation. Soaking in vinegar, oils, or both, in combination with spices improved flavour of the meat and extended shelf-life (or at least mask off-flavours). More recently, marination has been proven to offer additional advantages including functionality of product use and improved yield for the processor (Smith & Acton, 2010). Marinades were primarily a mixture of salt, organic acids, nitrates and spices in solution in which the meat was soaked, or with which it was injected prior to smoking and/or curing. Whole carcasses and parts can be injected with a flavoured salt or phosphate solution prior to manufacture of roasted products. The marinade produces a more tender product, with more flavour, lower cooking losses and increased juiciness. Boneless meat can be marinated in a tumbler, operated in a static, vacuum or high pressure environment to improve marinade absorption and uniformity. These product can be sold directly to the consumer as pre-marinated, ready to cook meat, or they can be frozen for distribution for canteens or restaurants (Fletcher, 2004). Rabbit meat is generally lean and because of that it presents a scarce juiciness and marked fibrousness which represent the main sensory defects of rabbit meat (Dalle Zotte, 2002). Many traditional recipes include a pre-treatment with vinegar, wine or lemon juice, salt and spices of rabbit meat before cooking with the aim to improve its juiciness and tenderness. According to poultry and pork, also rabbit meats are very suitable to application of modern marinating techniques (injection and tumbling). Injection can accommodate a wide variety of product size and shapes leaving bone intact. It is ideal for whole carcass, halves and large and small cut-up parts. Such products can be used for oven-cooked, smoked and roasted rabbit products. Otherwise tumbling, or mechanical massaging, is more suitable for whole meat, such as deboned loin or leg meat. Recently, Petracci *et al*. (2012) showed that rabbit meat ability to retain water during processing and tenderness can be improved by marination. These authors also proposed the use of sodium bicarbonate as alternative to phosphates in order to address natural and clean label trends.

Emulsified and formed products

In rabbit, formed products include basically meat patties (such as pre-formed hamburger patties) which are prepared with coarsely ground meat obtained from fore and hind leg. To reduce cost of raw materials, also meat from culled rabbit does are often used to prepare formed products. Until now traditional coarse-ground sausages manufactured by rabbit meat have not gained much interest in marketplace.

On the other hand, to produce modern emulsified products, such as hot dogs and bologna, raw meats are finely ground and typical fibrous structure disappears. In pork and poultry, since most consumers prefer the fibrous nature of whole-muscle meat, these products, although very popular, are often viewed as having less prestige than whole-muscle products (Fletcher, 2004). The majority of poultry emulsified products are manufactured using MDM which allow to radically reduce formulation costs (Froning & McKee, 2004). As previously described, technical difficulties to yield rabbit MDM dramatically limit potential development of emulsified products made by rabbit meat which would have costs not competitive in respect to nowadays marketed products.

Coating

The coating of products made by rabbit meat can potentially vary from minimal seasoning with salt and pepper through sophisticated sauces to completely battered and breaded (enrobed) products. Coating is often used as basic preparation technique to add flavour, seal the product so that moisture and juiciness are retained during cooking and improve product appearance. Potentially rabbit meat products could be those in which carcass parts, patties or preformed products are pre-dusted, battered, breaded (or some combination thereof) and “flash fried” merely to partially cook or “set”, the coating. The products can then be cooked in other types of oven, such as forced-air convection or steam oven,

without drying the product or compromising the textural quality of the coating. The products can be frozen and ready to "heat and eat". The industry is currently under pressure to lower the fat content of products used by institutions or sold directly to consumers. Coating mixes have been developed to coat meat products that can be cooked in conventional ovens to simulate fried foods, but without the added fat (Fletcher, 2004). Today, rabbit coated meat products are fairly not marketed because of the reasons described before (e.g. not competitive cost, scarce consumer habit, etc.). However it should not forgotten that coated products are very popular for children and young people, so coated products manufactured with rabbit meat can be viewed as alternative in order to expand existing market share.

TRENDS IN INGREDIENTS INCOPORATED IN MEAT PRODUCTS

Several ingredients and additives can be applied during the manufacture of meat products in order to increase, restore or enhance attributes such as taste, colour, texture, firmness and shelf life. Major trends to be adopted in rabbit meat product formulation are summarised as follows.

Modulation of lipid content and composition in meat products

Rabbit meat is leaner in respect with other kinds of meat (Dalle Zotte & Szendro, 2011), as a consequence when used to manufacture emulsified and coarsely ground sausages should be added with other kind of meats (pork, poultry meat) and/or fats (i.e. pork lard) which may increase lipid content up to 30%. This should be avoided in order to preserve the current healthy image of rabbit meat. As alternative, fat from plant rather animal resources, and other ingredients such as fat replacers may allow to modulate fat levels and its composition (i.e. low cholesterol content, high PUFA level). Manufacturing finely ground meat products such as emulsified, boiled sausages (frankfurter style) is extremely challenging and poses difficulties in term of appearance, flavour, water holding capacity (lower ability to hold liquid during cooking) and texture (i.e. increase of firmness) (Weiss *et al*., 2010). For this reason, a number of hydrocolloids systems with water-holding capacity that are able to promote the formation of gels have been examined for their ability to replace fat. Main possibilities are alginate, carrageenan, xanthan gum, cellulose derivatives, starches and pectins. Furthermore, incorporating a certain amount of vegetable fibres in a meat product could be exploited as a way for nutritional enrichment of processed meats. In fact, based on their technological functionality and nutritional benefits, fibres can be used, either alone or in combination with other ingredients, for fibre enrichment, as sources of prebiotic fibre, to reduce fat, salt or phosphates, and to enable the use of plant oils rich in PUFA n-3 (Arihara, 2006; Decker & Park, 2010; Weiss *et al*., 2010; Zhang *et al*., 2010). On the other hand, fat composition can be also manipulated by dietary means as proven by many studies (Hernandez & Gondret, 2006). A considerable amount of work has been done to enhance the n-3 PUFA content of rabbit meat by the inclusion in the diet of raw materials rich in n-3 PUFA as reviewed by Cavani *et al*. (2009) and Dalle Zotte & Szendro (2011).

Decreased oxidation by the use of novel antioxidants

The oxidation of lipids in meat products is a key problem that reduces shelf life of frozen and fermented processed meat, but also of precooked meats. In the latter, lipid oxidation leads to formation of "warmed-over flavours" which refer to the development off-flavours in cooked product when reheated after refrigerated storage (Weiss *et al*., 2010). Rabbit meat has a quite high content of polyunsaturated fatty acids (Dalle Zotte & Szendro, 2011) which makes it rather susceptible to lipid oxidation and the subsequent off-flavor (and off-aroma) characteristic of warmed-over flavours (Bianchi *et al*., 2006). There are several compounds with antioxidant potential which may used as food ingredient (BHA, BHT, sodium nitrate, tocopherols, selenium, ascorbic acid, etc.) (Decker & Park, 2010; Weiss *et al*., 2010; Zhang *et al*., 2010) and/or dietary fortification (tocopherols, ascorbic acid, etc.) (Abdel-Khalek, 2010; Dalle Zotte & Szendro, 2011) in order to prevent or al least reduce meat oxidation processes. It is well-known that tocopherols are most effective antioxidants also in rabbit meats and their content can be easily increased both by dietary fortification (Lopez-Bote *et al*., 1997; Castellini *et al*., 1999) and its use as ingredient with beneficial effects on lipid oxidation during frozen storage (Castellini *et al*., 1999; Lo Fiego *et al*., 2004) and cooking (Dal Bosco *et al*., 2001), colour stability (Corino *et al*., 1999; Dalle Zotte *et al*., 2000) as well as some technological properties

(Castellini *et al*., 1998). During the last years, the interest in natural antioxidants usage is increasing both in animal nutrition and food industry. There are very active essential oil compounds in rosemary, oregano, thyme and sage and its use are allowed as both dietary compounds and meat additives (Decker & Park, 2010; Weiss *et al*., 2010; Zhang *et al*., 2010). The influence of dietary supplementation with oregano essential oil has been also studied in rabbits by Botsosglu *et al*. (2004) who found that 200 mg/kg level was effective on meat protection against lipid oxidation. More recently Chia seed (Meineri *et al*., 2010) and tannins (Gai *et al*., 2009; Dalle Zotte *et al*., 2010) dietary supplementation did not result effective on retarding lipid oxidation.

Salt and sodium reduction

Salt, or sodium chloride (NaCl) is the most important ingredient in the production of meat products. In recent decades, with the increasing consumption of many different processed foods containing high level of sodium, the perception of dietary salt has evolved to a point where it is now considered, by some, to be a potential health threat. Since these high levels of dietary sodium are associated with a high prevalence of hypertension, prehypertension and, possibly, other adverse effects on health, many national and international health organizations recommend that sodium intake should be significantly decreased (Doyle and Glass, 2010). It should be mentioned that even if raw rabbit meat is often claimed because of its very low sodium content if compared with other kind of meats, however the amount of sodium added during culinary preparation of raw meats or industrial food processing is much higher (300 to 800 mg/100 g of edible product) in respect to the its intrinsic content which can be vary from 37 to 47 mg/100g as reported by Dalle Zotte & Szendro (2011). One of the biggest barriers to salt replacement is cost as salt is one of the cheapest food ingredients available. Also, consumers have grown accustomed to salt through processed foods so in some cases it has being difficult to remove as previously discussed. Another issue is that although there are alternatives to salt in term of functionality some consumers and retailers may not be comfortable with these new ingredients on the label (Desmond, 2006). In meat systems, besides the organoleptic factors, an important consideration when replacing NaCl with other chloride salts, is the effect on the physical properties of the final product. Sodium chloride reduction by itself will result in lowered WHC of the raw meat, which, upon heating, will result in higher cooking losses, drier product and, if cooking losses are too extensive, a totally unacceptable product (Barbut, 2002).
The main strategies for sodium reduction are the use of sodium chloride substitutes, in particular, potassium chloride (KCl) and flavour enhancers which enhance the perception of salt in the finished products (Desmond, 2006). No specific studies have been conducted on processed products manufactured by rabbit meat, however there are not difficulties in transposing knowledge gained in other kinds of meat.

MAIN PACKAGING SOLUTIONS FOR RABBIT MEAT PRODUCTS

Evolution from whole carcass and cut-up to processed products in rabbit sector would imply demand of some degree of extended shelf-life, product diversification and convenience. Convenience is a very important function of modern package together with containment, information and protection. For example, single serving size of sliced meat and microwavable packages allow for cooking/rehating and consumption of the product in a part of the package (Dawson, 2010). In modern retails, rabbit meat products are retailed for display and they are store branded or branded by the supplier . Currently stretchable and clear polyvinylchloride (PVC) film overwraps with product placed on an expanded polystyrene (foam) tray is the common case ready display package for most traditional rabbit products such as whole carcass and cut-up. An absorbent pad can be placed under the meat to adsorb purge (Dawson, 2010). Products manufactured by uncooked ground rabbit meat require different packaging due to enhance microbial shelf-life and colour stability. These product are usually packaged under modified-atmosphere in polystyrene foam trays with overwrap non-oxygen permeable film. A further solution is “lidded” tray in which high barrier film with shrink capacity are sealed to pre-formed barrier tray having a top surface lip to provide a film-to-tray sealing area (Acton *et al*., 2007). Different gas mixture combinations are recommended depending on the product. For example, boneless portion may use 60 to 80% oxygen for colour maintenance (oxymioglobin), 20 to 25% carbon dioxide, and the remainder as nitrogen as filler to prevent packaging collapse (McMullin, 2008;

Singh *et al*., 2011). Several packaging formats used for processed ready-to-eat products can be the same as those for fresh rabbit meat. It may be used barrier foam or solid trays with barrier overwraps (but not lidded trays) and thermoformed packages using vacuum packaging or modified atmosphere packaging (Acton *et al*., 2007). However, modified atmospheres used are not the same as for most fresh rabbit meat, consisting of 25-30% carbon dioxide and the remainder as nitrogen. Exclusion of oxygen is a major requirement for all products in these categories. Barrier systems ensure no or minimal loss of the flavours through control of lipid oxidation that leads to development of rancidity (Acton *et al*., 2007; McMullin, 2008; Singh *et al*., 2011).

CONCLUSIONS

According to poultry, rabbit meat has a nutritional profile and technological traits being very adapted to be included in added-value products in order to meet demand of both modern consumer towards food health and convenience and industry in term of flexibility. There are not real technical limitations to manufacture processed products using rabbit meat, but this has always taken second place to the realities of the marketing and economic viability. Indeed the very high cost of rabbit raw meats for further processing if compared with pork and poultry together with some cultural and ethical constrains are strongly limiting their use in the formulation of processed products. However the failure of processed products marketing will seriously risk to impair the future development of industrial-scale rabbit production. In this circumstance, rabbit meat sales through modern retail and catering channels could even decline and this meat can be just become an important niche in both traditional (i.e. local and ethnic markets, typical restaurants, etc.) and rich and diverse food supply (i.e. high class restaurants, specialized meat shops, etc.).

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