

Sheep Meat Processed Products

Subjects: Zoology

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A concise review of the origin and type of the most important sheep and goat processed meat products produced in different countries and world regions is made. The manuscript also summarizes the most recent studies on sheep and goat processed meats on the physicochemical characterizations, sensory quality, microbiological quality and safety. Some conclusions and future trends in production, processing and commercial potentiality for sheep and goat processed meat products are discussed.

Keywords: sheep ; goat ; processed products ; quality

1. Introduction

Despite not being the most consumed meat in the world, in the decade from 1994 to 2004, there was a notable increase of 75% and 42% in the production of sheep and goats, respectively, with a trend that continued until 2018 ^[1]. Countries with a long tradition of consuming sheep and goat meat also consume many products, such as hams, sausages and pates, or other processed products. Many of these products correspond to ancient methods of preserving meat at a time when there was no other way of preserving than curing with salts, air drying or smoking. Smoking, drying and salting are the oldest ways to preserve the meat, and particularly, some of them are nowadays recognized as protected origin designation (POD) or geographical protected indication (GPI) brands, as has been mentioned by Teixeira and Rodrigues ^[2]. Some of them are linked to the peculiar consumption traditions of some countries. For example, in Northern Europe, particularly in Scandinavian countries, there are typical and traditional dry-cured sheep and goat meat products, such as Fenalår and Pinnekjøtt in Norway or Hangikjöt and Skerpikjöt in Iceland and the Faeroe Islands ^[3]. In countries where the religious traditions prohibit the use of pork meat in processed Halal products, meat and fatty tissues from sheep and goats, as well as the tail fat from sheep breeds, are used, as in Turkish sucuk ^[4] and the Algerian, Moroccan and Tunisian Kaddid or Gueddid ^[5]. In the Northeast of Brazil, specifically in Petrolina-Pernambuco but, also, in Ceará, the carcasses of boneless and semi-dehydrated sheep and goats and, recently, the product called “Manta de Petrolina” have been distinguished as cultural heritage and registered as a quality brand. In some Mediterranean European countries, young lambs and kids producing light carcasses are highly appreciated by consumers, and many of them are very popular PDO (protected designation origin) or PGI (protected geographical indication) brands ^[6]. The meat of sheep and goats coming out of these quality marks, as well as culled animals, are cured and processed, producing popular products such as the Spanish Cecina de castron ^[7] or the Italian violin di capra ^[8]. Recently, studies on the use of goat and sheep meats in the production of new processed products and methods^{[9][10][11][12][13][14][15][16][17]} confirm the importance of research and innovation as key factors in advances in the production of sheep and goats, particularly in the control of food processes, physicochemical characterization, food safety and the sensorial properties of new products^[18]. Thus, the purpose of this review is to summarize the most recent studies on the quality of sheep and goat processed meat products and to contribute to a better awareness and spreading the information about these products.

2. Classification and Influences

The need to preserve meat for later consumption dates back to ancient times. Salting, drying and smoking are the oldest forms to preserve and keep meat in the world. Fermentation and ripening together is another efficient methodology with no cooling required or other processes of meat preservation also used a long time ago to increase the shelf life.

Currently, the processing of meat is not exclusively for the need for preservation but, mostly, to satisfy consumer demand and the acceptability for products with traditional palatability and flavor characteristics. Given the huge variety of existing products industrial or handmade-manufactured, we decided to group the products into three groups: dried and semi-dried products, sausages and cooked or precooked prepared products.

2.1. Dried and Semi-Dried Products

All products that are naturally or artificially dehydrated, salted, cured, smoked or not will be considered as dry and semidry products. Some fermented sausages with short or longer ripening periods will also be part of this group.

In South America, dried meat strips from several animal species, including sheep and goats exposed to sun, wind and smoke, are called jerky or charqui. According to Fadda and Vignolo ^[19], the charqui is made from small pieces of fresh meat salted and pressed for several days, dried and with most of the water removed and that can be stored for several months without the need for refrigeration. In Northern Brazil, it is very common to have goat and sheep charqui called Carne de sol. In Northeast Brazil, ripened and cured goat or sheep meat locally known as manta correspond to a deboned carcass, only maintaining the rib bones and cutting the main muscles into thin meat layers, exposing them, resembled a blanket (manta is the Portuguese word that means blanket) that is lightly salted and hung in boxes protected with anti-fly nets and sun-dried. The most famous product is the Manta de Petrolina and the CYTED (Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo) Iberian American Network of Quality Brands of Ibero American Meat and Meat Products (MARCARNE), which sponsored and promoted events in the past two years to recognize and protect its geographical designation.

One of Norway's most important dry-cured meat products, with a long tradition of consumption since the time of the Vikings, is Fenalår, a dry-cured ram leg or mutton, and the Pinnekjøtt, a dry-cured side of lamb or mutton ^[3]. The designation Fenalår derives from the old Norwegian words fenad and lår used to designate mutton and leg. Legs are brine- or pickle-curing. Traditionally the salted legs were dried and hanging from pillars in storehouses and smoked, but today, production plants with control of the temperature, relative humidity and air velocity are used. Smoke today is slightly used only to add taste and flavor. The Pinnekjøtt is a dry-cured meat from the side of lamb or mutton placed in boxes in layers of meat and coarse salt for 1.5 to 3–4 days and rinsed in freshwater to prevent the salt precipitation during the dry period: 10 to 15 days in a room at 10–15 °C temperature and 65–75% of relative humidity or 6–7 weeks if pre-tending a more dry product.

Hangikjör, an Iceland-smoked shoulder or leg of lamb, is consumed in the festive meals of Christmas and Easter ^[20]. The legs and forequarters are salted and dried or immersed in brine for 1–6 days and smoked. Traditionally, they are always smoked with dried sheep manure and birchwood. In Iceland, there are different preferences for the various types of Hangikjör, and the main trends are actually the use of less salt and less smoke, but dried sheep manure is always needed, because the smoke gives the meat its unique and different flavor ^[21]. Furthermore, in Iceland, there are still other soured (pickled) and fermented lamb meat products: Blóðmör—a blood sausage, Lifrarpylsa—a liver sausage, Lundabaggi—the rolled lamb flanks, Bringukollar—a lamb brisket, Hrótsprungar—the pressed testicles and Sviðasulta—a head cheese from boiled singed sheep heads ^[20]. Skerpikjör, wind-dried fermented lamb, as well the Ræstkjör (semi-dried mutton), are two popular meat products from the Faroe Islands and are especially highly valued ^[22]. Carcasses are opened up and flattened, cutting through the ribs on one side close to the backbone and hung up along the rivers or brooks on low banks or places with good air circulation ^[3]. Additionally, being a traditional dish from Faroe Islands, Sperðil is made from the tallow around the rectum of sheep and prepared into a type of primitive sausage that can be used as spread on bread, eaten with fish or added to the traditional unleavened bread ^[22].

In Asia, mainly in the Himalayan area (Nepal, Northeastern India, Tibet and Bhutan), there are different fermented meat products, using pork, beef, yak and sheep and goat meats ^[23]. Suka ko Masu is a dried/smoked product usually consumed in Nepal and India. The dried and smoked goat and buffalo meats ^[24] are sliced in strips of 25–30 cm hanging above the kitchen oven for 7 to 10 days and are consumed mixed with mustard oil, turmeric powder and salt. In the Kumanu Himalayas, the greema/arija is a popular semidry sausage^[25]. Some other ethnic meat products, such as kheuri in Sikkim India, are a mixture of yak or beef stuffed and pressed into the sheep stomach and hung in open-air space for one to two months ^{[24][25]}.

Pastrami is a traditional Romanian dry meat product without heat cure preserved by nitrite or nitrate salts and seasoned with fenugreek and garlic normally made by beef and buffalo water and, in Egypt, also from sheep, goat and camel meats ^[14].

Over the last few years, in the Mediterranean area of Europe, several goat or sheep processed products have been produced. Mainly in Spain but, also, in other European countries, such as Italy, culled goats meat are, salted, smoked and air-dried following a recipe for cured ham established 2000 years ago as Cecina, after the Latin siccina, which means cured meat, known as Cecina de cabra and Cecina de castron made from goat meat legs ^[7] and, also, Violin di capra, an Italian traditional goat dry-cured leg ^[8].

The Kaddid or Gueddid is a traditional salty and dry meat product typically prepared from mutton meat salted and dried outdoors in Maghreb countries (Tunisia, Algeria and Morocco) [5]. The Gueddid can be stored at room temperature for more than a year, and, before consumption, it is desalted after immersion in water, being used in various dishes, such as Aiche, Couscous, Elhessa and Marloga in Algeria [26]. In addition to Gueddid, there are other dry and fermented or not fermented products of North Africa and the Mediterranean of sheep and goat meats, such as Kourdass (a sausage prepared from offal lamb stomach, intestines, liver, lung, spleen and fat), Tidkit (a sun-dried product), Boubnita (a dry lamb fermented sausage), Soudjouk or sucuk (a dry fermented and uncooked sausage of Turkish origin) or Maynama and Merdouma (smoked products) [5].

In Southern Africa, a goat meat drying technique using salting and smoking processes and known as chinkui in Mozambique's Northern Tete Province is also commonly used [27] as a complementary source of protein in local rural areas of developing countries with large undernourished populations.

The large amounts of dry and semidry sheep and goat products worldwide, with a special focus on the most depressed areas of agriculture and livestock in the world, are evidence of the importance of sheep and goat productions as a way to overcome protein deficits using food preservation ways that respect the environment, producing and consuming meat products with low carbon footprints.

2.2. Sausages

Although not so common in sheep or goat meats, there are some sausages traditionally recognized for their individuality and linked to the consumption history in the regions that produce them. Some of them are fermented sausages fresh or smoked. In Middle Eastern countries, fermented sausages are produced from many different animals instead of pork (beef, buffalo, camel, horse, lamb, goat and mutton) [28][29][30]. Sucuk, also known as sujuk, is a dry-fermented Turkish sausage very common in Southeastern Europe, the Middle East and Middle Asia [30]. Sucuk and other similar sausages are made of beef, goat and sheep meats and tail fat [31], with garlic, salt and other ingredients such as sugar, nitrites and/or nitrates and various seasonings and spices [32]. Sheep tail fat is a constituent of Turkish fermented sausages and kebabs.

Fjellmorr and Lambaspaeipylsa, are dried fermented sausages traditionally produced in Norway and Iceland that contain lamb, as well as beef and pork [33]. Another Norwegian product is Fårepølse, a mutton sausage made with a large meat variety, including goat [34].

Arija and Geema (jamma) are traditional goat meat products from Kumanu Himalaya in Northern India. To prepare Geema, the meat goat is minced and mixed with salt, wild pepper, chili powder, water and fresh blood. This mixture is stuffed into small goat intestines, and then, the sausages are boiled and then are dried for a period of 15–20 days hung above the kitchen oven. The Arija is the same process, but the goat meat is mixed with goat lungs, and the mixture is stuffed into goat large intestines [22][35].

Several studies are investigating the incorporation of sheep or goat meat in sausages. In Vienna sausages, a cured and smoked product [36], a study was conducted to evaluate the consumer acceptability of goat meat frankfurters using three different diets, including canola oil or beef fat [37], using different levels of pork fat in goat mortadella [38] and using sheep tail fat and lean mutton for manufactured dried fermented sausages and studying the effects of the combined starter and species in physicochemical and microbiological properties [39] and studying the suitability of goat meat to the restructuring techniques, assessing the quality during refrigerated storage of the cured goat product [40][41]. In a study, meats of sheep and goats from culled animals were pointed out as valuable alternatives to that meat-producing sausages with different levels of pork fat [9]. The nutritional characteristics and consumer acceptability of different combinations of goat meat with beef have been studied [42], and the technological properties in frankfurter productions were studied using meat from culled animals [13].

Rediscovering processed products based on sheep and goat meats, incorporating functional additives and improving their nutritional and food quality, is increasingly a practice that may add value to meats of low commercial values.

2.3. Cooked or Precooked Prepared Products

The process for producing sliced, easy-to-prepare, prepackaged food products from a goat or a sheep meat is not common. However, we found some examples of processed sheep and goat meat products that can be considered cooked or precooked products. In Northeast Brazil, there is a product called “Buchada de Bode” (buchada coming from the

Portuguese word *bucho*, the animal's stomach, and *bode* is the Portuguese designation of the male goat) made with reticulum stuffed with entrails or organs, such as blood, intestines, liver and lungs, seasoned and then sewn up and cooked.

In Turkey, the traditional meat used to make kebabs is lamb. There are several types of kebabs, but the world-famous one is the *Döner*, made conventionally from lamb, which is slowly roasted on a vertical spit and then thinly sliced off. In local markets, it is very popular to order precooked kebabs of minced lamb mixed with tail fat and vegetables such as eggplants, tomatoes, peppers and onions, ready to roast at home. In India and Pakistan, there are many varieties of kebabs commonly prepared with lamb. In reality, the consumption of kebabs has now extended to the whole world but occupies a prominent place in the Mediterranean area.

Lamb and goat are the most popular meats used in Arab countries, where there are some popular street-prepared dishes such as *Shawarma* (a food made with marinated cuts of meat skewered on a vertical rotary roasting fork (spit) and baked by radiant heat), *Kibbeh* or *kebbah* (a traditional food consisting of a mixture of ground bulgur and minced lamb or beef meat, which are made as a dough) or the *Kofta* (another dish made with minced meat) ^[43].

In the Mediterranean countries of North Africa, there are several cooked and crystallized products from sheep and goats seasoned and stuffed with local species, such as *Laknaf*, *tha Cachir* and *Khliaa ezir* in Algeria; *Osbana* in Algeria Tunisia, Libya and Morocco; *kabiba* in Egypt; *Mcharmia* in Algeria and Morocco; *Boubnit* or *Membar* in Algeria and Egypt; *Mkila*, *Tehal* and *Tangia* in Morocco; *Bekbouka* in Morocco, Algeria and Tunisia or *Mrouzia* in Morocco and Tunisia ^[5].

In Mexico, *barbacoa* is a very traditional dish prepared with lamb or goat, which is slow-cooked in an underground oven lined with hot coals and covered with agave leaves until very tender and juicy. Today there are some food industries that commercialize precooked *barbacoa* ready to eat at home and that can be exported mainly to countries with Mexicans immigrants.

In Spain, one of the most famous dishes is "*Lechazo de castilla*", a milk-fed lamb slow-roasted in firewood ovens. Corresponding to modern lifestyles, there are also food industries that offer a delicatessen product, such as *Lechazo*, in a precooked and vacuum-packed form, ready to serve on the table in 30 min.

Chanfana is an old, traditional Portuguese dish cooked in black clay pots made from local clay inside a wood oven slowly cooking old goat or sheep meats in red wine with some herbs and spices, making the meat tender and more palatable. The resulting dish turned out to be so tasty that it is now a regional delicacy in Portugal.

In the last years, several studies using sheep and goat meats with cooked or precooked products and some products ready to cook have been developed as patties ^{[44][45][46][47]}, nuggets ^{[48][49][50][51][52][53][54]}, hamburgers ^{[55][56]} or *pâté* ^{[11][57][58][59]} and others ^{[60][61][62][63]}. In the Indian subcontinent (India, Pakistan, Bangladesh, Nepal and Sri Lanka), there are several traditional meat products and recipes using sheep and goat meats, such as *Rogan Josh*, a lamb meat marinated with Kashmiri chilies, *Aab Gosht*, a lamb curry cooked in milk, *Rista* and *Goshtaba*, a minced lamb meat cooked in mutton stock gravy, *Haleem* prepared from goat or buffalo meats or *Kolhapuri mutton* with different curries ^[64].

Unfortunately, many of these products are unknown to the general public, but they are the basis of foods for populations in developing countries, with peculiar sensory qualities and, at the same time, with high nutritional values and nutraceutical characteristics. Most of them deserve to be recognized as cultural heritages of the gastronomy of these countries and with world recognition with support and protection.

3. Conclusions

Several sheep and goat processed meat products confirm the importance of these species in consumer cultures around the world, and most of them have a great demand and are very well-appreciated in many countries and regions, such as North Europe, the Mediterranean area, Middle East, North Africa or Central Asia. In countries without a tradition of goat or sheep consumption, they are frequent in delicatessen stores or ethnic markets. Processed products such as sausages, *pâtés* or *frankfurters*, blending different animal or vegetal fat sources, can give additional value to the less-appreciated goat meat from culled animals. Using some natural antioxidant byproducts in meat processing, sheep and goat products can be used as functional health-promoting foods and can also improve the shelf life, product color and reduce the lipid and protein autoxidation. The rediscovery of a new generation of goat and sheep meat products as functional foods and eating quality is an exciting food research field, answering to the constant innovation requirements by the meat industry. Several possibilities exist to process sheep and goat meats to make them more diversified and appealing to the market.

The use of starter cultures, spices, essential oils and other additives may provide nutritional and sensory advantages of dry fermented sheep and goat sausages. Cured and smoked goat and sheep legs have great commercial potential, with a highly acceptable consumer commodity.

Traditional goat and sheep meat products are part of the cultures of their countries, and many of them must be better studied and characterized as a way to preserve and protect them in terms of certifications of their origins. The deep knowledge of the formulations, the optimization of processing methods, improving advancing packaging and preservation procedures and the organization of the distribution and marketing chains are actions that should be prioritized. Everything related to food safety and the increasing importance of traceability is detailed information to consumers and will continue to be a matter of constant concern and should be considered in the future.

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