



Aged to Perfection: The Art and Science of Fermented Meats

(*Mohamed Shabeer P M, Shruthi V S and Ashtami A M)

Department of Molecular Biology and Plant Biotechnology, College of Agriculture,
Kerala Agricultural University, Vellayani, Thiruvananthapuram-695522

*Corresponding Author's email: mohamedshabeer60@gmail.com

Abstract

Fermentation of meat is a traditional process of preserving meat. It has unique flavour, colour, aroma, and nutritional qualities due to various microorganisms present in it. The microbial diversity influences the flavour and nutritional quality of meat. Fermented sausages hold a larger share in the fermented meat product industry. Lactic acid bacteria are the important group of microorganisms present naturally in fermented meat products. Lactic acid bacteria improve the physio-chemical properties of fermented meat and inhibit the growth of unwanted microorganisms. Microorganisms used in these products show health benefits comprising better female reproductive health, gastrointestinal activities, immune response. Future of fermented products continues to grow because of advancements in production methods and safety standards.

Introduction

Fermentation is a metabolic process in which glucose is partially broken down to produce energy, acid, or alcohol without the presence of oxygen. Alcoholic fermentation produces ethanol and CO₂ in yeast. Lactic acid fermentation produces lactic acid in muscle cells and some bacteria. Meat fermentation is a traditional preservation method that involves the use of beneficial microorganisms such as bacteria, yeast, and Moulds to break down sugars and proteins in the meat and results in an acidic environment that inhibits the growth of harmful bacteria. Thus, this process not only increases shelf life but also enhances flavour and texture. Some common examples of fermented meat products are Sucuk, Hungarian Salami, Bologna, Frankfurters, Bacon, Ham, Summer Sausage, Nuoc-mam, Katsubushi, Loaves, Boudin blanc. The history of fermented meat dates back to ancient civilizations. The Chinese were among the first to produce raw, cured ham. Sausages, initially made from meat scraps, were essential to Roman military success and evolved into dry, fermented varieties across Europe. Fermented sausage production spread widely, with notable developments like Hungary's long-matured, Mould-covered sausages crafted by Italians in the 19th century. The general process of fermentation of meat involves incubating meat with starter culture, which involves beneficial bacteria, salt, and spices. This meat is left for fermentation at a controlled temperature for specific periods of time in a container. During fermentation, it is important to check the meat for spoilage and adjust the temperature or humidity accordingly to provide an ideal environment for fermentation. Fermented meat includes several health benefits, including increased nutritional content. Useful bacteria contain in fermented products help in digestion of food. Thus, meat become more digestible and also increases nutritional quality. These microorganisms also provide some probiotic benefits. Probiotics are beneficial bacteria that maintain gut bacteria balance, promoting overall digestive health. Beneficial bacteria in fermented meat can colonize the gut and keep harmful bacteria in check.

Ferment Meat Products

Fermented Sausages: Fermented sausages hold a larger share in the fermented meat product manufacturing industry. These are consumed in larger quantities by Europe and the United States, along with Germany. Fermented sausages are ground meat combined with salt and curing ingredients, then packed into casings and allowed to go through a fermentation process, where microorganisms are essential. Since most fermented sausages are dried, they don't require refrigeration when kept in storage. Due to additional salt, nitrite, and/or nitrate, as well as early lactic acid production by LAB organisms and subsequent drying that lowers the water activity, fermented sausages frequently have an extended shelf life.

Classification	Production	Characteristics	Sausages
Fresh sausages	Sausages are made from comminuted, uncured, raw meat (chiefly pork), seasoned and stuffed into casings, require cooking before consumption.	Fresh sausages have a high moisture content, which contributes to their juiciness when cooked. Low shelf life.	Bratwurst, Bockwurst, Fresh pork sausage
Dry sausages	Sausages are cured, air dried or smoked before drying, and do not require cooking before consumption.	Final moisture content between 25-44% and moisture protein content 2.3:1 or less.	Salami, Chorizo, Saucisson sec
Semi dry sausages	Sausages are partially dried through a controlled fermentation process and may be smoked. They require some cooking before eating.	Final moisture content 40-50% and moisture protein ratio of more than 2.3:1.	Summer Sausage, Pepperoni
Fresh, smoked sausages	Sausages are fresh meats cured or uncured, smoked to add flavour and aid in preservation. They must be fully cooked before serving.	Similar to fresh sausages but undergo an additional smoking process that imparts a distinct flavour and slightly extends their shelf life	Kielbasa, Andouillie, Mettwurst, Smoked country
Cooked sausages	Sausages are fully cooked during the production process and can be eaten as it is or reheated.	Typically, firm and smooth due to the cooking process.	Bologna, Frankfurters, Liver sausage.
Cooked meat sausages	Sausages are made from pre-cooked meats and are typically fully cooked during the production process.	The cooking process intensifies the meat and seasoning flavours.	Loaves, Boudin blanc, Goetta

Ham: Ham is meat from the posterior extremities of swine. The subcutaneous and intramuscular fat content determine the time necessary for ham drying and consequently affect flavour development. Iberian and Duroc breeds are popular in Spain for long-aged hams due to high fat content. The Hungarian Mangalitza breed is now used for dry-cured hams, while lean pigs produce dry-cured hams with shorter drying periods. Ham technology varies greatly, with variations in air-drying, smoking, curing methods, and local specialties. Uncooked ham production technologies, such as Parma-style ham, Ardennes-style ham, Coburg-style ham, and Holsteiner Katenschinken, also vary. Three distinct fabrication

methods, such as dry rub, cover pickle, and pumping, are employed, with differences in table salt concentration, nitrate presence, sugar, and spices. Drastic differences in processing can be observed between the Italian Parma-style ham, treated with table salt only and subsequently air-dried, and the Black Forest-style ham, which is cured with table salt, nitrate, and juniper-berries and thoroughly smoked until black, making it popular among various hams.

Bacon: Bacon is the salted and cured meat taken from the belly of pigs. Bacon is usually made from young animals of 6-7 months old which weigh about 140-250 pounds. Different types of bacon are made from different parts of pigs. But they have common salting and curing techniques which causes the varying texture, taste and flavours. Bacon can be produced through many ways like dry curing, wet curing etc.

In dry curing, the pork meat is rubbed with salt and seasonings which adds flavour and taste to the meat. This is the kept for some days. This process does not involve any wet ingredients. Dry curing takes more time compared to other process.

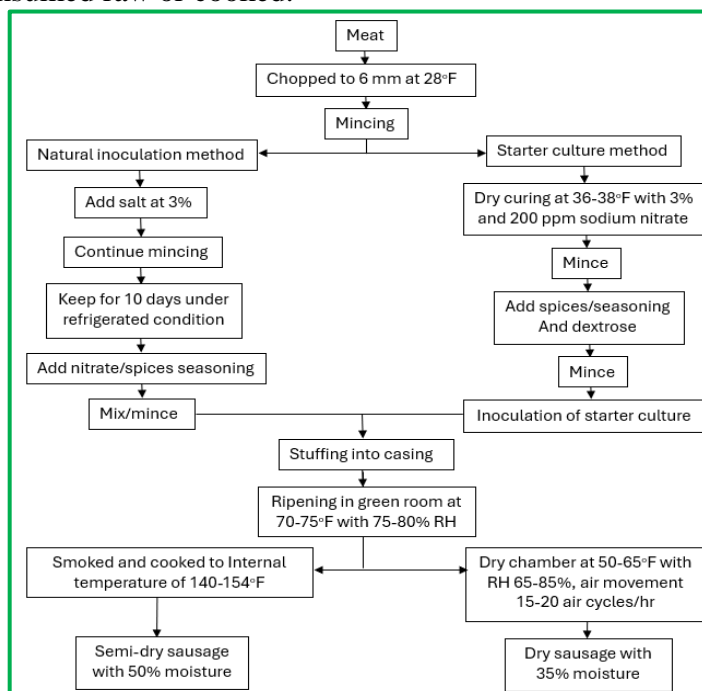
In wet curing the pork meat is either soaked in a brine solution or brine solution is injected which includes sodium nitrate, sugar, salt and other additives.

Fermented fish products

Fermented fish products are traditional foods produced by allowing fish to undergo a controlled fermentation process. This ancient preservation method enhances the flavour, texture, and nutritional profile of the fish. Common examples include fish sauce, widely used in Southeast Asian cuisines, and surströmming, a Swedish delicacy known for its strong aroma. The fermentation process involves salt and beneficial bacteria, which break down proteins and fats in the fish, creating unique taste profiles and preserving the fish for extended periods. Fermented fish products are rich in probiotics, which contribute to gut health, and are integral to many cultural diets worldwide.

Various fermented fish products include:

- **Nuoc-mam**, a clear brown liquid, is a fermented fish product made in Cambodia and Vietnam. Fish are brined with salt, and after initial fermentation, the liquid (nuoc-boi) is collected. The fish is then aged for months, with the superior first quality nuoc-mam drawn off and a second-rate product obtained by further extraction.
- **Bagoong** is a Filipino fish paste made from sea fish or shrimps, fermented with salt in clay vats for three months. It is consumed raw or cooked.
- **Prahoc**, from Cambodia, involves a two-stage fermentation process of descaled and salted fish, packed in wicker baskets, and later pounded into a paste and sun-dried. The fluid collected is used as a sauce, and the paste in soups.
- **Phack** (or mamchao) is another Cambodian paste made from salted fish and glutinous rice, with added roasted rice, sugar, or spices for flavour.
- **Katsuobushi** is a Japanese dried, hard fish product made from skipjack tuna or bonito, inoculated with *Aspergillus glaucus* to speed up ripening.



General production technology of fermented meat products

Microflora of Meat Fermentation

The growth of microorganisms in meat causes the deterioration of meat. Certain strains of fermentation microorganisms, such as Lactic Acid Bacteria (LAB), are naturally present in meat or introduced for fermentation to increase taste and flavour. However, the presence of these microbes in raw meat and meat products is not acceptable. Starter cultures are the culture of desired microorganisms added to meat dough to inoculate the process of fermentation. Starter cultures might consist of a single species or a range of microorganisms. A common microbe used to produce fermented meat products is lactic acid bacteria. While preventing the growth of undesirable microorganisms, lactic acid bacteria enhance the physiochemical properties of fermented sausages. However, LAB has also been identified as a spoiling bacterium because it promotes slime and smell production in sausages.

Micro-organisms use as culture	Effect on food	Formation of end substance	Changes in sensory attributes	Microorganism used in starter culture preparations
<i>Lactobacillus sp.</i> <i>Pedococcus sp.</i>	Acidulation and reduction of pathogenic as well as undesirable micro-organisms that compete with starter inoculation of meat products	Formation of ethanol acetin formats and strong-smelling sulphide, biogenic amine and bacteriocins are reported (Jessen, 1995)	Enhancement in meat products flavour	<i>L.plantarum</i> <i>L.eake</i> <i>L.curvatur</i> <i>L.pentosus</i> <i>P. lacidilactici</i> <i>P. pentosaceus</i>
<i>Saphylococcus xylosus</i> , <i>S. carnosus</i> , <i>Kocuria varians</i>	The flavour of the fermented meat products develops quickly and profoundly.	Methyl ketones from free fatty acid is e the end products	May or may not control sausage flavour in fermented meat products Olesen and Cutilis (Stahnke, 2000)	<i>S. xylosur</i> <i>S. carnosus</i> <i>M.varians</i>
<i>Debaryomyces hansenii</i>	In stabilisation of meat products colour particularly in sausages (Gehlenk et al., 1991)	Ammonia is the main end product in fermented meat products (Geisen et al., 1992) Acetates (Olesen and Stahnke, 2000)	May or may not control sausage flavour in fermented meat products Olesen and Cutilis (Stahnke, 2000)	<i>D.hansenti</i>
<i>Penicillium nalgiovense</i> , <i>P. camemberti</i> , <i>P. crysogenum</i>	Restrict the extent of mold that spreads on substrates and stop the growth of fungus that could cause mycotoxin	Some compound Popcorn-smelling compound 2-acetyl-1 pyrroline (Stahnke, 2000)	flavour	<i>P. nalgtovense</i>

Health aspects of fermented meat products

The main purpose of fermenting meat is to increase its shelf-life, although it also affects taste, texture, physical and chemical properties leading to products with desirable colour, flavour, and aroma. Microorganisms used in these products show additional health benefits including improved immune response, digestion of food, female reproductive health, and helps in

managing diseases like traveller's diarrhoea and microbial infections. Natural probiotics present in fermented meat products enhances diversity and option for starter culture. Consuming fermented meat products with probiotics may reduce immunological responses to allergens and improve overall health status in various clinical conditions. Daily uptake of fermented meat products is associated with an increased risk of cardiovascular diseases and cancer due to use of nitrate and nitrite salts in meat products which leads to formation of carcinogenic nitrosamines. Also, Sodium chloride used in fermented meat products, can contribute to an increased risk of cardiovascular disease when consumed above recommended levels. The World Health Organization has classified processed meat products in the same carcinogenic category as tobacco and asbestos. Despite their preservative benefits, nitrate and nitrite salts pose health risks, including potential cancer development.

Conclusion

Fermented meat products have a rich tradition and have become a vital part of culinary tradition. It has several health benefits. Selecting a starter culture with good characteristics is challenging and difficult. The fermented products not only provide increased shelf life but also enhance flavour and nutritional profile. The microbial diversity influences the flavour and nutritional quality of meat. Current research focuses on finding combinations of microbial strains that provide unique flavour and how these microorganisms produce different compounds through production pathways.

Studies indicate that microorganisms help in promoting desirable flavours and inhibiting harmful chemicals such as biogenic amines (Bas) and nitrosamines, though the precise mechanisms remain under investigation. As future research develops, it will provide valuable information and methods of producing fermented meat with more safety and less risk. Thus, it will help in the modernization and standardization of fermented meat production. Even though fermented meat provides many health benefits, it should be consumed in moderation due to potential health concerns like its high sodium content. The future of fermented products continues to grow because of advancements in production methods and safety standards. Fermented product's lasting popularity makes them an irreplaceable part of modern cuisine, which strikes a perfect balance between tradition and innovation.

References

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