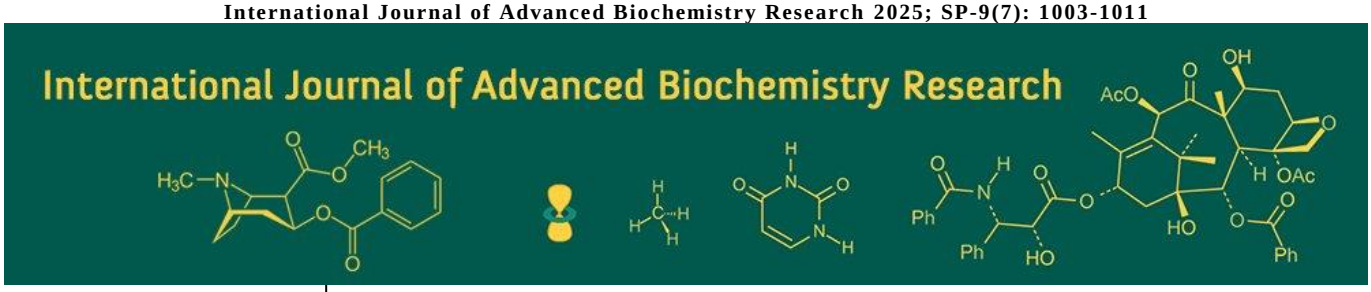


ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(7): 1003-1011
www.biochemjournal.com
Received: 22-04-2025
Accepted: 24-05-2025

Ashlesha Ranade
Assistant Professor, Department of Livestock Products Technology, Apollo College of Veterinary Medicine, Jaipur, Rajasthan, India

OP Malav
Associate Professor, Department of Livestock Products Technology, College of Veterinary Science, Rampura Phul, Bathinda, Punjab, India

Corresponding Author:
Ashlesha Ranade
Assistant Professor, Department of Livestock Products Technology, Apollo College of Veterinary Medicine, Jaipur, Rajasthan, India

Fermented meat products-A review

Ashlesha Ranade and OP Malav

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i7Sm.5062

Abstract
Fermentation is an old food preservation method that is commonly utilized in meat product manufacturing. Along with lactic acid bacteria (LAB), some yeasts & moulds are also utilized as starting cultures for the manufacture of fermenting food products. Bacteria such as *Lactobacilli*, *Staphylococci* and *Micrococcus* also involved in production of the fermented foods. Most common fermented meat products are sausages, other products that are included in this category are hams and jerky. Sausages are of four types-dry, semi-dry, moist and fresh. The Suckuk, Hungarian salami, summer sausage, Salchichon, Pepperoni and chorizo are the popular varieties of fermenting meat product. Fermentation also leads to the production of important compounds (bacteriocins, hydrogen peroxide, lactic acid, CO_2 etc.) that helps in the bio preservation of meat and meat products. Bacteriocins such as nisin, pediocin, curvacin suppress the growth of pathogens such as *Bacillus cereus*, *Staph aureus*, *klebsilla spp*., *E. coli*, *L. monocytogens* and *Kampylobacter* spp. Starter culture in fermented meat product also regulate the buildup of amine neurotransmitters in soured products without compromising flavor.

Keywords: Bacteriocin, biopreservation, lactic acid bacteria, sausages and starter culture

Introduction
The word "fermentation" was first used in reference to wine and beer about 6000 B.C. It is derived from the Latin Language verb fermentare, indicating the word ‘raise’. Fermentation is among the majority of affordable methods used in the food business to add flavor, nutrient content and longer shelf life to food products. Beneficial microorganisms, such as *Lactobacillus, Streptococcus, Lactococcus, Bifidobacterium*, and others, are applied during this process. Products made from fermented meats have a distinct aroma and higher nutritious content (Hao *et al.*, 2023) [29]. LAB are ubiquitous microbes for biopreservation, quick natural acid production, extended connection and approval as widely accepted as safe (Raman *et al.*, 2023) [57].

The different definitions of fermentation given by various researchers are provided below:

A method wherein microorganism-produced enzymes cause chemical reactions to take place in an organic substrate. (Liu and Kokare, 2017) [47].

Glycolysis is the biocatalyzed, energy-providing mechanism in the cells via "energy" substances like blood sugars are broken down without oxygen. Adenosine triphosphate (ATP), an energy-rich molecule, is always one of the pathway's products. The additional products come in a variety of forms: butyl alcohol, acetone, 2-hydroxy propanoic acid, vinegar; intoxicant, glycerol, and carbon dioxide from the alcoholic or ethanol fermentation of different carbohydrates. Bacteria fermentation leads to the production of antibiotics, gluconic acid, citric acid, whereas mold fermentation may lead to production of Vitamin B12 and B2. By using bacterial fermentation method Japanese create L-glutamic acid, an amino acid whose consequent is frequently employed as a seasoning/flavoring ingredient (Campbell-Platt, 1987) [8].

The breakdown of carbohydrates results in the release of gas. An analogue of respiration in biology that allows some organisms to survive and thrive in the absence of oxygen; It is employed in a number of industrial processes like to produce cheese, alcohols, and acids through the action of bacteria, yeasts, and molds. Zymosis generally refers to alcoholic fermentation. Alcoholic fermentation of sugars is a prerequisite for bread leavening.

The carbon dioxide gas is produced and trapped in the thick dough which causes the dough to rise **(**Nill, 2002**)** [51].

Meat fermentation

If microorganisms are involved in the ripening process, a meat product may be referred to as "fermented." Microbial activity on raw and/or salted meat pieces is limited to the surface, whereas cutting and grinding disperses both naturally occurring and introduced microbes throughout the product. Since ancient times, fermentation has been a cheap, easy way to preserve meat and meat products. Because of its improved keeping quality, health advantages, and bio preservative effect, fermented meat products are gaining popularity among masses (Hamm *et al.*, 2008) [28].

Currently, fermented meat products—mostly fermented sausages—make up twenty to forty percent of all cured meats products sold in European nation. In Europe, fermented foods are highly popular and make up between 3 and 5% of all meat consumption. Currently, the varieties of fermented meat products prepared is similar to cheese varieties produced. In Germany and Spain, respectively, there are over 350 and over 50 varieties of fermented sausages. Germany, Spain, France, and Italy are estimated to consume around six hundred million kg of soured sausage (Hutkins, 2006; Krockel, 2006) [33, 39]. The earliest reports of fermented meat product reported by Indian researchers by adding clarified butter, which contains LAB, throughout the manufacturing of cured meats (Hamm *et al.*, 2008) [28].

The increased nutritional value of foods products after fermentation is due to the increased soluble fraction, reduction of antinutritional components to a harmless level, production of macronutrients (primarily thiamine, B12, Vitamin B9 and vitamin B2), and necessary amino acid also, the process of fermentation also decreases the DM content (Adam, 1990). According to Gadaga *et al.* (1999) [26], fermentation eliminates and detoxifies unwanted ingredients like tannins, polyphenols, and phytates from raw foods. LAB in soured food, such as meat, which also enhance nutritional and organoleptic characteristics by blocking pathogenic germs. Meat fermentation enhances the eating quality parameters such as reddening and sliceability. Foods that have undergone fermentation are more easily digested, need less fuel or energy to heat when stored, and save money on transportation (Simango, 1997) [65].

In addition, the World Health Organization (WHO) suggested using fermentation technology to prepare and store different food items in order to avoid diarrheal illnesses, which are responsible for one-tenth of all baby deaths globally owing to dehydration. The advantages from fermented meat products over conventional meat based items were enumerated by Singh *et al.* (2012) [66]:

a) Development of meat products with enhanced flavor, taste, color, and odour.
b) Fermented meat products have soft texture due to proteolysis generated by microbial cultures throughout the ripening/souring process.
c) Fermented meat products have an extended life span because of its acidity, relatively little water and bacteriocin synthesis.
d) Meat products that have undergone fermentation are safe for human consumption because they stop the growth of harmful and spoiling bacteria.
e) Products made from fermented beef are less energy-intensive and simpler to produce.

Starter culture

Starter cultures, also called mixed or individual microbe cultures that are added to meat products at specified doses to initiate and facilitate fermentation. Yeasts, molds, and bacteria—especially non-pathogenic staphylococci & lactobacilli—can be employed as starters to boost the meat products safety that have undergone fermentation. The Federal Drug Administration (FDA) classifies starter cultures as safe for consumption. Starter cultures having ability to prevent the production of variants of unwanted pathogens i.e. disease causing agents (Holzapfel *et al.*, 2003 [32]; Young and O'sullivan, 2011 [81]; Fraqueza *et al.*, 2016) [25]. According to Šuškovič *et al.* (2010) [70] and Wang *et al.* (2013) [77], starting cultures consist of many species and strains of microorganisms that limit the development of harmful bacteria also suppress the formation of spoiling microbes.

According to Leroy *et al.* (2006) [45], the souring process in fermented meat products be either solely dependent on the "native or indigenous micro-organisms" for conventional foods or requires microbial strains for both handmade and commercial bologna. These starter cultures must be able to inhibit the growth of native microbes. Starter cultures becomes very popular for the production of fermented meat by the middle of the 20th century (Talon and Leroy, 2011) [73]. The microorganism cultures known as protective cultures are incorporated into the final product to protect it against any temperature fluctuations that may have occurred during storage. Lactic acid bacteria normally employed as culture in soured meat products are usually aerotolerant anaerobes and primarily classified into genera *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Lactococcus* and *Enterococcus* (Fraqueza *et al.*, 2016) [25]. The aerotolerant anaerobes *S. carnosus* and *Staph. xylosus* are among the more commonly employed strain in the fermentation of muscle foods (Stavropoulou *et al.*, 2018) [69]. The aerobic microbes belonging to the family Micrococcaceae, namely *Kocuria spp*. Along with the LAB bacteria are of value for the development of desired flavour and other characteristics in fermented meat products (Cocconcelli and Fontana, 2015) [10]. Meat batters contain both bacterial and yeast inoculants (Laranjo *et al.*, 2017a) [42].

LAB such as *Lactobacillus L. plantarum*, Pediococcus, *L. sakei and L. curvatus* are used for acid production. Curing bacteria *Micrococcus*, *Staphylococcus K. varians* and *S. xylosus* are used for color and flavor. Yeast such as *Debaromyces D. hanseii* and Candida *C. famata* are used for flavor development. Moulds such as *Penicilium P. naigiovense* are used for formation of white mold/white crust over the surface of meat products specifically the dry cured sausages. (Montel, 1999) [50].

Manufacturing of fermented meat products

Around the world, fermented meat products are made by many different ways. There are many names and procedures in every nation, the majority of which are customary to that nation. Prominent examples of soured animal source food items are Sucuk (Turkey), Hungarian Salami, Kantwurst (Austria), Lup Cheong (China), Milano Salami (Italy), summer sausage (USA), salami aeros (Greece), Chorizo (Mexico, Spain), Salchichon (Spain), Fuet (Spain), and Pepperoni (Canada, USA).

The decrease in the pH and the water activity on incubation of meat products is basic principle behind the manufacturing

of the different fermented meat products (Stadnik *et al.*, 2022) [68]. Aquilanti *et al.* (2007) [4] reported that the physical and chemical properties of the Italian salami *Ciauscolo* revealed gradual decrease in water activity and pH as the salami ripened. Based on viable counts, it was shown that LAB outnumbered non-staphylococcus cocci and yeasts. According to the molecular typing, the most common species among the yeasts was *Debaryomyces hansenii*, which was isolated during the entire ripening process. The most common species among the bacteria was *Lactobacillus curvatus*, *Lb.plantarum*, and *Staphylococcus xylosus*. *Trichosporon brassicae* and *Rhodotorula mucillaginosa*, two minority species, were also found in the meat batter (Aquilanti *et al.*, 2007) [4].

Turkish dry-fermented sausage, or sucuk, is a well-known example of fermented pork product manufactured in vast quantities throughout Turkey (Erkmen and Bozkurt, 2004) [20]. *Lactobacillus Sake*, *Lactobacillus Plantarum*, *Lactobacillus Curvatus*, and *Lactobacillus Brevis* are the main lactic acid producing organisms in Sucuk, despite the fact that the indigenous microbiota of meat are typically employed as a starting strain (Erginkaya *et al.*, 2019) [21].

Steps for preparation of fermented meat products: (Yilmaz and Velioglu, 2009) [80]

1. Inoculation

Starter culture, or lactic acid bacteria, is added after minced meat and other components are combined. The "back slopping" approach to immunization is sometimes employed. Using this technique, one day before production inoculation is done using the raw mixture. Starter culture contains a large number of lactic acid bacteria.

2. Fermentation

Following inoculation, the meat mixture is packed into casings and left to ferment for one to four days at average temperature from eighteen to fourty three degree Celsius and moisture content between 70% & 80%. The humidity chamber is used to control the temperature and humidity, which allows for adequate acid production and color development. Proper pH, temperature, and relative humidity monitoring are crucial for producing high-quality product.

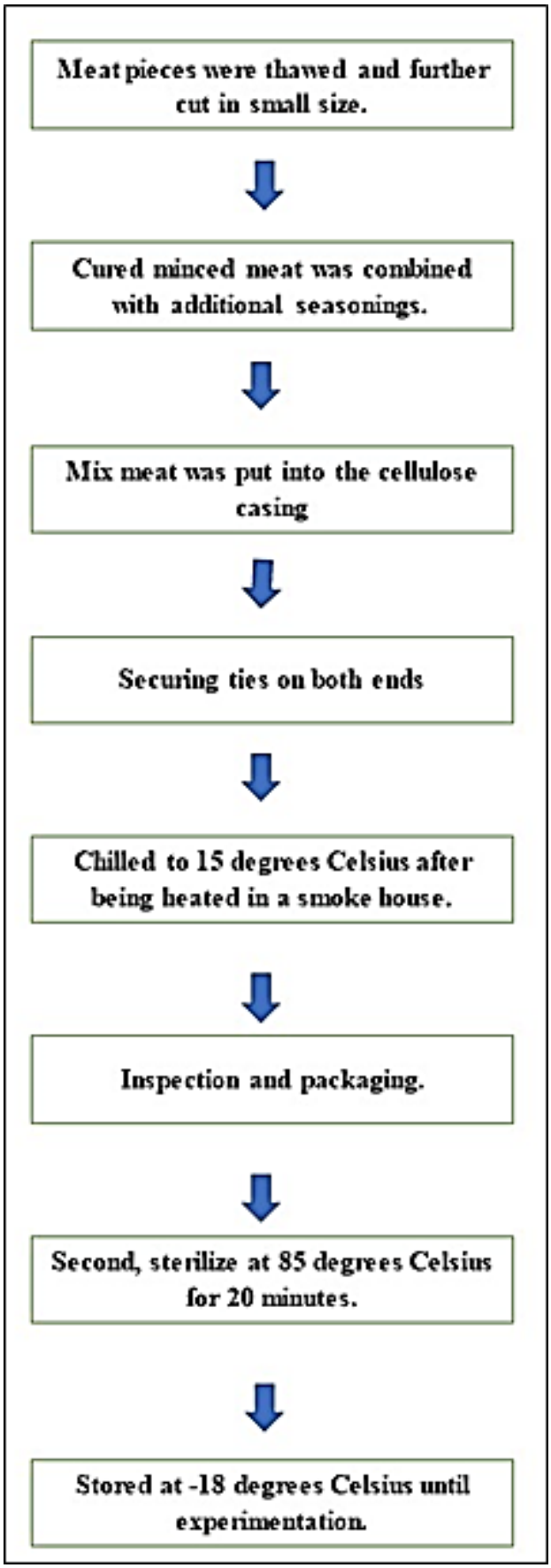
3. Drying

After fermentation finished, products are dried to the appropriate moisture content. Sausage that is semi-dry, meaning it contains 40-50% moisture, needs to be aged or dried for a maximum of five days. However, to attain the appropriate moisture: protein ratio, dry sausages (with moisture content of 30 to 40%) are dried for at least 10 days in a drying chamber. Products are cooked and/or smoked after drying, depending on requirements.

4. Storage

Dry sausages doesn't need to be stored at a cold temperature. Bacteria that cause spoiling cannot proliferate in environments with reduced pH, moisture content, and water activity. However, to avoid microbial deterioration during storage, semi-dry sausages need to be refrigerated.

Important steps for the processing of meat in fermented meat products are presented in Flow chart 1. Different fermented meat products are popular in the different regions of the globe. Many researchers also involved in the standardization of the procedure for the development of fermented meat products. This information is compiled and presented in Table 1



Flow chart 1: Procedure for fermented sausages processing (Lee *et al.*, 2018)

Table 1: Fermented meat products prepared by different researchers

Sr No.	Fermented meat products	Scientists involved
1.	Chinese dry sausage	Zhao *et al.*, (2020) [82]
2.	Salami (Europe)	Toldra, 2007 [74]
3.	Alheira in Portugese white sausage	Albano *et al.*, 2008 [3]
4.	Suckuk -Dry fermented sausage from Turkey	Kesmen *et al.* 2012, Gagaoua and Boudechicha, 2018 [27, 38]
5.	Nham (fermented pork product in Thailand	Chokesajjawatee *et al.* 2009 [9]
6.	Nem chua in Vietnam	La Anh, 2015 [40]
7.	Tiwanese ham	Tu *et al.*, 2010 [75]
8.	Wakalim-Ethiopian fermented sausage	Bacha *et al.*, 2010 [5]
9.	Jamma, Arjia and Kargyong in India	Oki *et al.*, 2011 [52]
10.	Boubnita- dry fermented Moroccan sausage	Gagoua and Boudechicha, 2018 [83]
11.	Pastirma -ready to eat pressed Egypt	Lucke, 2016 [84]
12.	Afo-hnama-fermented dried pork product from Nigeria	Uzogara *et al.*, 1990 [85]
13.	kargyong, suka komasu and satchu (India and Nepal)	Rai *et al.*, 2010 [56]
14.	Gueddid-salty, traditional dry meat from Moroccan, Algerian and Tunisian meat product.	Gagaoua and Boudechicha, 2018 [27]
15	Khlii-salted dried beef	Gagaoua and Boudechicha, 2018 [27]

Fermented sausage

The word "sausage" derives from the Latin term "salsus," which means salt. The meat used for making the sausages is chopped or minced and salted to preserve it. Sausage-making and consuming were documented as early as 1500 years before Christ in Babylonia & China. The materials for making bologna mix include minced or homogenized meat, binders, salts, spices, and flavorings. For fermentation, sugar is used as a medium to get the required substrate for the acid production. This uncooked bologna mixture has placed into a variety of natural, collagen, or artificial casings with different diameter and properties, and it is stretched upright in the ripened room for a preset time period (Xing *et al.*, 2023) [79].

Fermented meat products might be classified into two categories depending on the acid produced during fermentation: Products with lower acid levels (with a pH level as 6-5.3, preserved by air drying, Nacl-2.3-3.0 per cent) and meat products with higher acidity levels (with a pH level as 5.3-4.8), these products are preserved by infusing and removing moisture, temperature plays hardly important role in storage quality (Pearson and Gillet, 1997) [54]. For preservation of fermented sausage by lowering the water content and inhibiting the growth of microorganisms in these food items, common salt (2.5-3.0%) is essential. The higher acidity, lower water availability from acidification, and dehydration in the soured meat products are other potential variables that are preventing the microbial growth. (Holck *et al.*, 2017) [31].

Four varieties of fermented sausage are popular, namely fresh, dry bologna, semi-dry bologna, and moist/undried/spreadable bologna/emulsion, depending on the composition and processing circumstances. Goat or sheep meat is used in fresh sausages; they are not cooked, smoked, or fermented. With respect to method used, or the length of maturity, production time for semi-dry or dry bologna is essentially divided into two stages: fermenting and then dehydration. Emulsion sausages are made by combining sheep/ goat meat with varying quantities of hog fat (Leite *et al.* 2015) [44]. Fresh sausages need to be prepared just before eating, usually by grilling or frying, as they become perishable if not refrigerated. Fermented sausages are defined as various cuts of meat, such as sheep, goat, or pork that have been mixed to varying degrees with additional ingredients or additions and exposed to different temperatures & moisture levels. Their unique flavor, texture, and color, along with their quality and longevity, are determined by factors such as interaction of water (aw), salt, curing, drying & acidulation (particularly the lactic acid formed during the maturity process by various helpful microbes such as *lactobacillus*). (Holck *et al.*, 2017) [31].

Uncontrolled meat fermentation led to excessive acid production, which results into the production of fermented products with unacceptable sensory qualities (Ray, 2004) [58].

Dry fermented sausage

In the meat industry, dry bologna are referred to as Ne-plus Ultra. The term "dry soured sausages" refers to meat products that are prepared by ripening, curing, and occasionally smoking meat and fat, along with the addition of spices, sauces, and other approved additives (Juan *et al.*, 1999) [36]. Dry sausage production is an extremely time-consuming and skilled operation. Dry sausages are often merely dried, uncooked, and occasionally lightly smoked. Compared to semi-dry sausages, dry-fermented sausages have less acidity. In traditional dry fermented sausage manufacturing, the incubation and ripening stage lasts approximately ninety days. It is susceptible to a decline in quality over such an extended period. Therefore, meticulous ripening control is essential to the creation of salami (dry sausages).

During preparation of dry, cured and salted products, each ingredients is put in refrigeration before filling to provide a media for the cultivation of bacteria. The drying area maintains an air velocity of fifteen to twenty rotations/ hour, resulting in a weight loss of twenty-five to thirty percent. To achieve the required levels of concentration of lactic acid and pH level (4.8 to 5.3), ripening is carried out between 15-35°C. The ultimate hydration level of an item in the product is regulated between twenty five and fifty percent. The proportion of moisture relative to protein is less than 2.3: 1 at this degree of dryness. In the US, fermentation is done for 24 hours at a high temperature (30 to 45°C) to speed up the process. (Feiner, 2006) [24]. In starter cultures, *Pediococci* outperform *Lactobacilli* in this quick approach. *Lactobacilli* are typically utilized at a temperature of 20 to 26°C, which is the standard in Europe. At temperatures above 30°C, the

rapid acid production by *Pediococci* inhibits the development of other pathogenic microbes. *Micrococcaceae* are not inhibited by a decreased rate of acid generation at colder temperatures. Because the *Micrococcaceae* convert nitrates to nitrites, they have a significant impact on the development of color during ripening. Some common dry fermented sausages are cervelat, pepperoni, geneo, salami, and mortadella. The incorporation of probiotics or starter culture into these sausages is possible because they aren't being heated/cooked. (Farnworth & Champagne, 2016) [23].

Nham is a type of traditional Thai sausage that is made by combining garlic and salt with pork. The mixture is agitated for 72 to 80 hrs at 30 degree celsius after being wrapped in banana leaves or placed within cellulose casings. It is consumed uncooked, with the major microbiota being *Lactococcus* and *Pediococcus*. (Valyasevi and Rolle, 2002) [76].

Semi dry sausages

The ground beef, pork, or a mix of beef and pork is used to make the semi-dry sausages. Temperature, duration of ripening, and salt combinations, control the fermentation process. The entire process of fermentation takes about one to four weeks to finish. Because of high acidity levels, these sausages have an acidic and tangy flavor. The goal of the fermentation process is to produce finished products with a pH of between 4.7 and 5.3, acidity levels of 0.5-2.3% lactic acid, 3.5 percent level of Nacl, and thirty to fifty percent moisture level. The low pH, more Nacl content and hydration ratio, and heat treatment are responsible for the improved shelf life of semi-dry sausages. About 6-12 grams of dextrose are added to 100 pounds of meat as a fermentation substrate to achieve the appropriate degree of acidity. Some common semi-dry sausage varieties are Thuringer, summer sausage, and cervelat. (Rust, 2007) [63].

Bacteriocins and host defense peptides

Bacteriocins, are one of the several antibacterial substances made by LAB. According to several researchers (Cotter *et al.*, 2005 [14]; Hassan *et al.*, 2012 [30]; Collins *et al.*, 2017 [12]; Mokoena, 2017) [49], bacteriocins might be considered as a different class of antimicrobial agents. They are a class of peptides that have bacterial growth inhibitor activity against closely related species, such as several Gram-positive and other bacteria that are pathogenic, cause food poisoning, and spoilage, including *Bacillus cereus, E. coli, S. aureus, L. monocytogenes and Campylobacter spp.* (Laranjo *et al.*, 2017a) [42]. They are produced ribosomaly and extruded from the microbial cells (Keşka *et al.*, 2017) [37]. Nisin, pediocin, sakacin, curvacin, plantaricin, and bacteriolytic enzyme including lysostaphin and enterolysin A are a few examples of bacteriocins. Some bacteriocins also has a wide-ranging inhibitory effect that includes both monoderm and diderm as well as fungi (Keşka *et al.*, 2017) [37].

Cuvacin is produced by *Lactobacillus curvatus and* their sensitive micro-organisms are *Listeria monocytogens, Staphylococcus aureus, Brochothrix thermosphacta, Escherichia coli & Pseudomonas spp.* (Dicks *et al.*, 2004 [16]; Cocolin and Rantsiou, 2007) [11]. Nisin producing species is *Lactococcus lactis and its* sensitive micro-organisms is *Listeria monocytogens Staphylococcus aureus, Clostridium tyrobutyricum* (Dal Bello *et al.*, 2010; Biscola *et al.*, 2013 [6]; Parapouli *et al.*, 2013). Pediocin producing bacteria is *Pediococcus spp.* and its sensitive micro-organisms are *Listeria monocytogens, Brochotrix spp., Clostridium spp., Bacillus spp. and Enterococcus spp.* (Suskovic *et al.*, 2010; Keska *et al.*, 2017) [37]. Enterolysin A producing species are *Enterococcus faecalis, Enterococcus malodoratus* and their sensitive micro-organisms are *Listeria monocytogens and Staphylococcus aureus* (Suskovic *et al.*, 2010). Lysostaphin is produced by *Staphylococcus simulans* and its sensitive organism is *Staphylococcus aureus* (Suskovic *et al.*, 2010).

The decreased efficacy of bacteriocins in food matrix might be due to the bacteriocin molecules adhering to the fat in the dietary matrix, as well as from proteases and other enzymes weakening the structure. Pragalaki *et al.* (2013) [55] stated that bacteriocins are not uniformly distributed throughout the food matrix and can be suppressed by curing chemicals and salt. Nevertheless, to stop pathogen growth in sausages, bacteriocin containing Lactic Acid Bacteria have been employed as biopreservation cultures. Indeed, De Martinis and Franco (1998) [15] reported that the use of a *Lb. sakei* variety for inoculum in soured bologna resulted in decreased growth of *L. monocytogenes*. Bacteriocin produced by Lactobacilli and other bacteria have the potential as advantageous ingredients in dry-cured and soured products because of their antimicrobial activity (Keşka *et al.*, 2017) [37].

Possible health hazards from fermented meat products

Microbial hazards: The primary microbiological risks associated with fermented meat products include contamination with foodborne pathogens such as *Salmonella species*, *Campylobacter species*, *L. monocytogenes*, verocytotoxigenic *Escherichia coli (VTEC*), *Yersinia enterocolitica*, and *Yersinia pseudotuberculosis*, in addition to their poisonous substance of *Staphylococcus aureus*, *Clostridium perfringens*, and *Clostridium botulinum* (EFSA, 2015) [19]. On the other hand, a starting culture can postpone the commencement of additional contamination, prolonging a food product's shelf life (Young and O'Sullivan, 2011) [81]. Primary function of Lactic Acid Bacteria starting cultures is to prevent or control microbial risks.

Mycotoxins

Mold and fungus may contaminate the muscle foods resulting in production of mycotoxins. These are lower-level fungus derivatives with varying degrees of toxicity that can cause sickness. They damage the immune response, neurological system, liver, kidneys, blood. Certain mycotoxins such as aflatoxin is cancer causing agent and may have several other detrimental effects on health. Aflatoxin A (OTA), Patulin, Fusarium toxins, and aflatoxins are the most significant in terms of their effect on health. The most harmful ones are thought to be aflatoxins, and liver disorders have been linked to low-level, prolonged exposure to aflatoxins (Afum *et al.*, 2016) [2]. A number of fungi from the genera *Penicillium* and *Aspergillus* have been shown in recent studies to contain OTA, an important secondary metabolite in dry-cured hams and sausages (Iacumin *et al.*, 2009; Rodríguez *et al.*, 2012; Comi and Iacumin, 2013; Rodríguez *et al.*, 2015) [13, 34].

Biogenic amines

Nitrogenous molecules called biologically active amines (BA) are produced from biomolecules (Suzzi and Torriani, 2015; Elias *et al.*, 2018) [22, 72]. Numerous investigations

have examined for the composition & profile for Biogenic Amines found in soured pork items (Suzzi, 2003; Roseiro *et al.*, 2010; Laranjo *et al.*, 2016) [41, 61, 72]. The most common dietary BA linked to health issues are histamine, tyramine, and phenylethylamine; these can cause changes in blood vessel and changes in mental state, such as scromboid poisoning, food-induced migraines. Sensitivity to dietary histamine resulting in food sensitivity, and tyramine presser response (Spano *et al.*, 2010; Linares *et al.*, 2011) [46, 67]. The autochthonous starter cultures can regulate the build-up of Biogenic Amines in soured beef items without compromising its flavor (Lorenzo *et al.*, 2017) [48]. Conversely, the *P. pentosaceus* and *S. xylosus* variety as microbial culture strains failed to stop the build-up of putrescine and tyramine generated by certain native Lactic Acid Bacteria, indicating an inefficient employ of inoculum (Pasini *et al.*, 2018) [53].

Nitrosoamines

In bromatology, fermentation and spoiling processes have occasionally been linked to BA. Particularly when nitrites are present, these amines have the ability to nitrosate to generate nitrosamines (Ruiz-Capillas and Jimenez-Colmenero, 2004) [62]. Nitric oxide, a nitrosating agent that can combine with amines to form nitrosamines, can be obtained by converting nitrite. Indeed, nitrosamines, which are very carcinogenic, can be created when nitric oxide combines with secondary amines. While tertiary amines can scarcely create N-nitrosamines, these are longer lasting than those made from original amines, which degrade rapidly (Douglas *et al.*, 1978) [17]. The International Agency for research on Cancer (IARC) of the World Health of Organization (WHO) has reported link between the eating of processed meat products and the danger of colon and rectum cancer due to the presence of nitrosamine in the cured meat products (Bouvard *et al.*, 2015, IARC, 2015) [7, 35]. Alternative vegetative curing agents should be employed to prevent the formation of nitrosamine in the fermented meat products (Sebranek *et al.*, 2012) [64].

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAH's), are formed in the foods treated with high temperature, these compounds don't include oxygen atom and nitrogen atom or molecules modified by these groups in the structure (Wenzl *et al.*, 2006; Lawal, 2017) [43, 78]. Dietary source are the most common ways for the exposure of people to the PAH's (Duan *et al.*, 2016) [18]. PAHs found in the surrounding environment, as well as those produced during food processing and cooking, can contaminate food items (Lawal, 2017) [43]. A common method of flavoring used on several kinds of cured meat products is smoking. According to Holck *et al.* (2017) [31], smoking has the benefit of preventing the formation of mold & germs on items surfaces. It slows down the oxidation of lipids and imparts a distinct smokey flavor.

Conclusion

The development of innovative fermentation-based meat products has promising future due to the enhanced convenience, nutritional content, sensory qualities, biopreservation, and unique tangy flavour is a promising future prospect in meat processing. In the recent years, demand for cured, fermented and smoked meat and meat products had increased dramatically. As an outcome, the meat production sector is searching for effective microbial strains to enhance meat products' visual appeal, nutrient content & biosecurity. Additional research is required to determine the contribution of starters in regulating the level of nitrosamines or PAH, despite the truth that starters have been shown beneficial microbial safety by preventing the growth of pathogenic microorganisms in the fermented muscle foods.

References

1. Adams MR. Topical aspects of fermented foods. Trends Food Sci Technol. 1990;1:141-144.
2. Afum C, Cudjoe L, Hills J, Hunt R, Padilla LA, Elmore S. Association between aflatoxin M1 and liver disease in HBV/HCV infected persons in Ghana. Int J Environ Res Public Health. 2016;13:377. doi:10.3390/ijerph13040377
3. Albano H, Henriques I, Correia A, Hogg T, Teixeira P. Characterization of microbial population of "Alheira" (a traditional Portuguese fermented sausage) by PCR-DGGE and traditional cultural microbiological methods. J Appl Microbiol. 2008;105:2187-2194. doi:10.1111/j.1365-2672.2008.03947.x
4. Aquilanti L, Santarelli S, Silvestri G, Osimani A, Petruzzelli A, Clementi F. The microbial ecology of typical Italian salami during its natural fermentation. Int J Food Microbiol. 2007;120(1-2):136-145. doi:10.1016/j.ijfoodmicro.2007.06.010
5. Bacha K, Jonsson H, Ashenafi M. Microbial dynamics during the fermentation of wakalim, a traditional Ethiopian fermented sausage. J Food Qual. 2010;33:370-90. doi:10.1111/j.1745-4557.2010.00326.x
6. Biscola V, Todorov SD, Capuano VSC, Abriouel H, Galvez A, Franco BD. Isolation and characterization of a nisin-like bacteriocin produced by Lactococcus lactis strain isolated from charqui, a Brazilian fermented, salted and dried meat product. Meat Sci. 2013;93:607-13. doi:10.1016/j.meatsci.2012.11.021
7. Bouvard V, Loomis D, Guyton KZ, Grosse Y, El Ghissassi F, Benbrahim-Talla L. Carcinogenicity of consumption of red and processed meat. Lancet Oncol. 2015;16:1599-600.
8. Campbell-Platt G. Fermented foods of the world - a dictionary and guide. London: Butterworths; 1987. ISBN: 0-407-00313-4
9. Chokesajjawatee N, Pornaem S, Zo YG, Kamdee S, Luxananil P, Wanasen S, Valyasevi R. Incidence of Staphylococcus aureus and associated risk factors in Nham, a Thai fermented pork product. Food Microbiol. 2009;26:547-551.
10. Cocconcelli PS, Fontana C. Bacteria. In: Toldrá F, editor. Handbook of Fermented Meat and Poultry. Chichester: John Wiley & Sons; 2015. p. 117-128.
11. Cocolin L, Rantsiou K. Sequencing and expression analysis of Sakacin genes in Lactobacillus curvatus strains. Appl Microbiol Biotechnol. 2007;76:1403-1411. doi:10.1007/s00253-007-1120-1128
12. Collins FWJ, O'Connor PM, O'Sullivan O, Gomez-Sala B, Rea MC, Hill C. Bacteriocin gene-trait matching across the complete Lactobacillus pan-genome. Sci Rep. 2017;7:3481. doi:10.1038/s41598-017-03339-y

13. Comi G, Iacumin L. Ecology of moulds during the pre-ripening and ripening of San Daniele dry cured ham. Food Res Int. 2013;54:1113-1119. doi:10.1016/j.foodres.2013.01.031
14. Cotter PD, Hill C, Ross RP. Bacteriocins: developing innate immunity for food. Nat Rev Microbiol. 2005;3:777-88. doi:10.1038/nrmicro1273
15. De Martinis ECP, Franco BD. Inhibition of Listeria monocytogenes in a pork product by a Lactobacillus sake strain. Int J Food Microbiol. 1998;42:119-126. doi:10.1016/s0168-1605(98)00059-2
16. Dicks LM, Mellett FD, Hoffman LC. Use of bacteriocin-producing starter cultures of Lactobacillus plantarum and Lactobacillus curvatus in production of ostrich meat salami. Meat Sci. 2004;66:703-708. doi:10.1016/j.meatsci.2003.07.002
17. Douglas ML, Kabacoff BL, Anderson GA, Cheng MC. Chemistry of nitrosoamine formation, inhibition and destruction. J Soc Cosmet Chem. 1978;29:581-606.
18. Duan X, Shen G, Yang H, Tian J, Wei F, Gong J. Dietary intake polycyclic aromatic hydrocarbons (PAHs) and associated cancer risk in a cohort of Chinese urban adults: inter- and intra-individual variability. Chemosphere. 2016;144:2469-2475. doi:10.1016/j.chemosphere.2015.11.019
19. European Food Safety Authority (EFSA). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013. EFSA J. 2015;13:3991. doi:10.2903/j.efsa.2015.3991
20. Erkmen O, Bozkurt H. Quality characteristics of retailed sucuk (Turkish dry-fermented sausage). Food Technol Biotechnol. 2004;42(1):63-69.
21. Erginkaya Z, Yalanca İ, Ünal Turhan E. Geleneksel et ürünlerindeki laktik asit bakterilerinin antibiyotik direnç profili. Pamukkale Univ J Eng Sci. 2019;25(7):834-838.
22. Elias M, Fraqueza MJ, Laranjo M. Biogenic amines in food: presence and control measures. In: Stadnik J, editor. Biogenic Amines (BA): Origins, Biological Importance and Human Health Implications. New York: Nova Science Publishers, Inc.; 2018. p. 129-176.
23. Farnworth ER, Champagne CP. Production of probiotic cultures and their incorporation into foods. In: Watson RR, Preedy VR, editors. Bioactive Foods in Promoting Health. Cambridge: Academic Press; 2016. p. 303-318. doi:10.1016/B978-0-12-802189-7.00020-4
24. Feiner G. Typical raw fermented salami products from around the world. In: Meat Products Handbook - Practical Science & Technology. Woodhead Publishing Series in Food Science, Technology and Nutrition; 2006. p. 376-382.
25. Fraqueza MJ, Patarata L, Laukova A. Protective starter cultures and bacteriocins in fermented meats. In: Zdolec N, editor. Fermented Meat Products: Health Aspects. New York: CRC Press; 2016. p. 228-269.
26. Gadaga TH, Mutukumira AN, Narvhus JA, Feresu SB. A review of traditional fermented foods and beverages of Zimbabwe. Int J Food Microbiol. 1999;53:1-11.
27. Gagaoua M, Boudechicha HR. Ethnic meat products of the North African and Mediterranean countries: An overview. J Ethn Foods. 2018;5(2):83-98.
28. Hamm WP, Haller D, Ganzle MG. Fermented meat products. In: Farnworth ER, editor. Handbook of Fermented Functional Foods. USA: CRC Press; 2008.
29. Hao M, Wang W, Zhang J, Chen L. Flavour characteristics of fermented meat products in China: A review. Fermentation. 2023;9(9):830. doi:10.3390/fermentation9090830
30. Hassan M, Kjos M, Nes IF, Diep DB, Lotfipour F. Natural antimicrobial peptides from bacteria: characteristics and potential applications to fight against antibiotic resistance. J Appl Microbiol. 2012;113:723-36. doi:10.1111/j.1365-2672.2012.05338.x
31. Holck A, Axelsson L, McLeod A, Rode TM, Heir E. Health and safety considerations of fermented sausages. J Food Qual. 2017;2017:9753894. doi:10.1016/j.fm.2011.06.016.
32. Holzapfel WH, Schillinger U, Geisen R, Lücke FK. Starter and protective cultures. In: Russell NJ, Gould GW, editors. Food Preservatives. Boston, MA: Springer; 2003. p. 291-320. doi:10.1007/978-0-387-30042-9_14.
33. Hutkins RW. Meat fermentation. In: Microbiology and Technology of Fermented Foods. Ames, Iowa: Blackwell Publishing; 2006.
34. Iacumin L, Chiesa L, Boscolo D, Manzano M, Cantoni C, Orlic S. Moulds and ochratoxin A on surfaces of artisanal and industrial dry sausages. Food Microbiol. 2009;26:65-70. doi:10.1016/j.fm.2008.07.006.
35. IARC. Consumption of red meat and processed meat. In: IARC Monographs. Lyon: IARC; 2015.
36. Juan AO, Eva MH, Jose MB, Lorenzo DLH. Changes in the components of dry-fermented sausages during ripening. Crit Rev Food Sci Nutr. 1999;39(4):329-367. doi:10.1080/10408699991279204.
37. Keska P, Stadnik J, Zielinska D, Kolozyn-Krajewska D. Potential of bacteriocins from LAB to improve microbial quality of dry cured and fermented meat products. Acta Sci Pol Technol Aliment. 2017;16:119-26. doi:10.17306/J.AFS.0466.
38. Kesmen Z, Yetiman AE, Gulluce A, Kacmaz N, Sagdic O, Cetin B. Combination of culture-dependent and culture-independent molecular methods for the determination of lactic microbiota in sucuk. Int J Food Microbiol. 2012;153:428-435. doi:10.1016/j.ijfoodmicro.2011.12.008.
39. Kröckel L. Use of probiotic bacteria in meat products. Fleischwirtschaft. 2006;8:610-619.
40. La Anh N. Health-promoting microbes in traditional Vietnamese fermented foods: a review. Food Sci Hum Wellness. 2015;4:147-161. doi:10.1016/j.fshw.2015.08.004.
41. Laranjo M, Gomes A, Agulheiro-Santos AC, Potes ME, Cabrita MJ, Garcia R. Characterisation of "Catalão" and "Salsichão", Portuguese traditional sausages with salt reduction. Meat Sci. 2016;116:34-42. doi:10.1016/j.meatsci.2016.01.015.
42. Laranjo M, Elias M, Fraqueza MJ. The use of starter cultures in traditional meat products. J Food Qual. 2017;2017:9546026.
43. Lawal AT. Polycyclic aromatic hydrocarbons: a review. Cogent Environ Sci. 2017;3:1339841.
44. Leite A, Rodrigues S, Pereira E, Paulos K, Oliveira AF, Lorenzo JL, *et al.* Physicochemical properties, fatty acid profile and sensory characteristics of sheep and goat meat sausages with different pork fat levels. Meat Sci. 2015;105:114-120.

45. Leroy F, Verluyten J, De Vuyst L. Functional meat starter cultures for improved sausage fermentation. Int J Food Microbiol. 2006;106:270-285.
46. Linares DM, Martin M, Ladero V, Alvarez MA, Fernandez M. Biogenic amines in dairy products. Crit Rev Food Sci Nutr. 2011;51:691-703. doi:10.1080/10408398.2011.582813.
47. Liu X, Kokare C. Microbial enzymes of use in industry. In: Biotechnology of Microbial Enzymes. Production, Biocatalysis and Industrial Applications. 2017. p. 267-98.
48. Lorenzo JM, Munekata PES, Dominguez R. Role of autochthonous starter cultures in the reduction of biogenic amines in traditional meat products. Curr Opin Food Sci. 2017;14:61-65. doi:10.1016/j.cofs.2017.01.009.
49. Mokoena MP. Lactic acid bacteria and their bacteriocins: classification, biosynthesis and applications against uropathogens. Molecules. 2017;22:E1255. doi:10.3390/molecules22081255.
50. Montel MC. Fermented meat products. In: Academic Press; 1999. p. 744-753.
51. Nill K. Glossary of Biotechnology Terms. 3rd ed. Florida: CRC Press; 2002.
52. Oki K, Rai AK, Sato S, Watanabe K, Tamang JP. Lactic acid bacteria isolated from ethnic preserved meat products of the Western Himalayas. Food Microbiol. 2011;28:1308-15. doi:10.1016/j.fm.2011.06.001.
53. Pasini F, Soglia F, Petracci M, Caboni FM, Marziali S, Montanari C. Effect of fermentation with different lactic acid bacteria starter cultures on biogenic amine content and ripening patterns in dry fermented sausage. Nutrients. 2018;10:E1497. doi:10.3390/nu10101497.
54. Pearson AM, Gillett TA. Sausages. In: Processed Meats. New York: Chapman and Hall; 1997. p. 210-241.
55. Pragalaki T, Bloukas JG, Kotzekidou P. Inhibition of Listeria monocytogenes and Escherichia coli O157:H7 in broth and fermented sausage using autochthonous starter culture. Meat Sci. 2013;95:458-64. doi:10.1016/j.meatsci.2013.05.034.
56. Rai AK, Palni U, Tamang JP. Microbiological studies of ethnic meat products of the Eastern Himalayas. Meat Sci. 2010;85:560-567.
57. Raman J, Kim JS, Choi KR, Eun H, Yang D, Ko YJ, *et al.* Application of lactic acid bacteria in sustainable agriculture. Int J Mol Sci. 2022;23(14):7784. doi:10.3390/ijms23147784.
58. Ray B. Fundamentals of Food Microbiology. USA: CRC Press; 2004.
59. Rodriguez A, Rodriguez M, Martin A, Delgado J, Córdoba JJ. Presence of ochratoxin A on the surface of dry cured Iberian ham after initial fungal growth in the drying stage. Meat Sci. 2012;92:728-734. doi:10.1016/j.meatsci.2012.06.029.
60. Rodriguez A, Bernádez V, Rodriguez M, Andrade MJ, Núñez F, Córdoba JJ. Effect of selected protective cultures on ochratoxin A accumulation in dry cured Iberian ham. LWT Food Sci Technol. 2015;60:923-8. doi:10.1016/j.lwt.2014.09.059.
61. Roseiro LC, Gomes A, Gonçalves H, Sol M, Cercas R, Santos C. Effect of processing on proteolysis and biogenic amines formation in "Chouriço Grosso de Estremoz e Borba PGI". Meat Sci. 2010;84:172-179. doi:10.1016/j.meatsci.2009.08.044.
62. Ruiz-Capillas C, Jiménez-Colmenero F. Biogenic amines in meat and meat products. Crit Rev Food Sci Nutr. 2004;44:489-499.
63. Rust RE. US products. In: Toldrá F, editor. Handbook of Fermented Meat and Poultry. Hoboken, NJ: Blackwell Publishing; 2007. p. 303-306.
64. Sebranek JG, Jackson-Davis AL, Myers KL, Lavieri NA. Advances in natural/organic curing processes in the United States. Meat Sci. 2012;92:267-273. doi:10.1016/j.meatsci.2012.03.002.
65. Simango C. Potential use of traditional fermented foods for weaning in Zimbabwe. Soc Sci Med. 1997;44:1065-8.
66. Singh VP, Pathak V, Verma AK. Fermented meat products: organoleptic qualities and biogenic amines—a review. Am J Food Technol. 2012;7:278-288.
67. Spano G, Russo P, Lonvaud-Funel A, Alexandre H, Grandvalet C. Biogenic amines in fermented foods. Eur J Clin Nutr. 2010;64(Suppl 3):S95-100. doi:10.1038/ejcn.2010.218.
68. Stadnik J, Keska P, Gazda P, Siłka Ł, Kołozyn-Krajewska D. Influence of LAB fermentation on the color stability and oxidative changes in dry-cured meat. Appl Sci. 2022;12:11736. doi:10.3390/app122211736.
69. Stavropoulou DA, De Vuyst L, Leroy F. Nonconventional starter cultures of coagulase-negative staphylococci: a SWOT analysis. J Appl Microbiol. 2018;125:1570-86. doi:10.1111/jam.14054.
70. Šuškovič J, Kos B, Beganović J, Pavunc AL, Habjanič K, Matošić S. Antimicrobial activity of probiotic and starter LAB. Food Technol Biotechnol. 2010;48:296-307.
71. Suzzi G. Biogenic amines in dry fermented sausages: a review. Int J Food Microbiol. 2003;88:41-54. doi:10.1016/S0168-1605(03)00080-1.
72. Suzzi G, Torriani S. Editorial: biogenic amines in foods. Front Microbiol. 2015;6:472. doi:10.3389/fmicb.2015.00472.
73. Talon R, Leroy S. Diversity and safety hazards of bacteria involved in meat fermentation. Meat Sci. 2011;89:303-309.
74. Toldrá F. Handbook of Fermented Meat and Poultry. Oxford: Blackwell Publishing; 2007.
75. Tu RJ, Wu HY, Lock YS, Chen MJ. Microbial dynamics during ripening of traditional Taiwanese naturally fermented ham. Food Microbiol. 2010;27:460-7. doi:10.1016/j.fm.2009.12.011.
76. Valyasevi R, Rolle RS. An overview of small-scale food fermentation technologies in developing countries. Int J Food Microbiol. 2002;75:231-239.
77. Wang XH, Ren HY, Liu DY, Zhu WY, Wang W. Effects of inoculating Lactobacillus sakei starter cultures on microbiological quality and nitrite depletion of Chinese fermented sausages. Food Control. 2013;32:591-6. doi:10.1016/j.foodcont.2013.01.050.
78. Wenzl T, Simon R, Anklam E, Kleiner J. Analytical methods for PAHs in food and the environment. Trends Anal Chem. 2006;25:716-725. doi:10.1016/j.trac.2006.05.010.
79. Xing B, Zhou T, Gao H, Wu L, Zhao D, Wu J, *et al.* Flavor evolution of normal and low fat Chinese sausage

during natural fermentation. Food Res Int. 2023;169:112937.
80. Yilmaz I, Velioglu HM. Fermented meat products. In: Quality of Meat and Meat Products. New Delhi: Studium Press; 2009. p. 1-16. ISBN: 978-81-7895-386-1.
81. Young NWG, O'Sullivan GR. The influence of ingredients on product stability and shelf life. In: Kilcast D, Subramaniam P, editors. Food and Beverage Stability and Shelf Life. Sawston: Woodhead Publishing; 2011. p. 132-183. doi:10.1533/9780857092540.1.132.
82. Zhao B, Zhou H, Zhang S, Pan X, Li S, Zhu N, *et al.* Changes of protein oxidation, lipid oxidation and lipolysis in Chinese dry sausage with different sodium chloride content. Food Sci Hum Wellness. 2020;9:328-37. doi:10.1016/j.fshw.2020.04.013.
83. Gagoua E, Boudechicha R. Fermented meat products: Production and microbiological safety. Afr J Microbiol Res. 2018;12(10):222-230.
84. Lucke FW. Fermented meat products. Food Res Int. 2016;89(Pt 1):464-474.
85. Uzogara SG, Morton ID, Daniel JW. Traditional fermented foods of Nigeria and their significance to health and national economy. J Sci Food Agric. 1990;50(3):265-279.