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Fermented Meat Products: Organoleptic Qualities and Biogenic Amines-a Review

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ABSTRACT

Fermented foods are value added products which have higher nutrients, prolong shelf life and easy in digestibility and are more suitable for the intestinal tract. The organoleptic qualities of such foods are higher particularly in terms of flavour, taste, aroma and colour. For the production of fermented products we require starter culture such as Lactic Acid Bacteria (LAB) strains, most of the meat starter cultures are *Lactobacillus pentosus, L. casei L. curvetus, L. planterum, L. sakei, Pediococcus acidilactici* and *P. pentosaceus*. These foods are also able to produce certain biogenic amines; the most commonly found biogenic amines in the meat and meat products are tyramine, cadaverine, putrescine and also histamine. The formation of such bioamines further enhances the functional properties of the foods besides addition in nutrients.

Key words: Fermentations, biogenic amines, nutrients, starter culture, organoleptic qualities

INTRODUCTION

Fermented foods are those which are subjected to the act of microbes or its enzymes for induction of useful biochemical changes and significant modification in foods (Campbell-Platt, 1987). However, Microbiologist describes the fermentation as a form of energy-yielding microbial metabolism in which an organic substrate, generally a carbohydrate, is partly oxidised and an organic carbohydrate acts as the electron acceptor (Adams, 1990). This explanation means that processes regarding ethanol production by yeasts or organic acids via Lactic Acid Bacteria (LAB) are believed as fermentations. Fermented foods are those foods which are infected or overgrown by safe to eat micro-organisms whose enzymes, mainly amylases, proteases, lipases hydrolyse the polysaccharides, proteins and lipids to harmless commodities with flavours, aromas and textures pleasurable and appealing to the human consumer (Singh and Sachan, 2011b). If the commodities of enzyme actions have objectionable odours or undesirable, unappealing flavours or the products are poisonous or disease producing the foods are considered as spoiled.

In the South East Asia the fermented food product is known as the sour meat give the impression to be increasing in fame as consumer search for further varieties in their food choices. Meat products that inoculated with micro-organisms at the time of processing under controlled condition to develop desirable characteristics are known as the fermented meat products (Acton, 1977). However, generally local producers depend on natural fermentation without inoculation or any controlled condition (Singh and Sachan, 2009; Singh and Sachan, 2011a). In such case, the micro-organisms present in these products normally originate from the meat itself or from the environment. Fermentation of meat imparts five major functions in meat products such as:

- Improvement in human nutritional through development of a spacious diversity of flavours, aromas and textures in foods
- Preservation of considerable amounts of food by the use of lactic acid, alcoholic, acetic acid, alkaline fermentations and high salt
- Enhancement of food qualities in terms of vitamins, proteins, essential amino acids and essential fatty acids
- Detoxification through food fermentation processing
- Reduction in cooking times and energy requirements

Origin of fermented meat products: Fermented sausages perhaps originated in the Mediterranean region during Roman period. Some products like Salami Milanese and Hungarian Salami have succeeded for centuries and are till now day being consumed. The process of fermentation was carried out throughout centuries without any scientific information regarding the nature of the processes involved in the fermentation of meat products. Recently, sausage-manufacturer would transfer old curing brine to the newly-prepared one. As a result novel brine would become inoculated with useful micro-organisms, causing the important changes in the cured meat at the time of ripening. This conventional process was depended on practical observations without the information of bacteriology (Singh and Sachan, 2010a). So, the results were not forever acceptable.

In 19th century, Pasteur reported that fermentations are completed by particular types of organisms. The first definite bacterial starter cultures, proposed for the fermentation of milk, were introduced during 100 years before.

Benefits of fermented meat products: Fermentation of meat is a low energy process which brings various changes in the meat products such as natural acidulation, preservation modus operandi which gives exclusive and characteristic meat properties such as flavour and palatability, colour, microbiological safety, softness etc. Antioxidant properties of phenolic compounds exert various antibacterial properties, flavour, colour etc. (Amadou *et al*., 2009; Chukeatirote *et al*., 2010; Qazi *et al*., 2003). In the process of fermentation, raw meat changes into the fermented meat products by the 'cultured' micro-organisms with the help of lower the pH of the meat products. The reduction in pH lowers the water activity (a_W) and creates the microbial hurdles which help in producing a safe and sound product. Fermented meat products commonly have a long storage life due to added salt, low pH due to lactic acid formation by LAB in the early stages of storage and afterwards drying that reduces the water activity (a_W). The beneficial effects of fermented meat products may be summarized as:

- Increase the demand of consumption of the meat products due to the improvement in the flavour, taste, aroma and colour
- Fermented meat products have long storage life as compared to non fermented meat products due development of acidulation at the time of fermentation
- Fermented meat products are safer from dangerous and pathogenic micro-organism because starter culture inhibit their growth in fermented meat products

- Fermented meat are more tender (soft) as compare to non fermented due to activity of certain enzyme (like protease etc.) produced by the starter culture
- The nutritional status of these foods is high due to production of peptides, amino acid at the time of fermentation
- For the fermented meat products less cooking time is required as compared to non fermented meat food which saves the energy and cost of production

Starter culture for meat fermentation: Hammes and Knauf (1994) defines the meat starter cultures as the "preparations that include living or inactive micro-organism that build up the desired metabolic activity in the meat". As an act, they are of facultative hetero fermentative strains of micro-organisms which form lactic acid from hexose sugars, for e.g., glucose and lactose as their metabolic products (via glycolysis). Though, from pentose, such as arabinose and xylose they formed both lactic acid as well as acetic acid (through the 6-phosphogluconate/phosphoketolase pathway) (Kandler, 1983). The formation of the amount of acetic acid is typically 1/10th of the amount of lactic acid (Deketelaere *et al.*, 1974). As designated in industrial catalogues of Lactic Acid Bacteria (LBA) strains, most of the meat starter cultures are *Lactobacillus pentosus, L. casei L. curvetus, L. planterum, L. sakei, Pediococcus acidilactici, P. pentosaceus.* Starter culture Micro-organisms for Fermented Meat products are presented in Table 1.

Fermented meat products: Meat and meat products are consumed in almost all communities of the World. Meat is one of the richest food sources of protein (Lucke, 2000). However, it gets easily contaminated by pathogenic micro-organisms present in animals prior to being slaughtered. It is therefore important to make meat safe for consumers in terms of stability, transportation and storage (Singh and Sachan, 2010b). One of the preferred methods used to achieve these qualities is meat fermentation. Fermentation of meat sausages, for example, using selected LAB strains, strongly inhibited the spoilage bacterial growth but left the organoleptic properties of the products intact (Metaxopoulos *et al.*, 2002; Aderiye *et al.*, 2006). Thus, LAB strains can be effectively used to preserve meat products for quality purposes. *Lanhouin*, a fermented fish product consumed by the locals in the West African country of Benin (Anihouvi *et al.*, 2006) is processed by spontaneous and largely, uncontrolled fermentation. The product was found to be safer and free of pathogenic bacteria such as *Salmonella*. It has also been demonstrated that fish products, which were LAB fermented could be stored for longer periods, free of the fishy odour and taste (Gelman *et al.*,

Table 1: Starter culture Micro-organisms for fermented meat products (Hammes and Knauf, 1994)

Micro-organisms	Strain
Yeast	*Debaryomyces hanseniL*
	Candida famata
	Pencillium chrysogenum
Fungi	*P. nalgiovense*
Bacteria	*Lactic acid bacteria*
	Lactobacillus plantarum, L. sake, L. curvatus. Pediococcus acidilactici, P. pentosaceus, Lactococcus lactis
	Micrococci
	Micrococcus varians
	Staphylococci
	Staphylococcus carnosus, S. xylosus
	Actinomycetes Streptomyeces griseus
	Enterobacteria

Table 2: Role of micro-organisms in fermented meat products

Micro-organisms use as culture	Effect on food	Formation of end substance	Changes in sensory attributes
Bacteria			
Lactobacillus sp. *Pedicococcus* sp.	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
Micrococcaceae			
Saphylococcus xylosus, *S. carnosus, Kocuria varians*	Fast and exaggerate the development of flavour in the fermented meat products	Methyl ketones from free fatty acid is the end products	Improvement of the Sensory quality mainly flavour in the meat products (Stahnke, 2000)
Yeast			
Debaryomyces hansenii	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 *C.utilis* (Stahnke, 2000)
Moulds			
Penicillium nalgiovense, *P. camemberti, P. crysogenum*	Stop development of fungi which are able to produce mycotoxin and to condense the mould coverage	Some compound Popcorn-smelling compound 2-acetyl-l pyrroline (Stahnke, 2000)	flavour

2000). Furthermore, the nutritional quality of fish remained intact (Achi *et al.*, 2007). Role of micro-organisms in fermented meat products is enlisted in Table 2.

Formation of different aroma compounds in fermentation

Aroma compounds from carbohydrate degradation: At the time of fermentation most of the supplementary carbohydrate is transformed into lactic acid. The formation of different amounts of other products depending on the applied lactic acid bacteria, temperature, type and content of carbohydrate and other processing parameters (Bhattacharya and Das, 2010; Adebayo and Aderiye, 2010). Other than lactic acid bacteria some starter cultures like staphylococci or yeast also have some effects in changing sugars to products other than lactic acid. At the time of fermentation of sausage some volatile compounds were formed from carbohydrate catabolism such as acetic, propionic and butyric acids, acetaldehyde, diacetyl, acetoin, 2, 3-butandiol, ethanol, acetone, 2-propanol and more (Gottschalk, 1986; Demeyer, 1982; Stahnke, 1999; Awan *et al.*, 2003). However, pyruvate derived compounds may originate from many sources other than carbohydrate during microbial metabolism (Demeyer *et al.*, 1987).

Aroma compounds from protein break-down: During the process of fermentation of sausages extensive proteolysis takes place which forms peptides and free amino acids. At the time of maturation amino acids and small peptides are taken up by the micro-organisms and transformed into numerous aroma compounds by different pathways. Some important biochemical conversions of the amino acids such as leucine, isoleucine, valine, methionine and phenylalanine take place into the sensory important branched aldehydes and corresponding secondary products, such as acids, alcohols and esters (Montel *et al.*, 1998; Stahnke, 2000; Shah *et al.*, 2002). The changes are mainly due to micro-organisms species from the *Micrococcaceae* family. Some worker also reported that both in model experiments and in sausages that different staphylococci and Micrococci (kocuria) produce 2, 3-methylbutanal, 2-methylpropanal, 2, 3-methylbutanoic acid, 2-methylpropanoic acid, 2, 3-methylbutanol, ethyl 2, 3-methylbutanoate, methional, phenylacetaldehyde, phenylethanol and many more (Berdague´ *et al.*, 1993; Stahnke, 1994; Stahnke, 1999; Montel *et al.*, 1996; Masson *et al.*, 1999; Larrouture *et al.*, 2000). The quantity of compounds is extremely influenced by the processing circumstances. In sausages it has been shown that parameters such as temperature, pH, glucose, salt, nitrite, nitrate and ascorbate all influence the amount of aroma compounds in one way or the other (Stahnke, 1995b, Stahnke, 1999; Masson *et al.*, 1999; Larrouture *et al.*, 2000). It has also been reported that due to reaction between the corresponding amino acids and adiketone such as diacetyl (nonenzymatic Strecker reactions) the branched-chained aldehydes were formed in this reaction (Stahnke, 1995b; Barbieri *et al.*, 1992). Some other workers describe the presence of different pyrazines in unspiced fermented sausages (Stahnke, 1995b; Johansson *et al.*, 1994; Berdague´ *et al.*, 1993).

Aroma compounds from lipid catabolism: At the time of fermentation and maturation the lipid fraction of the sausage is moderately hydrolysed by lipolytic reactions in which triglycerides and phospholipids are liberating free fatty acids. Lipolysis has been widely studied since free fatty acids are assumed to be chief precursors for oxidation products of significance for flavour development. Recent study designate that due to the microbial-oxidation of free fatty acid methyl ketones are formed which may be important for maturity (Stahnke, 2000) but possibly the quantity of free fatty acids is so plenteous that augmented amounts of this precursor do not control the flavour profile. Aroma compounds are present in the ppb to ppm levels whereas the level of free fatty acids are between 0.5 to 7% depending on sausage type (Nagy *et al.*, 1989; Stahnke, 1994; Johansson *et al.*, 1994; Navarro *et al.*, 1997).

There are two method of lipolysis that is caused both by microbial enzymes and endogenous enzymes in the meat and fat and there has been much debate about which mechanisms are the dominant. However, the current study illustrate that the addition of antibiotics is a most important component of the lipolytic breakdown and is documented to endogenous enzymes in the presence of strong lipolytic strains of *Staphylococcus* are used as a starter culture (Molly *et al.*, 1997; Stahnke, 1994). It has also been reported in sausages that the amount of free fatty acids is increased by high fermentation temperature and reduced salt levels (Stahnke, 1995a).

Occurrence of biogenic amines in meat and meat products: Meat and meat commodities have commonly been reported to contain biogenic amines (Bover-Cid *et al.*, 2006; Galgano *et al.*, 2009; Hernandez-Jover *et al.*, 1997; Kanioua *et al.*, 2001; Ruiz-Capillas and Jimenez-Colmenero, 2004). Among these different biogenic amines, the most commonly biogenic amines found in the meat and meat products are tyramine, cadaverine, putrescine and also histamine (Ruiz-Capillas and Jimenez-Colmenero, 2004). Therefore, an opposite relation between spermidine and sperminet contents is a characteristic of foods of animal source as compared with plant commodities (Kalac and Krausova, 2005). Occurrence of few amines such as tyramine, putrescine and cadaverine is a normal phenomenon at the time of storage of meat products (Galgano *et al.*, 2009; Hernandez-Jover *et al.*, 1996). The concentration of tyramine in stored beef was found more at the surface so on washing the concentration reduced (Kanioua *et al.*, 2001; Paulsen *et al.*, 2006). Fermented meat commodities comprises of significant amounts of biogenic amines but the draw back is poor quality raw materials, contamination and unsuitable conditions during processing and storage. In addition, the micro-organisms responsible for the fermentation process also imparts the biogenic amines accumulation (Bover-Cid *et al*., 2006; Latorre-Moratalla *et al*., 2010; Ali, 2010; Gernah *et al*., 2011). The accumulation of the non-protein nitrogen in the fermented meat products includes the free amino acids, precursors of biogenic amines. Naturally raw meat acts as the substrate from which the biogenic amines are formed. It is also a biggest part of the matrix in which the decarboxylation reactions take place and any circumstances that change its nature and characteristics will influence the formation of biogenic amines (Ruiz-Capillas and Jimenez-Colmenero, 2004). Many authors such as Eerola *et al*. (1997), Komprda *et al*. (2004) and Maijala *et al*. (1995) reported the formation of the biogenic amines considerably different in fermented meat commoditise and it is depends mainly on the raw material hygienic quality. Though, the level of the amine is depending on the raw material, presence of decarboxylating micro-organisms either from ecological contamination or from inoculation culture and the environment supporting their growth and activity. The quantity of amines and its profiles depends on various factors through manufacturing process such as pH, Nacl, redox potencial and temperature, the size of the sausage, sanitary conditions and importance of starter cultures (Gardini *et al*., 2001; Komprda *et al*., 2004; Latorre-Moratalla *et al*., 2008; Omafuvbe, 2008). Among these factors pH is a chief factor that influences amino acid decarboxylase activity. The formation of the amine is certainly influenced by the temperature. The optimum growth for the most of decarboxylase containing bacteria is in between 20 and 37°C temperature and the reduced temperature inhibit their growth (Karovicova and Kohajdova, 2005). Comparatively less concentration is committed to the effect of the chemical substances supplementary during made of the fermented meat products. Even though the recognized antimicrobial properties of some spices, the direct assessment of an effect of spices on microflora in association with biogenic amines making it present in accessible literature (Komprda *et al*., 2004). Suzzi and Gardini (2003) reported that the concentration of biogenic amines decreases obviously with increase of Nacl concentration, at the same time proteolytic activity is much higher for middle concentration of salt, pointing out that there is not essentially an association between these two variables. According to the Karovicova and Kohajdova (2005), the existences of Nacl stimulate tyrosine decarboxylase activity and hamper histidine decarboxylase activity. A correlation can also be established between biogenic amines substance and the size of dry fermented sausages. The size (diameter) of the sausage affects the surroundings in which micro-organisms grow; for e.g., the salt content is normally low and water activity is high in sausages having large diameter. The high production of the certain amines, such as putrescine and tyramine is possibly due to larger diameter. Usually, the level of the biogenic amines is higher in the thicker diameter of the sausage as compared to the thinner diameter sausage and in the mid portion of the sausage than the rim of the sausage (Ruiz-Capillas and Jimenez-Colmenero, 2004; Suzzi and Gardini, 2003).

Role of starter culture in formation of biogenic amines: The selection of appropriate starter culture with amino oxidase activity is the basic in preventing the development of high levels of biogenic amines in fermented meat products (Karovicova and Kohajdova, 2005; Suzzi and Gardini, 2003). The choice of lactic acid bacteria for the meat fermentation is dependant on the particular needs of the fermentation process (*J. Stadnik, Dolatowski*), (Roig-Sagues and Eerola, 1997). The incapability of the culture to form biogenic amines, capability to grow well at the temperature proposed for processing of the manufactured goods and competitiveness in diminishing the development of wild amine producing microflora should be taken into concern in the selection of starter cultures (Suzzi and Gardini, 2003). The formation of curvacin A by the bacteriocin strains may enhance the competitiveness (Hammes and Hertel, 1996; Somda *et al.*, 2011). A fast pH diminishing caused by amine negative starter cultures is able to basically stop biogenic amines growth in fermented meat products. Furthermore, starter cultures capable to compete among non-starter bacteria during the ripening and storage can further avoid too much biogenic amines production (Suzzi and Gardini, 2003). For the increase of the acidification in the fermented meat products is primarily due to the lactic acid bacteria along with the micrococci and/or coagulase-negative staphylococci. They are responsible for addition of colour and aroma due to their proteolytic and lipolytic actions. Thus the micro-organisms commonly used in the meat industry as inoculation culture (Latorre-Moratalla *et al.*, 2010; Suzzi and Gardini, 2003). In Europe commonly used strains are the *Lactobacillus curvatus* and *Lactobacillus sake* as compared to the other. Though, a number of strains of *Lactobacillus curvatus* can be used as starter cultures to form four different biogenic amines. Strains of *Lactobacillus sake* are free from this potential (Koiozyn-Krajewska and Dolatowski, 2009). It indicates that *Lactobacillus sake* is more appropriate than *Lactobacillus curvatus* for use as a starter culture to stop the development of biogenic amines (Roig-Sagues and Eerola, 1997).

Present and future of fermented meat products: In genetic engineering use of recent starter cultures for bioamines products and product development is a new area. In the future by the use of genetic engineering we can get better production and activity of microbial protease, lipase, catalase, nitrate reductase. By this technique we can give newest properties, or make stronger the popular ones already present in the microbe. By the use of this technology it is also possible to transfer the new gene from one to other micro-organisms. So that it can generate aroma components, vitamin, certain desirable metabolites and so on. In addition to investigation oriented in the direction of the result of old, conventional trouble of meat fermentation, there are new elegant methods to produce superior cultures with stronger activity that favour a good fermentation process can be evolved. A lot of study has been conducted in the field of meat fermentations. However, we are away from the thoughtful entire interrelations involving the microbiology, the technology and external factors use in fermentation and ripening procedure.

CONCLUSION

On the basis of above discussion it can be concluded that the fermentation of foods in particular meat and meat products enhances its nutritional value. The products prepared by fermentation can keep for a longer period of time. The biogenic amines produced through fermented foods may serves the functions of functional foods. The sensory attributes alongwith the digestibility are quite higher in fermented foods as compared to traditional foods.

REFERENCES

Achi, O.K., I.C. Anokwuru and F.C. Ogbo, 2007. Microbiological and chemical changes during fermentation of crabs for *Ogiri-nsiko* production. Am. J. Food Technol., 2: 301-306.

Acton, J., 1977. The chemistry of dry sausages. Proc. Annu. Reciprocal Meat Conf., 30: 49-62.

Adams, M.R., 1990. Topical aspects of fermented foods. Trends Food Sci. Technol., 1: 141-144.

Adebayo, C.O. and B.I. Aderiye, 2010. Antifungal activity of bacteriocins of lactic acid bacteria from some Nigerian fermented foods. Res. J. Microbiol., 5: 1070-1082.

Aderiye, B.I., S.A. Laleye and H.A. Akinduro, 2006. Spoilage of some stored fermented foods in Southwest Nigeria. J. Biol. Sci., 6: 659-663.

Ali, A.A., 2010. Beneficial role of lactic acid bacteria in food preservation and human health: A review. Res. J. Microbiol., 5: 1213-1221.

Amadou, I., S. Yong-Hui, J. Sun and L. Guo-Wei, 2009. Fermented soybean products: Some methods, antioxidants compound extraction and their scavenging activity. Asain J. Biochem., 4: 68-76.

Anihouvi, V.B., G.S. Ayernor, J.D. Hounhouigan and E. Sakyi-Dawson, 2006. Quality characteristics of *Lanhouin*: A traditionally processed fermented fish product in the republic of benin. Afr. J. Food Agric. Nutr. Dev., 6: 1-15.

Awan, U.F., K. Shafiq, S. Mirza, S. Ali, Asad-ur-Rehman and Ikram-ul-Haq, 2003. Mineral constituents of culture medium for lipase production by *Rhizopus oligosporous* fermentation. Asian J. Plant Sci., 2: 913-915.

Barbieri, G., L. Bolzoni, G. Parolari, R. Virgili, R. Buttini, M. Careri and A. Mangia, 1992. Flavor compounds of dry-cured ham. J. Agric. Food Chem., 40: 2389-2394.

Berdague, J.L., P. Monteil, M.C. Montel and R. Talon, 1993. Effects of starter cultures on the formation of flavour compounds in dry sausage. Meat Sci., 35: 275-287.

Bhattacharya, S. and A. Das, 2010. Study of physical and cultural parameters on the bacteriocins produced by lactic acid bacteria isolated from traditional indian fermented foods. Am. J. Food Technol., 5: 111-120.

Bover-Cid, S., M.J. Miguelez-Arrizado, L.L. Latorre Moratalla and M.C. Vidal Carou, 2006. Freezing of meat raw materials affects tyramine and diamine accumulation in spontaneously fermented sausages. Meat Sci., 72: 62-68.

Campbell-Platt, G., 1987. Fermented Foods of the World-A Dictionary and Guide. Butterworths, London.

Chukeatirote, E., K. Dajanta and A. Apichartsrangkoon, 2010. Thua nao, Indigenous Thai fermented soybean: A review. J. Biol. Sci., 10: 581-583.

Deketelaere, A., D. Demeyer, P. Vandekerckhove and I. Vervaeke, 1974. Stoichiometry of carbohydrate fermentation during dry sausage ripening. J. Food Sci., 39: 297-300.

Demeyer, D.I., 1982. Stoichiometry of dry sausage fermentation. Antonie Van Leeuwenhoek, 48: 414-416.

Demeyer, D.I., A. Verplaetse and M. Gistelinck, 1987. Fermentation of meat: An integrated process. Proceedings of the 32nd European Meeting of Meat Research Workers, March1, 1987, Food Science and Technology, Belgium, pp: 241-247.

Eerola, S., A.X.R. Sagues, L. Lilleberg and H. Aalto, 1997. Biogenic amines in dry sausage during shelf-life storage. Zeitunig Lebensmittel Fur. Unters Forsch. A., 205: 351-355.

Galgano, F., F. Favati, M. Bonadio, V. Lorusso and P. Romano, 2009. Role of biogenic amines as index of freshness in beef meat packed with different biopolymeric materials. Food Res. Int., 42: 1147-1152.

Gardini, F., M. Martuscelli, M.C. Caruso, F. Galgano and M.A. Crudele *et al*., 2001. Effects of pH, temperature and NaCl concentration on the growth kinetics, proteolytic activity and biogenic amine production of *Enterococcus faecalis*. Int. J. Food Microbiol., 64: 105-117.

Gehlenk, H., C. Meisel, A. Fischer and W.P. Hammes, 1991. Influence of the yeast *Debaryomyces* hansenii on dry sausage fermentation. Proceedings of the 37th Proceedings of the 37th international congress of meat science and technology, September 1-6, 1991, Federal Centre for Meat Research, Kulmbach, Germany, pp: 871-876..

Geisen, R., F.K. Lilcke and L. Krbckel, 1992. Starter and protective cultures for meat and meat products. Fleischwirtsch, 72: 894-898.

Gelman, A., V. Drabkin and L. Glatman, 2000. Evaluation of lactic acid bacteria, isolated from lightly preserved fish products, as starter cultures for new fish-based food products. Innovative Food Sci. Emerging Technol., 1: 219-226.

Gernah, D.I., C.C. Ariahu and E.K. Ingbian, 2011. Effects of malting and lactic fermentation on some chemical and functional properties of maize (*Zea mays*). Am. J. Food Technol., 6: 404-412.

Gottschalk, G., 1986. Bacterial Metabolism. 2nd Edn., Springer-Verlag, New York, pp: 208-282.

Hammes, W.P. and C. Hertel, 1996. Selection and improvement of lactic acid bacteria used in meat and sausage fermentation. Lait, 76: 159-168.

Hammes, W.P. and H.J. Knauf, 1994. Starters in the processing of meat products. Meat Sci., 36: 155-168.

Hernandez-Jover T., M. Izquierdo-Pulido, M.T. Veciana-Nogues, A. Marine-Font and M.C. Vidal-Carou, 1997. Biogenic amine and polyamine contents in meat and meat products. J. Agric. Food Chem., 45: 2098-2102.

Hernandez-Jover, T., M. Izquierdo-Pulido, M.T. Vecina-Nogues and M.C. Vidal-Crou, 1996. Biogenic amine sources in cooked cured shoulder pork. J. Agric. Food Chem., 44: 3097-3101.

Jessen, B., 1995. Starter Cultures for Meat Fermentation in Campbell-Plant G and Cook PE, Fermented Meat. Blackie Acad Prof, London, pp: 130-159..

Johansson, G., J.L. Berdague, N.T. Larsson and E. Borch, 1994. Lipolysis, proteolysis and formation of volatile components during ripening of a fermented sausage with *Pediococcus pentosecaus* and *Staphylococcus xylosus* as starter cultures. Meat Sci., 38: 203-218.

Kalac, P. and P. Krausova, 2005. A review of dietary polyamines: Formation, implications for growth and health and occurrence in foods. Food Chem., 90: 219-230.

Kandler, O., 1983. Carbohydrate metabolism in lactic acid bacteria. Ant. V. Leuwenhoek, 49: 209-224.

Kanioua, I., G. Samourisa, T. Mouratidoua, A. Eleftheriadoub and N. Zantopoulosa, 2001. Determination of biogenic amines in fresh unpacked and vacuum-packed beef during storage at 4°C. Food Chem., 74: 515-519.

Karovicova, J. and Z. Kohajdova, 2005. Biogenic amines in food. Chem. Pap., 59: 70-79.

Koiozyn-Krajewska, D. and Z.J. Dolatowski, 2009. Probiotics in fermented meat products. Acta Sci. Pol., Technol. Aliment., 8: 61-74.

Komprda, T., D. Smela, P. Pechova, L. Kalhotka, J. Stencl and B. Klejdus, 2004. Effect of starter culture, spice mix and storage time and temperature on biogenic amine content of dry fermented sausages. Meat Sci., 67: 607-616.

Larrouture, C., V. Ardaillon, M. Pepin and M.C. Montel, 2000. Ability of meat starter cultures to catabolize leucine and evaluation of the degradation products by using an HPLC method. Food Microbiol., 17: 563-570.

Latorre-Moratalla, M.L., S. Bover-Cid, R. Talon, M. Garriga and E. Zanardi *et al.*, 2010. Strategies to reduce biogenic amine accumulation in traditional sausage manufacturing. LWT-Food Sci. Technol., 43: 20-25.

Latorre-Moratalla, M.L., T. Veciana-Nogues, S. Bover-Cid, M. Garriga and T. Aymerich *et al.*, 2008. Biogenic amines in traditional fermented sausages produced in selected European countries. Food Chem., 107: 912-921.

Lucke, F.K., 2000. Utilization of microbes to process and preserve meat. Meat Sci., 56: 105-115.

Maijala, R., E. Nurmi and A. Fischer, 1995. Influence of processing temperature on the formation of biogenic amines in dry sausages. Meat Sci., 39: 9-22.

Masson, F., L. Hinrichsen, R. Talon and M.C. Montel, 1999. Factors influencing leucine catabolism by a strain of *Staphylococcus carnosus*. Int. J. Food Microb., 49: 173-178.

Metaxopoulos, J., M. Mataragas and E.H. Drosinos, 2002. Microbial interaction in cooked cured meat products under vacuum or modified atmosphere at 4°C. J. Applied Microbiol., 93: 363-373.

Molly, K., D. Demeyer, G. Johansson, M. Raemaekers, M. Ghistelinck and I. Geenen, 1997. The importance of meat enzymes in ripening and flavour generation in dry fermented sausages: First results of a European project. Food Chem., 59: 539-545.

Montel, M.C., F. Masson and R. Talon, 1998. Bacterial role in flavour development. Meat Sci., 49: 111-123.

Montel, M.C., J. Reitz, R. Talon, J.L. Berdague and A.S. Rousset, 1996. Biochemical activities of *Micrococcaceae* and their effects on the aromatic profiles and odours of a dry sausage model. Food Microbiol., 13: 489-499.

Nagy, A., V.M. Lyi and K. Incze, 1989. Ripening and storage of Hungarian salami: Chemical and organoleptic changes. Fleischwirtsch, 69: 587-588.

Navarro, J.L., M.I. Nadal, L. Izquierdo and J. Flores, 1997. Lipolysis in dry cured sausages as affected by processing conditions. Meat Sci., 45: 161-168.

Olesen, P.T. and L.H. Stahnke, 2000. The influence of *Debaryomyces* hansenii and Candida utilis on the aroma formation in garlic spiced fermented sausages and model minces. Meat Sci., 56: 357-368.

Omafuvbe, B.O., 2008. Effect of temperature on biochemical changes induced by *Bacillus subtilis* (SDA3) during starter culture fermentation of soybean into condiment (soy-daddawa). Am. J. Food Technol., 3: 33-41.

Paulsen, P., U. Hagen and F. Bauer, 2006. Changes in biogenic amine contents, non-protein nitrogen and crude protein during curing and thermal processing of *M. longissimus*, pars *Lumborum* of pork. Eur. Food Res. Technol., 223: 603-608.

Qazi, I.M., S. Wahab, A.A. Shad, A. Zeb and M. Ayuab, 2003. Effect of different fermentation time and baking on phytic acid content of whole-wheat flour bread. Asian J. Plant Sci., 2: 597-601.

Roig-Sagues, A. and S. Eerola, 1997. Biogenic amines in meat inoculated with *Lactobacillus sake* starter strains and an amine-positive lactic acid bacterium. Zeitschrift fuer LebensmittelUntersuchung und-Forschung, 205: 227-231.

Ruiz-Capillas, C. and F. Jimenez-Colmenero, 2004. Biogenic amines in meat and meat products. Crit. Rev. Food Sci. Nutr., 44: 489-499.

Shah, A.H., A. Hameed and G.M. Khan, 2002. Fermentative production of L-lysine: Bacterial fermentation-I. J. Medical Sci., 2: 152-157.

Singh, V.P. and N. Sachan, 2009. Role of milk ingredients in bakery industry. Processed Food Ind., 13: 43-45.

Singh, V.P. and N. Sachan, 2011a. Nutraceutical properties of milk and milk products: A review. Am. J. Food Technol., 6: 864-869.

Singh, V.P. and N. Sachan, 2011b. Processing properties of milk. Processed Food Ind., 14: 23-26.

Singh, V.P. and N. Sachan, 2010a. Nanotechnology: The new opportunities and threats to food. Indian Food Ind., 29: 46-49.

Singh, V.P. and N. Sachan, 2010b. Role of biotechnology in preservation of meat and meat products. Processed Food Ind., 13: 20-23.

Somda, M.K., A. Savadogo, N. Barro, P. Thonart and A.S. Traore, 2011. Effect of minerals salts in fermentation process using mango residues as carbon source for bioethanol production. Asian J. Ind. Eng., 3: 29-38.

Stahnke, L.H., 1994. Aroma components from dried sausages fermented with *Staphylococcus xylosus*. Meat Sci., 38: 39-53.

Stahnke, L.H., 1995a. Dried sausages fermented with *Staphylococcus* xylosus at different temperatures and with different ingredient levels-Part I. Chemical and bacteriological data. Meat Sci., 41: 179-191.

Stahnke, L.H., 1995b. Dried sausages fermented with *Staphylococcus* xylosus at different temperatures and with different ingredient levels-Part II. Volatile components. Meat Sci., 41: 193-209.

Stahnke, L.H., 1999. Volatiles produced by *Staphylococcus xylosus* and *Staphylococcus carnosus* during growth in sausage minces: Part II. The influence of growth parameters. LW Sci. Food Technol., 32: 365-371.

Sunesen, L.O. and L.H. Stahnke, 2003. Mould starter cultures for dry sausages-selection application and effect. Meat Sci., 65: 935-948.

Suzzi, G. and F. Gardini, 2003. Biogenic amines in dry fermented sausages: A review. Int. J. Food Microbiol., 88: 41-54.