REVIEW

Lactic acid bacteria in traditional fermented Asian foods

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Abstract: Lactic acid bacteria play vital roles in various fermented foods in Asia. This paper reviews many types of the world's lactic acid fermented foods and discusses the beneficial effects of lactic acid fermentation of food. The lactic acid bacteria associated with foods now include species of the genera *Carnobacterium, Enterococcus, Lactobacillus, Lactococcus, Leuconostoc, Oenococcus, Pediococcus, Streptococcus, Tetragenococcus, Vagococcus* and *Weissella*. Lactic acid bacteria (LAB) are involved in many fermentation processes of Asian traditional foods, demonstrating their profound effects on improving food quality and food safety. During the past few decades' interest has arisen in the use of the varied antagonistic activities of LAB to extent the shelf-life of protein-rich products such as meats and fish. This review article outlines the main types of LAB fermentation as well as their typical fermented foods such as idli, kishk, sauerkraut, koumiss, Suan-tsai, stinky tofu, Chinese sausage and kefir. The roles of LAB and the reasons for their common presence are also discussed.

Keywords: Lactic acid bacteria, fermented foods, Asia

INTRODUCTION

Fermented foods in many countries constitute a major part of human diet because fermentation is reasonably priced technology which preserves food, as well as enriches its nutritional value and boosts its sensory properties (Ahmed *et al*., 2013). Courting back to 6000 BC, the civilizations of the Fertile Crescent in the Middle East used methods for the fermentation of milks, meats and vegetables (Ali *et al*., 2009). By using raw materials, microorganisms and various techniques now fermented foods are manufactured worldwide (Babu *et al*., 2009). Different microorganisms are well known in the production of fermented foods. Among them Lactic acid bacteria (LAB) play a vital role in the production of fermented foods and beverages (Ahmed *et al*., 2013; Babu *et al*., 2009). In the Asia and western world, most fermented foods are reliant on lactic acid bacteria (LAB) to mediate fermentation procedure (Ahmed *et al*., 2013).

Famous Traditional Asian fermented foods consist of a variety of products obtained from cereals (Idli, soy sauce, kishk), vegetables (sauerkraut, pickles, Suan-tsai), milk (yogurt, koumiss, ripened cheeses) and meat (Chinese-style sausage) (Nout, 2001). *Lactobacillus* species are the most common bacteria involved in production of traditional Asian fermentation foods, especially which are made from rice, vegetables or milk. *Leuconostoc mesenteroides* is supplementary with the fermentation of pickle and sauerkraut (Ahmed *et al*., 2013). This microorganism starts the desired lactic acid fermentation in the mentioned foodstuffs. It differs from other lactic acid species in that it can endure high concentrations of salt and sugar (up to 50% sugar). However other bacteria have their own characteristics that differentiate them like *L. mesenteroides* recruit's growth in vegetables more speedily over a range of temperature and salt concentrations than any other lactic acid bacteria (Xiong, *et al*., 2012).

Lactic acid bacteria (LAB) represent a diverse group of bacteria; Though there are some communal characteristics which are present in every member of them (Ali *et al*., 2009). They are Gram-positive, catalase-negative, non-sporing *microaerophilic rods* and *cocci,* usually non-motile. By producing organic acids, they acidify raw material, mainly by lactic acid (Xiong, *et al*., 2012). They also produce acetic acid, ethanol, aromatic compounds, bacteriocins, exo-polysaccharides, and many other important enzymes (Ahmed *et al*., 2013). As a result, they are successful in improving microbial safety and shelf life as well as texture, hence providing us a satisfactory end product. The common food-associated LAB genera are *Lactobacillus, Lactococcus, Leuconostoc* and *Pediococcus* (Ali *et al*., 2009). There are some typical LAB genera such as *Streptococcus, Enterococcus, Carnobacterium, Vagococcus, Oenococcus, Tetragenococcus* and *Weissella*, even though their uses to

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foods are more partial and commonly limited to certain sorts of products (for example *Streptococcus thermophilus* in thermophilic cheese and yoghurt starters, *enterococci* in many endogenous food products and *oenococci* in red wine ripening) (Nout, 2001). For their proper activity, they need various growth factors, the nature of which fluctuates among species. They are certainly present in media rich in organic products such as food or the mammal's digestive tract (Xiong, *et al*., 2012).

Lactic acid bacteria (LAB) play a solemn role in the effective fermentation of alcoholic beverages by obstructing the development of the number of spoilage and pathogenic microorganisms by producing bacteriocins, organic acids, diacetyl, hydrogen peroxide, and CO_2 (Calo *et al*., 2008). As pH reduces to 4.0 by the production of organic acids it becomes difficult survival for spoilage bacteria in cereals (Ahmed *et al*., 2013). In spite of their capability to produce organic acids, the LAB is also able to produce hydrogen peroxide through the oxidation of reduced nicotin-amide adenine dinucleotide (NADH) by flavin nucleotides, which react rapidly with oxygen. Hydrogen peroxide can accumulate and inhibit some microorganisms as LAB lack true catalase (Xiong, *et al*., 2012). On the other hand, tannin levels may be reduced as a result of lactic acid fermentation, leading to increased absorption of iron, except in some high tannin cereals, where little of no improvement in iron availability has been observed (Nout, 2001). Another advantage of lactic acid fermentation is that fermented products involving LAB have viricidal (Ahmed *et al*., 2013) and anti-tumor effects (Ali *et al*., 2009).

The flavor quality of alcoholic beverages is also dependent on the ester compounds formed from reactions between alcohol and carboxylic acid catalyzed by enzymes such as esterase, lipases and alcohol acetyl transferases, which are produced by LAB (Sumby *et al*., 2010). In addition, esterification improves the taste of alcoholic beverages through the reduction of acidity and sourness. These ester compounds have the potential to greatly affect the final aroma of alcoholic beverages, although excess growth of LAB could also throw off the flavor in the final product (Sumby *et al*., 2010). In addition to traditional food uses LAB are being increasingly used as health promoting or probiotic bacteria in functional food products (Babu *et al*., 2009).

This review aims to list and summarize the common fermented foods of Asia and to highlight, where available and some of the microbiological and biochemical properties of Lactic Acid Bacteria (LAB), involved in food fermentation.

Metabolism of sugars in lactic acid bacteria (LAB)

Sugars (hexoses) are generally the primary substrates for pyruvate and lactate formation in LAB. Pyruvate and lactate can also be produced by LAB from a number of substrates, such as carbohydrates, organic acids and amino acids (Babu *et al*., 2009). According to the pathways by which hexoses are metabolized they are divided into two groups: homo-fermentative and hetero-fermentative. Homo-fermentative such as *Pediococcus, Streptococcus, Lactococcus* and some *Lactobacilli* produce lactic acid as the major or sole end product of glucose fermentation (Ali *et al*., 2009). They produce more than 85 % lactic acid from glucose by fermenting 1 mole of glucose to 2 mole of lactic acid, generating a net yield of 2 mole of ATP per molecule of glucose metabolized. Hetero-fermenters such as *Weisella* and *Leuconostoc* and some *Lactobacilli* produce equimolar amounts of lactate, CO_2 and ethanol from glucose (Babu *et al*., 2009). They produce only 50% lactic acid and ferment 1 mole of glucose to 1 mole of lactic acid, 1 mole of ethanol, and 1 mole of CO_2. One mole of ATP is generated per mole of glucose, resulting in less growth per mole of glucose metabolized. A brief outline of metabolic pathways for the transformation of sugars to pyruvate and lactate by LAB is given in Fig. 1 (Reddy, 2007).

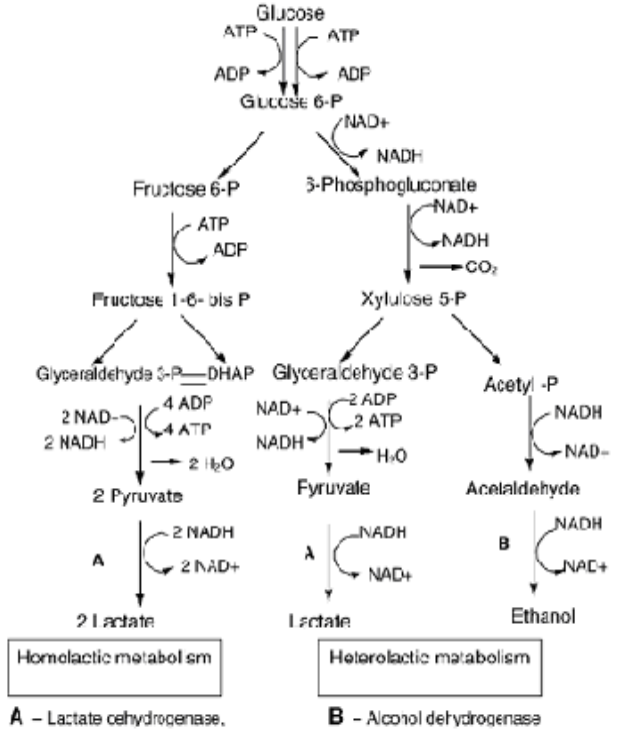

Fig. 1. Metabolism of lactic acid bacteria

The major end-product of LAB fermentation, lactate can be further metabolized by some LAB under certain circumstances. In addition, LAB can also convert the lactate precursor, pyruvate to other important compounds that are of significance in food and beverage fermentations (Babu *et al*., 2009).

Table 1: Compounds formed during cereal fermentation (Blandino *et al*., 2003)

Organic acids	Alcohols	Aldehydes and ketones	Carbonyl compounds
Butyric	Ethanol	Acetaldehyde	Furfural
Succinic	n-Propanol	Formaldehyde	Methional
Formic	Isobutanol	b-Phenylethyl alcohol	Glyoxal
Valeric	Isobutanol	n-Valderaldehyde	3-Methyl butanal
Caproic	b-Phenylethyl alcohol	2-Methyl butanol	
Lactic	2,3-Butanediol		
Acetic	Isoamyl alcohol		

Cereal- based fermented foods

IdlI.

Idli is a fermented, thick suspension used in several traditional foods in Southeast Asian countries (Blandino *et al*., 2009). It is made of a blend of rice (*Oryza sativum)* and dehulled black gram (*Phaseolus mungo*). Idliis a low calorie, starchy and nutritious food, which is consumed as breakfast or snack. Steamed idli contains about 3.4% protein, 20.3% carbohydrate and 70% moisture (Teniola & Odunfa, 2001). Large-scale production of idli is carried out in batch compartmental steaming units. This is labor intensive and has limited capacity. With the growing demands for breakfast foods, idlis are being consumed on a large scale in some Indian institutions such as army, railways, industrial canteens, etc. In order to meet the demand, numerous studies are carried out for the development of continuous units for the production of idli (Nagaraju & Manohar, 2000). The lactic acid bacteria *Leuconostoc mesenteroides, Streptococcus faecalis, Lactobacillus delbrueckii, Lactobacillus fermenti, Lactobacillus lactis* and *Pediococcus cerevisiae* have been found to be responsible for the fermentation process,. Although *L. mesenteroides* and *S. faecalis* are considered to be the microorganism essential for leavening of the batter and for acid production in idli (Teniola & Odunfa, 2001). The yeasts *Geotrichum candidum, Torulopsis holmii, Torulopsis candida* and *Trichosporon pullulans* have also been identified in idli fermentation (Blandino *et al*., 2003).

Soy sauce

Soy sauce is a dark brown liquid, made from a blend of soybeans and wheat. It is mainly used as an all-purpose seasoning in Japan, China and the Far East countries (Ali *et al*., 2009). Soy sauces have a salty taste, but sodium concentration is lower than traditional table salt (Bolotin *et al*., 2004). Fungi (*Aspergillus oryzae* and *A.soyae*), halo-tolerant LAB and yeast (*Zygosaccharomyces rouxii* and *Candida* species) responsible for the moromi fermentation (Bolotin *et al*., 2004).

The characteristic aroma and flavor of soy sauce is due to the enzymatic activities of yeasts and some LAB. During the last 2–3 decades the traditional process for soy sauce production has been significantly improved. Some examples of these developments include the introduction of improved microbial inoculation for soy sauce fermentation, the use of new techniques of preparation, and the use of new materials and modern technology for processing and fermentation (Calo *et al*., 2008).

Kishk

Fermented milk-wheat mixtures, known as kishkin the Middle East is important food. In addition to their well-established position in the dietary patterns of the people in the aforementioned country, these products have also been promoted in Mexico (Calo *et al*., 2008) and Europe (Ahmed *et al*., 2013). Kishkis a balanced food with excellent preservation quality, richer in B vitamins than either wheat or milk, and well adapted to hot climates by its content of lactic acid (Ali *et al*., 2009). The microorganisms responsible for the fermentation include *Lactobacillus plantarum, Lactobacillus casei* and *Lactobacillus brevis, Bacillus subtilis* and yeasts (Ahmed *et al*., 2013).Other compounds obtained by cereal fermentation is shown in table 1 which include organic acid, alcohol, aldehyde, ketones and carbonyl compounds

Milk based fermented foods:

Yoghurt

Yoghurt is one kind of fermented milk produced by a process known as proto-cooperation. Proto-cooperation is a process that produces yoghurt by mutual stimulation of growth of *Lactobacillus Delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus.* These interactions are known for decades. *L. bulgaricus* produces cell wall-bound proteases and in turn gets benefit from nutrients (formate and carbon dioxide) produced by *S. thermophilus* (Sieuwerts, 2008). Cultivation of these organisms in milk has supported multiple events of horizontal gene transfer including transfer of a gene cluster for the production of sulfur-containing amino acids from *L. bulgaricus* to *S. thermophislus.* This transfer supports combined growth and has been confirmed with the availability of multiple genome sequences (Bolotin, 2004).

Cheese

A range of cheese varieties, such as Swiss, Cheddar and Italian-type cheeses are being manufactured using LAB (Cheng *et al*., 2005). Lactate formation by Lactose and galactose, quantitatively the most important substrates, by

LAB is crucial for cheese production. In addition, lactate formation is also contributed by the fermentation of citrate and amino acids such as serine by LAB during cheese ripening up to some extent (Feng *et al*., 2005). Some *Lactobacilli* and *Pediococci* can further oxidize lactate to acetate and CO_2 under aerobic conditions and has been isolates from chadder cheese where this function is operative under the ripening conditions of Cheddar cheese (Cleveland *et al*., 2001). It addition, in Swiss-type cheese manufacture, *Propionibacteria* are known to further convert lactate produced from lactose by LAB to propionate, acetate and CO_2 and this conversion imparts a characteristic taste and texture (eye formation) to this type of cheeses (Ali *et al*., 2009).

Koumiss

Koumiss, also named "airag" or "chigee", produced by quick fermentation of lactose to lactic acid and alcohol, is another traditional fermented milk product that took its origin from Central Asia (Kücükcetin *et al*., 2003). Inhabitants of Mongolia and Xinjiang provinces have been using this dairy product for thousands of years and this is very popular between ends of May and autumn. Traditional koumiss is manufactured from fresh camel or mare milk by mixing it with prepared fermented koumiss (Wu *et al*., 2009; Wang *et al*., 2008). In the process of fermentation, *Lactobacilli* acidify the milk by converting sugar it into acid and yeasts change it finally to a carbonated, mildly alcoholic drink. *Lactobacillus* genus is very popular for its use in food due to its safe consumption and its role in the fermentation affects many characteristic of the product including aroma, texture, and acidity of the product with many benefits to human health (Danova, Petrov, Pavlov & Petrova, 2005). Due to high acid tolerance, the main LAB strains in koumiss are different species of *Lactobacilli* such as *Lactobacillus plantarum, Lactobacillus helveticus, Lactobacillus casei* and *Lactobacillus kefiri* (Wu *et al*., 2009; Wang *et al*., 2008; Liu, Du, &Huo, 2008; Uchida *et al*., 2007).

Vegetable- based fermented foods

Sauerkraut

Out of many traditional vegetable foods used in China, Chinese Sauerkraut is one of the widely consumed in many regions of China. For its preparation, various vegetables including cabbage, radish, tender ginger and pepper are immersed in 6-8% (w/v) salt solution with garlic and *Illicium verum* at ambient temperature (20-25 ^{0}C) for 6-10 days in pickle jars, allowing fermentation to proceed (Ahmed *et al*., 2013). This food does not use dry salting to draw juice out of cabbage. It is a brine-salted and lactic acid fermented vegetable product (Yan *et al*., 2008). *Lactococcu slactis subsp. lactis, Leuconostoc mesenteroides subsp. mesenteroides, Lactobacillus plantarum* and *Lactobacillus casei* are main fermenters for the production of Sauerkraut (Xiong *et al*., 2012).

Pickles

In Asian and African countries, fermented pickles are very popular and are part of daily diet. Fruits and vegetables are used in pickle formation using lactic acid fermentation, which occurs before the pickling process. Using this indigenous technique of bio-preservation, perishable and seasonal leafy vegetables such as radish, cucumbers and young tender bamboo shoots are fermented into edible products (e.g., pickling) (Tamang, 2012). Lactic acid fermentation is only way to preserve fruits and vegetables under poor technology conditions. These are pressed into containers and then brine is added containing 10-15% of NaCl. Following NaCl, vinegar is added and pickles are then allowed to ferment at 20 ^{0}C for 4 weeks. Fermentation by autochthonous lactic acid bacteria dominates while yeast fermentation (e.g., *Torulopsis sp., Hansenula sp*., and *Saccharomyces sp*.) occurs during the late stage (Kabak and Dobson, 2011).

Suan-tsai (Suan-cai):

Suan-tsai (Suan-cai) is a seasonal popular dish in some parts of China and is known for its sour taste. It can be made from cabbage or mustard. Due to simplicity and flexibility of this food preparation, this can be easily produced at a very small scale in homes by spontaneous fermentation. This is also produced at a larger scale in some regions of China. Dominant bacteria in this fermentation are *Lactobacillus, Leuconostoc*, and *Pediococcus* (Maki, 2004).

Soy based fermented foods:

Soymilk

Soymilk is a tradition beverage obtain by water extract of soy beans which are valuable and inexpensive source of protein and calories (Wang *et al*., 2004). Soyamilk is fermented by five LAB species namely *Lactobacillus casei, Lactobacillus acidophilus, Streptococcus thermophilus, Lactobacillus buldaricus, Bifidobacterium longum* (Tsai *et al*., 2006). Fermentation results in change in iso-flavones (aglycones, glycosides, acetyl and malonyl-glycoside) as well β-glycoside activity (Hsieh *et al*., 2006). Soymilk contain low isoflavone content (81.94-86.61 µg/ml) as compared to fermented soymilk (87.61µg/ml) (Hsieh *et al*., 2006). Soymilks fermented with β-glycoside producing probiotic stain allow acetyl and β-glycoside isoflavones to undergo enzyme hydrolysis to aglycone which has faster absorption (Tang *et al*., 2006). However, LAB fermented soymilk contain small proportion of stachyose and raffinose (Wang *et al*., 2004). Soymilk is use as antioxidant (Wang *et al*., 2006), probiotic (Shimakawa *et al*., 2003), use in treatment of breast cancer (Shu *et al*., 2009), maintain intestinal environment (Cheng *et al*., 2005). In addition, soymilk act as symbiotic (combination of prebiotic and probiotic) (Tang *et al*., 2007).

Table: 2 Asian fermented products by lactic acid bacteria

Fermented Products	Country	Microorganisms	Reference
Cereal-based			
Idli	Southern India	*Leuconostoc mesenteroides, Streptococcus faecalis, Torulopsis, pullulans, LAB*	(Sady *et al*., 2007; Uslu, 2010).
Kishk	Egypt, Syria, Arab world	*Lactobacillus plantarum, L. brevis, L. casei, Bacillus Subtilis* and yeasts	
Milk			
Yoghurt	-	*Lactobacillus bulgaricus subsp. Delbrueckii (L. bulgaricus) and Streptococcus thermophiles*	
Cheese	-	*Lactococcus (cremoris, lactis), leuconostoc* and *Propioni bacterium shermanii*	(Cleveland *et al*.,2001)
Koumiss	China	*Lactobacilli, such as Lactobacillus plantarum, Lactobacillus helveticus, Lactobacillus casei, and Lactobacillus kefiri*	(Wu *et al*., 2009; Wang *et al*., 2008)
Soybean-based			
Stinky tofu	China	*Leuconostoc fallax, Leuconostoc lactis, Lactobacillus pantheris*	(Chao *et al*., 2008)
Shoyu (soy sauce)	Japan, China, Philippines	*Aspergillus oryzaeor A. soyae, Lactobacillus*	
Vegetable-based			
Sauerkraut	China	*Lactococcus lactis subsp. lactis, Leuconostoc mesenteroides subsp. mesenteroides, Lactobacillus plantarum, Lactobacillus casei Tetragenococcus halophilus*	(Xiong *et al*., 2012)
Suan-tsai	China		(Chen *et al*., 2006)
Meat-based			
Chinese-style sausage	China	*Lactobacillus*	(Luangsakul *et al*., 2009; Liu, Ao, Li, & Zhan, 2007)
Beverages			
Kefir	Turkey	*Lactobacillus* spp. *Lactococcus lactis* subsp. *lactis, S. thermophilus*	(Witthuhn *et al*. 2005 Simova *et al*. 2002)

Sufu

Other names of sufu is furu (Han *et al*., 2001) and fermented tofu (Li-Jun *et al*., 2004), a traditional Chinese fermented soy bean curd which is creamy cheese like product (Han *et al*., 2001). Soy curd are as a byproduct of *Streptococcus thermophiles* and *Lactobacillus delbrueckii* subs*p bulgaricus* (Farnworth *et al*., 2007).Sufu contain large number of amino acids like leucine, alanine, isoleucine, valine and phenylalanine (Han *et al*., 2004). There are different methods of preparation of sufu. Four steps are involved in preparation of sufu. (1). Preparation of tofu by salt precipitation of soymilk. (2). Preparation of pehtze by spray inoculation of diced tofu (3). Salting (4). Ripening of the dressing mixture (Han *et al*., 2001). Manufacturing process has significant impact of isoflavone contents of sufu. Whereas isoflavones composition is closely related to corresponding glycoside. Preparation of tofu and salting of pehtze cause significant loss of isoflavone content. There is significant increase in level of aglycone while corresponding glycoside level decrease (Li-Jun *et al*., 2004).

Soy Sauce

Soy sauce is also known as *shoyu*in Japan, *chiang-yu* (or -*yi*) in China, *kecap*in Indonesia, *kanjang*in Korea, *toyo*in The Philippines, and *see-ieu*in Thailand (Tanasupawat *et al*., 2002).

Soy sauce is commonly use in asia (Fidler *et al*., 2003) has salty taste, sharp flavor (Van *et al*., 2001; Fidler *et al*., 2003). Halophilic lactic acid bacterium, *Tetragenococcus halophilus,* is responsible for deepening of taste and aroma (Masuda *et al*., 2008). Phenylacetaldehyde is an important flavorings component of Japanese soy sauce (Steinhaus & Schieberle, 2007). Masuda *et al*., 2008 has reported halophilic lactic acid bacterium, *Tetragenococcus halophilus* act as immune-modulator (Masuda *et al*., 2008). Tanasupawat *et al*., 2002 reported the Preasence of LAB in soy sauce (Tanasupawat *et al*., 2002). Soy sauce has many pharmacological activities. Example antioxidant (Wang *et al*., 2007). Antioxidant activity is attributed to presence of 2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (Wang *et al*., 2007). Antioxidant activity was also reported by long *et al*., 2000 using ABST assay (Long *et al*., 2000). In addition, it has Antihypertensive, natriuretic activity (Yamakoshi *et al*., 2007), Anti-allergic (Kobayashi *et al*., 2004) so use in treatment of allergic rhinitis (Kobayashi *et al*., 2004) prebiotic effect (Yang *et al*., 2011). There are two types of soy sauce (1) Chinese soy sauce (2) Japanese soy sauce (Wanakhachornkrai & Lertsiri, 2003). Soy sauce originates in china but Japanese soy sauce has good quality as compare to Chinese soy sauce (Yan *et al*., 2008). Fidler *et al*., 2003 reported that soy sauce inhabits iron absorption which is attributed to high phytic acid content thereby causing anemia, sodium iron EDTA fortified soy sauce helps to overcome anemia (Huo *et al*., 2002). Japanese soy sauce reported to contain 300 compounds obtained by combination of vacuum distillation, solvent distillation and gas chromatography-mass spectrometry, 90 in acid fraction and more than 140 in neutral volatile fraction (Steinhaus & Schieberle, 2007).

Miso

Miso is also known as soy cheese (Onda *et al*., 2002), is traditional Japanese soy bean fermented food (Onda *et al*., 2003; Onda *et al*., 2003). Miso is prepared by grinding the mixture of soy beans, rice koji and salt, thereby fermenting in 12% NaCl (Onda et al., 2003). Zaid & El-Shenawy, 2010 has demonstrated the anti-cancer activity of miso on human cell lines (HEPG2 (liver carcinoma), MCF7 (breast carcinoma), and HCT116 (colon carcinoma) (Zaid & El-Shenawy, 2010). Analysis of miso micro-flora elucidated the presence of halophilic *Tetragenococcus halophilus*, which play an important role in ripening of miso (Onda et al., 2003). Whereas few LAB like *Pediococcus acidilactici, Lactobacillus fructivorans* and *Lactobacillus plantarum* are interfere with the quality of Miso by over-acidification thereby causing swelling of packaged Miso (the so-called 'Fukure' effect) (Onda *et al*., 2003(b)). Whereas lactic acid is the end product of lactic acid fermentation, which inhabit the growth of undesirable bacteria. However, contamination of miso could be inhabited by using ethyl alcohol and pasteurization (Onda *et al*., 2002).

Tempeh

Tempeh also known as tempe, traditional Indonesian fermented food (Feng *et al*., 2005) also found in south east Asia (Jelen *et al*., 2013). Presence of LAB in tempeh was reported by many researchers (Suwanto *et al*., 2013). Feng *et al*., 2005 reported four LAB species in tempeh namely *Lactobacillus plantarum, Lactobacillus fermentum*, *Lactobacillus reuteri* and *Lactococcus lactis* (Fang *et al*., 2005). Tempeh preparation includes boiling which prevents contamination of tempeh with other unwanted microbes. However, the end product of LAB fermentation is lactic acid, which also contribute to tempeh safety (Feng *et al*., 2005). Tempeh has protective effect on bones, prevent cardiovascular diseases and also helpful in weight reduction (Babu *et al*., 2009).

Meat-based fermented foods

Chinese-style sausage

This traditional meat-based indigenous fermented food is a very famous Chinese style sausage and is consumed at a large level in China. *Lactobacillus* dominates in vacuum packed meat and provide flavor to meat (Kuo & Chu, 2003). By decomposing carbohydrates, *lactobacilli* produce lactic acid which decreases the pH in meat. This pH is not suitable for production and proliferation of food spoilage and food-borne pathogens and the production of enterotoxins which serve as food preservative (Castellano, González, Carduza & Vignolo, 2010). At refrigeration temperatures, antagonistic actions have also been reported. LAB can also impart desirable color to food by converting H_2O_2 to H_2O and O_2 (Tian& Zhang, 2001).

Cincaluk

Malaysian fermented sauce produce by shrimp fermentation (*Acetessp*) (Hajar & Hamid, 2013). locally known as *Udanggeragau, Udangbubok*or *Udanggari* (Ali *et al*., 2009). *Cincaluk*is also found in South Asian Countries (Hajar & Hamid, 2013). Hajar & Hamid, 2013 reported the presence of LAB strain *Staphylococcus piscifermentans* in *Cincaluk* (Hajar & Hamid, 2013). Liasi *et al*., 2009 also reported the presence of *Staphylococcu spiscifermentans in* malaysian fermented fish which does not found in malaysian fermented sauce (Liasi *et al*., 2009).

Shidal

Shidal is traditional fish in North East India (Assam) (Ahmed *et al*., 2013; Kaktati *et al*., 2013).

Similar product is known as known as Chepa Shutki in Bangladesh (Nayeem *et al*., 2010; Mansur *et al*., 2000; Khanum *et al*., 2001), seedal or hidal in Assam (Muzaddadi & Basu, 2003; Ahmad *et al*., 2013), Hentak

and Ngari in Manipur (Mahanta *et al*., 2012) Thapa *et al*., 2004) and Tungtap in Meghalaya (Thapa *et al*., 2004)

Japan fermented sish products

Narezushi is Japan fermented meat product. Few narezushi in Japan include funazushi, sabanarezushi, and izushi (Tsuda *et al*., 2012). Takahashi *et al*., 2010 reported the presence of *Lactobacillusacidipiscis, Lactobacillus versmoldensis, Lactobacillus plantarum, Tetragenococcus muriaticus* and *Tetragenococcus halophilu* (Takahashi *et al*., 2010). Kanno *et al*., 2012; Kuda *et al*., 2010 reported the antioxidant activity of narezushi, due *to* presence of antioxidant (2,2-diphenyl-1-picrylhydrazyl ($DPPH^{-}$)) and superoxide anion radical (O_2^{-}) (Kanno *et al*., 2012 ; Kuda *et al*., 2010*).* Nakamura *et al*., 2012 reported the inhibitory effect of narezushi on *Listeria monocytogenes* infection (Nakamura *et al*., 2012)

Chinese fermented meat products

Chouguiya (Stinky Mandarinfish)

Chouguiya also known as Stinky Mandarinfish, typical fish fermented food of China (Dai *et al*., 2013). Dai *et al*., 2013 reported the presence of *Lactobacillus sakei*, *Lactococcus* (*Lc*.) *garvieae*, *Lc. lactis*, *Lc. raffinolactis*, *Vagococcus*sp., *Enterococcus hermanniensis*, *Macrococcus caseolyticus, Streptococcus parauberis* (Dai *et al*., 2013).

Yu-lu

Yu-lu is tradition Chinese fish fermented sauce, mostly found in Southern and Eastern part of China especially in Guangdong and Fujian (Xiao *et al*., 2014; Jiang *et al*., 2007). Jiang *et al*., 2007 carried out studies to evaluate chemical and sensory properties of Yu-lu (Jiang *et al*., 2007). Jiang *et al*., 2014 reported seven biogenic amines tryptamine (TRY), tyramine(TYR), histamine (HIM), putrescine (PUT), cadaverine (CAD), spermine (SPM) and spermidine (SPD) by high-performance liquid chromatography with fluorescence detection (HPLC-FLD) (Jiang *et al*., 2014). Biogenic amines were also reported Gong *et al*., 2014 by in other Chinese food like douchi, sufu, fermented sausage, yulu, and shrimp paste which are abundant in Southern China by HPLC (Gong *et al*., 2014).

Suanyu

Suanyu is low salt traditional Chinese fermented fish (Kargozari *et al*., 2014). Microbial flora consist of *L. plantarum, S. xylosus, Saccharomyces cerevisiae* (Zeng *et al*., 2013). Zeng *et al*., 2013 observed Changes of biogenic amines in Chinese low-salt fermented fish pieces (Suanyu) inoculated with mixed starter cultures (Zeng *et al*., 2013).

Silver crap sausage

Silver crap (Hypophthalmichthys molitrix) is fresh water fish in china (Nie *et al*., 2014). Silver crap has antioxidant properties (Dong *et al*., 2008), Antimicrobial activity (Wu *et al*., 2014). However, antioxidant activity was reported to be close to a-tocopherol (Dong *et al*., 2008).

Fermented fish product in Asia from marine species include Hoki (*Macruronus novaezealandiae*), kahawai (*Arripistrutta*) and trevally (*Pseudocaranx dentex*). These fishes contain fats, proteins and Iron (Khem *et al*., 2013)

Thai fermented meat and fish products

Thai fermented fish include Nham (Thai fermented pork), SaiKrok Preaw (fermented pork sausage) and Plaa-ra (Thai fermented fish) (Pringsulaka *et al*., 2012). Srionnual *et al*., 2007 reported *Weissella cibaria* 110 from Plaa-Som has antimicrobial activity (S*rionnual et al., 2007). "Mum"* is another tradition thai fermented sausage found in northeastern region of Thailand. Microbial flora of "*Mum"* contain *Lactobacilli, Pediococci,* and *Micrococci* (Wanangkarn *et al*., 2014). Sitdhipol *et al*., 2013 reported the presence of histamine in Thai fermented food products (Sitdhipol *et al*., 2013).

Beverages

Kefir

By the fermentation of cow, ewe, goat or other type of milk (Kabak and Dobson, 2011), a smooth, white colored, lightly foamy drink is produced which is carbonated as well as viscous called kefir (Mistry, 2004; Yuksekdag *et al*., 2004). Due to microbial quality of grains present in kefir quality and physicochemical properties of the product s affected adversely. Other properties include temperature range, conditions of sanitation, storage parameters, and grains to milk ration. (Guzel-Seydim *et al*., 2010). Many researchers documented the composition of kefir as the total dry matter (8.88–16.73%), protein (3.10–4.72%) and fat contents (1.11–2.77%) (Cetinkaya and Elal-Mus, 2012; Dinc, 2008; Ertekin and Guzel-Seydim, 2010; Sady *et al*., 2007; Uslu, 2010). Stated by (Guzel-Seydim *et al*., 2010) as a result of fermentation lactic acid, ethanol, carbon dioxide and other flavor compounds such as acetaldehyde, diacetyl and acetoin occur in typical kefir product. (Witthuhn *et al*. (2005) reported that *Lactobacillus spp.* was the most regularly encountered microorganism in kefir grains. However, *Lactococcus lactis subsp. lactis* and *S. thermophilus* were determined as the predominating species in kefir grains (53-65%) and kefir samples (74-78%) by Simova *et al*. (2002). The kefir beverage contains approximately 0.2-0.7% kefiran, a polysaccharide produced by *Lactobacilli* in Kefir grains. It provides a slightly ropy texture to the final product (Mistry, 2004). table 2 show LAB fermented Asian foods.

Development in the biotechnology of LAB

The application of genetic engineering technology to improve existing strains or develop novel strains for these fermentations is an active research area world-wide (Sady

et al., 2007; Uslu, 2010). During past 20 years much of the research on LAB focused on dairy *lactococci*, investigations now include different LAB involved in wide variety of fermentation processes and, various *lactobacilli* and *bifidobacterial* belonging to the human microbiota. However, significant development in bacteriophage biology and resistance mechanisms, pyruvate metabolism and production of bacteriocins have also been made (Soomero *et al*., 2002).

New techniques such as ability to sequence large tracts of 16s and 23s rRNA genes using polymerase chain reaction (RAPD-PCR) and the use of pulsed field gel electrophoresis (PFGE) to finger print genomic restriction patterns have contributed enormously in strain identification and classification (Ali *et al*., 2009). This relates to field of probiotics where the ability to monitor strains through clinical trials and to evaluate their effects on the gastrointestinal tract micro flora as well as the protection of their proprietary value depends on exact and reproducible strain identification (Feng *et al*., 2005).

CONCLUSION

Lactic acid bacteria play important roles in many Asian fermented foods, especially in non-dairy fermented vegetable products. The recent advances in biotechnology have significantly increased the production of high quality, nutritious and tasteful foods that remain fresh for long time and are completely safe and less reliant on artificial additives. The probiotic functions of lactic acid bacteria in non-dairy fermented foods in Asia have not been fully investigated. More research is needed to identify the lactic acid bacteria in Asian fermented foods and their physiological functions in the human diet.

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