Traditionally preserved fish products are largely confined to east and south-east Asia which are still produced principally on a cottage industry or domestic scale (Adams, 1998). As commonly applied, the term 'fermented fish' covers two categories of product (Adams *et al.*, 1985): (i) fish-salt formulations, e.g. fish sauce products such as the fish pastes and sauces tend to contain relatively high levels of salt, typically in the range 15-25% and are used mainly as a condiment; and (ii) fish-salt-carbohydrate mixtures, e.g. pla-ra in Thailand and burong-isda in the Philippines. In hot countries, particularly in rural areas, fermented fish products continue to play a vital role in adding protein, flavour and variety to rice-based diets (Campbell-Platt, 1987). Table (A) summarises some of the common traditionally processed fish products of Asia.

Among the fermented fish products, the more widely used are fish sauces and pastes (van Veen, 1965; Orejana, 1983). In the fish-salt-carbohydrate product, lactic fermentation occurs and contributes to the extended shelf life (Adams *et al.*, 1985; Owens and Mendoza, 1985). Lactic acid fermented products can be prepared in a shorter time than the fish-salt products, which depend primarily on autolytic processes and offer greater scope for low-cost fish preservation in South East Asia than the simply low water activity products (Adams *et al.*, 1985). The principal carbohydrate source used in these traditional lactic fermented products is cooked rice, although in some products partially saccharified rice (mouldy rice: ang-kak, or pre-fermented rice) is used or, on occasion, small amounts of cassava flour, or cooked millet, e.g. sikhae in Korea (Lee, 1984).

Table A. Some common traditionally processed fish products of Asia

Product	Substrate	Type and use	Country	Reference
Pindang	Fish	Dried/salted; side-dish	Indonesia	Putro (1993)
Pedah	Mackerel	Partly-dried and salted; side-dish	Indonesia	Westenberg (1951)
Trassi	Shrimps/fish	Fermented paste; side-dish	Indonesia	Van Veen (1965)
Shottsuru	Marine fish	Fish sauce; condiment	Japan	Itoh *et al.* (1993)
Shiokara	Squid	Fermented; side-dish	Japan	Fujii *et al.* (1999)
Jeot-kal	Fish	High-salt fermented; staple	Korea	Lee (1993)
Sikhae	Fish-cereals	Low-salt fermented; sauce	Korea	Lee (1993)
Gulbi	Shell-fish	Salted and dried; side-dish	Korea	Kim *et al.* (1993)
Budu	Anchovies	Fish sauce; condiment	Malaysia	Merican (1977)
Pekasam	Freshwater fish-roasted rice	Fermented; side-dish	Malaysia	Karim (1993)
Belacan	Shrimp	Shrimp paste; condiment	Malaysia	Wong and Jackson (1977)
Mehiawah	Marine fish	Fermented paste; side-dish	Middle–East	Al-Jedah *et al.* (1999)

Product	Substrate	Type and use	Country	Reference
Nga-pi	Fish	Fermented fish paste; condiment	Myanmar	Tyn (1993)
Ngan-pyaye	Fish	Fish sauce; condiment	Myanmar	Tyn (1993)
Patis	Marine fish	Fish sauce; condiment	The Philippines	Baens-Arcega (1977)
Bagoong	Fish	Fish paste; condiment	The Philippines	Mabesa and Babaan (1993)
Bagoong alamang	Shrimp	Shrimp paste; condiment	The Philippines	Mabesa and Babaan (1993)
Balao-balao	Shrimp	Fermented shrimp; condiment	The Philippines	Arroyo *et al.* (1978)
Burong isda	Rice-fish	Fermented rice-fish mixture; sauce or main dish	The Philippines	Sakai *et al.* (1983b)
Nam-pla	Anchovies	Fish sauce; condiment	Thailand	Saisithi *et al.* (1966)
Kapi	Shrimp	Shrimp paste; condiment	Thailand	Phithakpol (1993)
Plaa-raa	Fish, rice	Fermented paste; condiment and main dish	Thailand	Phithakpol (1987)
Nuoc-mam	Marne fish	Fish sauce; condiment	Vietnam	van Veen (1965)

Few food anthropologists have mentioned the antiquity and cultural aspects of fermented fish products in Asia. It may be hypothesized that the deliberate preparation of fermented fish originated by accident when a batch of old or improperly prepared salted fish fermented, and the umami taste was first observed and found acceptable (Ishige, 1986). Fermented fish production may have originated independently in many different locations, but it would have only developed and been deliberately elaborated where the taste was culturally acceptable and where the products were found complementary to the established cuisine (Ishige and Ruddle, 1987). Ishige (1993) advocated that the Mekong and associated basins of south-west China, Laos and northern and north-west Thailand were the most probable place of origin of fermented fish products.

Fermented fish products are prepared from freshwater and marine finfish, shellfish, and crustaceans that are processed with salt to cause fermentation and thereby to prevent putrefaction (Ishige, 1993). If cooked carbohydrates are added to the fish and salt mixture, the product is called narezushi and if no vegetables are added, the salt-fish mixture yields fish sauce, which is commonly used as a condiment, and if the product of fish and salt that preserves the whole or partial shape of the original fish, it is called 'shiokara', which when comminuted by either pounding or grating yields shiokara paste (Ishige and Ruddle, 1987). Shiokara paste has synonyms in South-East Asia, as in Myanmar it is known as nga-pi, in Kampuchea as pra-hoc (Ishige, 1993). Shiokara is used mostly as a side dish, and is important in the food life of Kampuchea, Laos, north and north east Thailand; lower Myanmar, Luzon and the Visayas in the Philippines, and Korea (Ishige, 1993).

Squid skiokara is the most popular fermented sea food in Japan (Fujii *et al.*, 1999).

Fermented fish products are of very minor importance outside Asia. In Europe, fish sauces known as liquamen or garum were ubiquitous condiments for the Romans, who had adopted them from the Greeks (Adams, 1998). Norwegian gravlaks, or buried salmon, is a traditional, relatively mild tasting product; more heavily fermented products, rakefisk or surfisk, the most popular varieties of which are rakörret, fermented trout, in Norway and surströmming, made from herring in Sweden (Riddervold, 1990; Kobayashi *et al.*, 2000).

The diversity of fish used in fermented products and in the way in which they are handled prior to processing means that the initial microbial levels are far from uniform, and counts ranging from 10^4/g to >10^7/g have been reported (Adams, 1998). Lactic fermented fish products are often associated with inland areas such as the Central Luzon region of the Philippines and the north-east of Thailand where the freshwater fish are the usual raw material, and their microflora tends to reflect their local environment more than that of marine species (Adams, 1986). In a survey of fermented fish products in north-east Thailand, it was found that several different sources were used for the fish - the flooded rice fields, paddy ponds beside rice fields used for collecting fish when the field has dried up, and a large local freshwater reservoir (Dhanamitta *et al.*, 1989).

A key factor limiting fish utilization is its perishability, since fish flesh offers microorganisms conditions of good nutrient availability coupled with a high water activity (a_w) and moderate pH (Shewan, 1962). In tropical countries the problem posed by the intrinsic suitability of fish flesh as a medium for microbial growth is further compounded by a high ambient temperature (Adams *et al.,* 1987). Fish stored under these conditions is considered spoiled within 12 hours (FAO, 1981). In developing countries the necessity for low-cost methods of fish preservation has reduced the applicability of technologies such as chilling, freezing and canning (Cutting, 1999). Traditional curing processes, which depend upon the reduction of a_w as the principal preservative factor, are important, e.g. salting, drying and smoking (Sperber, 1983).

In several products, the rice may be added in a partially saccharified form such as kao-mark (Thailand), or, alternatively, a saccharifying agent such as koji (Japan) or ang-kak (the Philippines) may be added separately, which increase the amount of soluble sugars produced and thus the range of lactic acid bacteria that can grow lowering pH (Adams, 1998). In burong-isda where ang-kak is used pH decreases to 3.0-3.9 compared with the product without ang-kak addition (pH 4.1-4.5) despite other factors, such as salt content, being similar (Sakai *et al.,* 1983b). Sikhae, the Korean fermented fish product, is something of an exception since millet is used as the carbohydrate source (Lee, 1984). Saisithi (1987) reported that the function of the roasted rice added during pla-ra production is to improve texture and slow the fermentation rather than to serve as a substrate for lactic fermentation. Carbohydrate mix prevented yeasts growth in fermented fish products (Avurthi and Owens, 1990).

Most fermented fish products use salt as ingredient; therefore, both fermented fish and salted fish are alike in that both require the use of salt as a preservative (Ishige, 1986). A survey of fish products in Thailand noted that there were two empirical rules governing formulations: (i) the use of higher salt levels results in a longer production phase but a better keeping quality product, and (ii) inclusion of more carbohydrate gives a faster fermentation and a stronger acid taste (Adams *et al.,* 1985). The salt levels in some high-salt fermented fish sauces and pastes are sufficient to check microbiological spoilage (Saonos and Dhamcharee, 1986).

Although the ability to ferment starch is not widespread in the lactic acid bacteria, a number of amylolytic species have been described and an amylolytic strain of *Lactobacillus plantarum* has been isolated from burong bangus in the Philippines (Sakai *et al.,* 1983a). Solidum (1977) reported Gram-positive cocci in the initial stage of fermentation of balao-balao and in the later stage, high acid-producing rods predominated the product.

Species of *Lactobacillus, Pediococcus, Micrococcus, Bacillus* and few types of yeast including species of *Candida* and *Saccharomyces* were reported from nam-plaa and kapi, fermented fish products of Thailand (Watanaputi *et al*., 1983; Phithakpol, 1987). *Micrococcus* and *Staphylococcus* are dominant microorganisms during ripening of shiokara (Nishimura and Shinano, 1991; Tanasupawat *et al*., 1991; Fujii *et al*., 1994; Wu *et al*., 2000).

Tetragenococcus muriaticus and *Tetragenococcus halophilus* were isolated from the Japanese fermented puffer fish ovaries (Satomi *et al*., 1997; Kobayashi *et al*., 2000c). Kobayashi *et al.* (2000a,b) isolated and identified *Haloanaerobium praevalens* in surströmming, fermented herrings of Sweden and *Haloanaerobium fermentans* from the Japanese puffer fish ovaries.

Crisan and Sands (1975) reported that *Bacillus* spp. were found to be the predominant isolates, probably reflecting their ability as spore formers to survive rather than any capacity to multiply under the prevailing conditions in nam-pla and patis. Species of *Bacillus* mostly *Bacillus stearothermophilus, B. shaercus, B. circulans*, etc. are predominant microflora in nga-pi, fermented fish paste of Myanmar (Tyn, 1993).

Halobacterium and *Halococcus* sp were isolated from nam-pla with microbial load reaching upto 10^8/ml after 3 weeks of fermentation and also demonstrated their significant proteolytic activity during the first month of fermentation, suggesting that halophilic bacteria do play an important role in the production of fish sauce (Thongthai and Suntinanalert, 1991).

Bacillus licheniformis, Staphylococcus sp., *Aspergillus* sp. and *Candida* sp. were recovered from gulbi, salted and dried fish product of Korea (Kim *et al.*, 1993).

Avurhi and Owens (1990) found that any effective measure to exclude air from a fermenting fish/carbohydrate mix prevented spoilage yeasts. Traditional packing techniques used with lactic fermented fish products, such as wrapping in banana leaves, will not reliably exclude air, and surface mould growth has been shown to be a cause of rejection in the Thai product som-fak which suggests that the use of oxygen-impermeable wrapping films could extend the shelf-life of such products (Adams, 1999).

Fish is more susceptible to spoilage than certain other animal protein foods (Cutting, 1999). Studies have shown that the number of bacteria declines rapidly during the production of the Thai fish sauce nam-pla and that, after one month the product contained about 500 cfu/g comprising mainly *Micrococcus* and *Bacillus* spp. (Velankar, 1957; Saisithi *et al.,* 1966). Similar results were seen with patis, the

Philippines fish sauce, where the total counts dropped from 10^7 cfu/g to $<10^3$ cfu/g after 14 days and $<10^2$ cfu/g after 40 days (Velankar, 1957).

Fermentation promotes chemical change and the development of umami from amino acids where the fish flesh, itself a tasteless protein, is converted to amino acids, a simpler component with a characteristic taste (Kawamura and Kara, 1987). Narezushi, which is fish fermented together with rice or another starch, has a characteristic taste that develops from the auto-digestion of meat (Ishige, 1986). Free amino acids which increased during processing of gulbi were reported as important flavour components (Lee and Kim, 1975). Fujii *et al.* (1999) reported that the dominant microorganisms which included *Micrococcus* and *Staphylococcus* in shiokara during ripening produced organic acids imparting flavour to the product.

Lactic and anaerobic bacteria proliferate, and yeast is also an important ingredient, which act on the sugary content of the rice to produce many organic acids and alcohol (Mizutani *et al.*, 1988). The effect of the organic acids is to lower the pH, controlling the growth of putrefying bacteria, thus, narezushi can be preserved for long periods (Mizutani *et al.*, 1988). A novel fibrinolytic enzyme was purified from *Bacillus* sp, isolated from jeot-gal of Korea (Kim *et al.*, 1997).

Dried fish is produced with a moisture content of 17% to 45% (Clucas and Sutcliffe, 1981). Fermented fish products are generally high in protein and amino compounds (Beddows, 1985). Beddows *et al.* (1979) observed that budu, fermented fish product of Malaysia contains the amino acid profile of the original fish, and thus nutritive value is high. Teshima *et al.* (1967a,b) investigated the volatile compounds in shiokara and identified formic, ethanoic, propanoic, iso-butanoic, npentanoic acids as well as ammonia, amino-butane and 2-methyl propylamine due to microbial action.

Biogenic amines which are organic basic compounds are found to occur in fish products, cheese, wine, beer, dry sausages and other fermented foods (Ten Brink *et al.*, 1990; Halász *et al.*, 1994). Biogenic amines are formed by decarboxylation of their precursor amino acids, as a result of the action of either endogenous amino acid decarboxylase activity (Halász *et al.*, 1994) or by the growth of decarboxylase positive microorganisms (Silla-Santos, 2001). Histamine is generally found in spoiled scombroid fish and other marine fish that contain high levels of histidine in their muscle tissues (Lukton and Olcott, 1958), and is associated with the chemical intoxication called scombroid fish poisoning (Fujii *et al.*, 1997). Many workers isolated various histamine-producing bacteria from the fish which had been involved in food poisoning incidents (Stratton and Taylor, 1991).

Lactic acid bacteria frequently produce histamine and tyramine in a processed fish (Stratton *et al.*, 1991; Leisner *et al.*, 1994). Trace quantities of putrescine, tyramine, agmatine and tryptamine have been detected in Ghanaian fermented fish (Yankah *et al.*, 1993). Ornithine and citrulline were detected as decomposition products of arginine in fish sauce (Mizutani *et al.*, 1992). In anchovies, high level of biogenic amines was detected during manufacturing process (Ridriguez-Jerez *et al.*, 1994).