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To cite this version:
Anil Kumar Anal, Giorgia Perpetuini, Awanwee Petchkongkaew, Reasmey Phary Tan, Sylvie Avallone, et al.. Food safety risks in traditional fermented food from South-East Asia. Food Control, Elsevier, 2020, 109, pp.106922. 10.1016/j.foodcont.2019.106922. hal-02514915

HAL Id: hal-02514915
https://hal-agrosup-dijon.archives-ouvertes.fr/hal-02514915
Submitted on 20 Jul 2022

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Food safety risks in traditional fermented food from South-East Asia

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Abstract

South-East Asia is well-known for traditionally fermented foods. However, these products are generally still produced at small scale following traditional procedures. Nowadays, consumers are particularly aware of the health concerns regarding food additives; the health benefits of “natural” and “traditional” foods, processed with no added chemical preservatives, are becoming more and more attractive. Therefore, their confidence towards safety and quality of Asian fermented foods is low. Major food safety concerns are related not only to food production methods, but also to how foods are processed, stored, sold and consumed. In this review the main factors affecting food safety are analysed. They are not limited only to the improper use of chemicals such as pesticides or antibiotics, but also to improper processing and handling during storage which could provoke the accumulation of toxic compounds such as mycotoxins or biogenic amines. Urgent attention is required to improve the quality of the ingredients and the integration of food safety management systems for industrial growth. Therefore, in the last part of this review directions to improve the food safety of fermented foods are proposed.

Keywords: fermented foods, South-East Asia, food safety
1. Introduction

In South-East Asia, the economic and demographic developments together with the migration of the population to urban areas resulted in many changes in the organisation of the food production system. This increased the consumer concern about food safety (Ha, Shakur, & Pham Do, 2019). However, the level of concern is not only coming from an undefined perception of this change but it follows also several outbreaks that occurred in the recent years. Drivers of food safety unconformity have been analysed (Kendall, Kaptan, Stewart, Grainger, Kuznesof, Naughton, et al., 2018). They have multiple origins among them the lack of resources, the economic pressure, the structuration, the training and the will. As confirmed by the achievement of the Asifood Erasmus+ project (Anal, Waché, Louzier, Roy, Mens, Avalllone et al. submitted), the demand of actors of the field for food safety is huge. Among the various food products concerned, the case of traditional fermented food is special as these foods are usually produced at small scale, very popular and considered as delicacies in Asia but also, often as risky (Sarter, Ho, & To, 2014). Taking into account the classification proposed by Steinkraus (Steinkraus, 1997), popular fermented food in continental South-East Asia (Valyasevi & Rolle, 2002; Vu & Nguyen, 2016) are belonging to the (i) High salt/meat-flavored amino acid/peptide sauce (various fish sauces or pastes like nuoc mam, prahok, pla ra, soy sauces like Tuong), (ii) Lactic acid fermentations (vegetable leaves, bamboo, onions, fermented meat that can be uncooked (Nem chua, nahm), fish, shrimp), (iii) alcoholic fermentation (rice wine), (iv) acetic fermentation (rice vinegar), (v) alkaline fermentation of soy (thua-nao). With the general economic idea of decreasing the risks and increasing the scale of production, these products could be the victim of a food diversity extinction. However, other economic models exist like in Europe where small-scale fermented foods are considered as a way to increase typicity and bring value-added.
The goal of this review is to evaluate the dangers and risks to which traditional fermented food are exposed in South-East Asia. Recent studies, from 2007 to 2019, concerning the detection of pathogens and chemical contaminants in some of the most risky products are reported. From these results, directions to improve the food safety of fermented foods in Vietnam, Cambodia and Thailand will be proposed.

2. Contamination of raw or fermented products with pathogenic bacteria

In South-East Asia, and in particular in Vietnam, consumers’ confidence towards fermented products is low, especially because of the microbial safety risks of the raw material such as meat and vegetable (Sarter, Ho, & To, 2014).

One of the riskiest traditional fermented meat products is an uncooked pork sausage eaten after a short lactic fermentation. It is called nem chua in Vietnam, nahm in Thailand and nem chrouk in Cambodia. To elaborate this product, pork is bought in the wet market or supermarket and then the minced meat is mixed with herbs and spices such as garlic, guava leaf, fresh chili, etc. The finish products are packed into banana leaves to provide an anaerobic environment for the fermentation process and to inhibit entry of potentially pathogenic microorganisms. The products are stored at room temperature for spontaneous fermentation for several days.

The highest risk of nem chua is related to meat since this fermented sausage is uncooked and unheated. In pork raw meat from South-East Asia, Escherichia coli, Salmonella, Campylobacter, Listeria monocytogenes and Staphylococcus aureus are the main food-borne pathogens and they are frequently found in intestinal tract and faeces of food animals (Dao & Yen, 2006) (Nguyen Thi Nhung, Van, Cuong, Duong, Nhat, Hang, et al., 2018) (Ananchaipattana, Hosotani, Kawasaki, Pongsawat, Md.Latiful, Isobe, et al., 2012; Carrique-Mas, Bryant, Cuong, Hoang, Campbell, Hoang, et al., 2014; Dang-Xuan, Nguyen-Viet, ...
Unger, Pham-Duc, Grace, Tran-Thi, et al., 2017; T. N. M. Nguyen, Hotzel, El-Adawy, Tran, Le, Tomaso, et al., 2016; Takeshi, Itoh, Hosono, Kono, Tin, Vinh, et al., 2009; Toan, Nguyen-Viet, & Huong, 2013). These bacteria as well as antibiotic resistance genes can be horizontally transferred to human through direct and indirect contacts with the source of infection which can be animals or contaminated foods. In raw food, in the examples given in Table 1, these bacteria are found with at least 10% probability of contamination. The probability could rise up to 83% depending on the species, the raw food, and the origin of the sample.

In fermented meat, the contamination is still very high in the examples presented in Table 1 and they even reach 100% in the neighboring regions of India (Keisam, Tuikhar, Ahmed, & Jeyaram, 2019) although in one study not presenting whether fermented meat was cooked or not, contaminations ranged from 0 to 19% (Ananchaipattana, et al., 2012). A study focusing on Salmonella in the food chain and in nem chua confirmed through serovar analysis and genotyping that contamination of the raw meat was usually responsible for contamination of the fermented product (Le Bas, Hanh, Thành, Cuong, Quang, Binh, et al., 2008). The microbial safety of nem chua in Vietnam has been discussed in several studies ((Phan, Pham et al. 2006; Nguyen et al., 2010; 2013 ; Le, Do et al. 2012). Indeed, the concentration of E. coli and S. aureus in raw meat for preparing nem chua was 10-100 and 100-1000 fold higher than the National Vietnamese Standard (TCVN 7046:2002 for fresh meat), respectively. Consequently, the final products nem chua could not meet the requirement for hygiene and safety standard (TCVN 7050:2002 for unheated fermented products) (Le, Do, Le, Tran, & Van, 2012; Phan, Pham, & Hoang, 2006). However, cases of illness in human beings due to the consumption of nem chua have been rarely reported in Vietnam. Several explanations can contribute to this fact, including small scale production combined with incomplete epidemiological data, as well as the presence of a number of lactic acid bacteria (LAB)
present in the final product. These LAB and their metabolites can produce organic acid and
bacteriocins able to inhibit the growth of pathogenic microorganisms. The LAB of 30 samples
of nem chua were isolated and the presence of Lactobacillus plantarum (prevalence of
67.6%), Pediococcus pentosaceus (21.6%), Lactobacillus brevis (9.5%) and Lactobacillus
farciminis (1.3%) was reported (Tran, May, Smooker, Van, & Coloe, 2011). L. plantarum was
also reported as the most prevalent in meat and legume fermentation products (La Anh, 2015;
authors investigated thus the antibacterial properties of some L. plantarum strains isolated
from fermented food. L. plantarum B33 isolated from nem chua could inhibit food-borne
bacteria including E. coli NC31, E. coli K12TG1, E. coli 320 LCB, S. aureus, S.
Typhimurium with a zone of inhibition ranging from 4-14 mm (Lê, Hồ, Trần, Chu, Lê, Lê, et
al., 2011). Recently, the bacteriocins produced by other LAB isolated from nem chua were
characterized (Pilasombut, Rumjuankiat, Ngamyeesoon, & Duy, 2015). It was shown that L.
plantarum KL-1 could produce a bacteriocin inhibiting the growth of pathogens and of some
LAB such as Lactobacillus sakei, Leuconostoc mesenteroides and Enterococcus faecalis.
Additionally, 47% LAB isolates from nem chua exhibited strong antimicrobial activity
against moulds from the same products and L. plantarum and P. pentosaceus showed the best
antifungal activities (Phong, Van, Thanh, Long, & Dung, 2016). These strains could thus be
useful as backslap and/or starter cultures.

Vegetables can also be the source of microbiological contamination (Ha et al., 2019). In
South-East Asia, there are different kinds of fermented vegetables including cucumbers,
mustard greens, young melons, cabbages, chinese cabbages, papayas, bamboo shoots, and
bean sprouts with Asian spider flower. They are usually produced in small-scale using mostly
spontaneous fermentation and sometime back-slopping fermentation. The production of
fermented foods and beverages through spontaneous fermentation and back-slopping
represents an inexpensive and reliable preservation method in less developed countries (Owens, 2014). Most of the sellers of these fermented vegetables are producers and these products are usually sold in the local markets in open containers. The results of two studies carried out in Phnom Penh wet markets are reported in Table 1.

In these studies, the microbiological quality of fermented vegetables sold in Phnom Penh markets was investigated, showing a correlation between microbial contamination and hygienic conditions (quality and material of container, use of hands, hands with gloves, the same rice paddle for all the products, open containers, etc…). The authors supposed that the lack of hygienic precautions and bad cultural practices could be extended upward to the production of vegetables (González García, Fernández-López, Polesel, & Trapp, 2019).

This paragraph deals with pathogen bacteria but it should be noted that another source of disease has been characterized in Thai fermented fish. Indeed, liver fluke in its development cycle is ingested by fishes that, if eaten without cooking, can inoculate the disease in human consumers (Sriraj, Boonmars, Aukkanimart, Songsri, Sripa, Ratanasuwan, et al., 2016). It is particularly dangerous as liver fluke can be a factor of development of cholangiocarcinoma, especially when it is linked to high concentrations of nitrosamine (Mitacek, Brunnemann, Suttajit, Martin, Limsila, Ohshima, et al., 1999). However, it can be noted that the level of such cancers is not higher in North-East Thailand, the region where this fermented fish is produced and consumed.

3. Toxin or toxic compounds producing microorganisms
3.1 Mycotoxin risks

Mycotoxins are toxic secondary fungal metabolites mainly produced by five genera of filamentous fungi i.e. Alternaria, Aspergillus, Cladosporium, Fusarium and Penicillium. These molds can produce different types of mycotoxins, among them, some are unique to one species, but most can be produced by several fungi (Bräse et al., 2009). FAO reported that 25% of the world’s crops are affected by mold or fungal growth with losses of around 1 billion metric tons of food products annually. Economic losses occur because of: 1) yield loss due to diseases induced by toxigenic fungi; 2) reduced crop value resulting from mycotoxin contamination; 3) losses in animal productivity from mycotoxin-related health problems; and 4) human health costs. Moreover, additional costs associated with mycotoxin also include the cost of management at all levels (prevention, sampling, mitigation, litigation, and research costs). These economic impacts affect all along the food and feed supply chains: crop producers, animal producers, grain handlers and distributors, processors, consumers, and the society as a whole (due to health care impacts and productivity losses). Nowadays, more than 400 mycotoxin metabolites have been discovered but the eight most important mycotoxins (Top 8) with worldwide relevance in regard to public health are aflatoxins, ochratoxin A, fumonisin B₁, zearalenone, deoxynivalenol, nivalenol, T-2 toxin and patulin (FAO, 2001).

Mycotoxin can contaminate various agricultural commodities and particularly cereals and legumes such as wheat, barley, rye, oats, rice, maize, peanuts, alfalfa, clover, beans, peas, chickpeas, lentils, lupine, mesquite, carob, soybeans, tamarind and some other cereal grains that are normally used as substrates for traditional fermented food in South-East Asia. Those substrates can be contaminated with mycotoxin either before harvest or under post-harvest conditions (FAO, 1991), resulting in mycotoxin contamination in the finished products. Mycotoxin is relatively stable to cooking and processing temperatures. Once they contaminate
food and feed, they cannot be removed safely. This means that once foods are contaminated, human exposure is almost certain if the foods go into the market.

In South-East Asia, this problem is acute due to favorable humidity and temperature conditions for the development of molds. It is even hypothesized that the consumption of aflatoxin contaminated foods, which is recognized as a risk factor for human hepatocellular carcinoma, may contribute to the high incidence of this disease in South-East Asia (Tran-Dinh, Kennedy, Bui, & Carter, 2009). Several studies report a high level of contamination of agricultural products and, due to the great stability of mycotoxins, these compounds remain present in agriculture soils (Tran-Dinh, Kennedy, Bui, & Carter, 2009). They also remain in the raw product after processing and, if the raw material is used for animal feeding, they can contaminate meat products. As a result, despite a 20-year-old study showing in the north of Thailand that vegetarians can be more exposed to mycotoxins (Vinitketkumnuen, Chewonarin, Kongtawelert, Lertjanyarak, Peerakhom, & Wild, 1997), animal products are also likely to be contaminated. For instance in Vietnam, aflatoxins and zearalenone were found in all feed samples analyzed (Thieu, Ogle, & Pettersson, 2007) and then aflatoxin M1, in more than half of pig urine samples collected in various slaughterhouses of Vietnam (Lee, Lindahl, Nguyen-Viet, Khong, Nghia, Xuan, et al., 2017). As a result, mycotoxins can be expected in fermented products in a way similar to unfermented ones (Sivamaruthi, Kesika, & Chaiyasut, 2018). Although analyses of mycotoxins present in fermented products are rare, some have been detected in soy fermented products like Thua-nao (Petchkongkaew, Taillandier, Gasaluck, & Lebrihi, 2008) and Tuong (Vu & Nguyen, 2016). This latter soy sauce is fermented by *Aspergillus orizae* which is very near, and considerd as the domesticated form of, *A. flavus*, the aflatoxin producer, a fact that can explain the presence of aflatoxin in 4/14 brands of Tuong. A review presenting mycotoxins in world fermented
products has been published recently confirming that mycotoxins are often present in this class of products (Sivamaruthi, Kesika, & Chaiyasut, 2018).

3.2 Biogenic amines

Biogenic amines (BAs) are low molecular weight nitrogenous compounds naturally present in animals, plants, and microorganisms where they play several functions including gene expression regulation, cell growth and differentiation, etc. (Suzzi and Torriani, 2015). On the basis of their chemical structure, BAs are divided into aliphatic (putrescine, cadaverine, spermine and spermidine), aromatic (tyramine and phenylethylamine) or heterocyclic (histamine and tryptamine). Considering the number of amine groups, they are classified in monoamines (tyramine and phenylethylamine), diamines (putrescine and cadaverine) or polyamines (spermine and spermidine) (Park et al., 2019). The occurrence of some BAs (histamine, putrescine, cadaverine, tyramine, tryptamine, 2-phenylethylamine, spermine and spermidine) in fermented foods such as fish, meat, cheese, vegetables, and wines, has been widely described (for a review see Spano et al., 2010). Unfortunately, the consumption of foods or beverages containing high amounts of BAs is a risk for consumer health since they can have toxic effects (Park et al., 2019). The BAs encountered in fermented foods are mainly produced by microbial decarboxylation of amino acids (Mah et al., 2019). The main microbial groups associated with BAs accumulation are several Gram negative (enterobacteria and pseudomonads) and Gram positive bacteria including staphylococci, Bacillus spp. and lactic acid bacteria (LAB). The presence of decarboxylase positive microorganisms is not the only factor influencing BAs accumulation in foods, in fact, specific environmental conditions are required (e.g. availability of BAs precursors, presence of proteolytic enzymes involved in the release of free amino acids). Other factors involved are: raw materials characteristics in terms of composition, pH, ion strength, physico-chemical parameters (NaCl, pH and ripening
temperature) and processing, storage and distribution conditions (Suzzi and Torriani, 2015; Linares et al., 2012).

Several traditional fermented foods from South-East Asia including fish sauce and fermented soybean foods are characterized by a high amount of BAs (for reviews see Prester, 2011, Zaman et al., 2009; Park et al., 2019). The most popular fermented soybean foods are produced through bacterial fermentation and the main are: Natto, Miso, Cheonggukjang, Doenjang, Gochujang, Chunjang, Doubanjiang, and Douchi. The BAs composition of these products is reported in Table 2 (it should be noted that for Doenjang, the very high maximal concentration detected comes from one isolated study and most studies report values below thresholds).

Fermented fish products represent a source of BAs and especially histamine, which is one of the most dangerous for human health. In fact, it is the only BA with regulatory limits. The US FDA set a guidance level of 50 mg/kg for histamine in the edible portion of fish (FDA, 2011), and the European Commission established up to a maximum of 200 mg/kg in fresh fish and 400 mg/kg in fishery products treated by enzyme maturation in brine (EFSA, 2011). BA content in seafood for South-Korea and China is regulated imposing maximum limits of histamine content in fish, at 200 mg/kg and 200–400 mg/kg, respectively. According to EFSA (2011) dried anchovies and fish sauce are the fermented foods showing the highest mean content of histamine, with values of 348 mg/kg and 196-197 mg/kg, respectively. More in general, fish sauce is characterized by the highest mean values for the sum of BAs (582 - 588 mg/kg). The histamine content of some Asian fish products is reported in Table 3.

4. Chemical contaminations

4.1 Pesticides, heavy metals
In the past century, agriculture has increased productivity through mechanization, fertilization, pesticides, and selective breeding. Furthermore, intensification of cash-crop production and conventional agriculture with fertilizers and pesticides impair local resources (soil fertility, biodiversity). Some trace elements (e.g. iron, potassium, etc…) have undergone historical decrease in food in Finland, United States and United Kingdom (Mayer, 1997; Ekholm et al., 2007). This decline was attributed to varietal selection based mainly on yield and soil degradation due to intensive agriculture.

Great transitions are at work in Europe. The Ecophyto plan is implemented with the purpose of progressively reducing the use of pesticides. With international trades, food products are imported from numerous countries where the environmental rules do not correspond to European ones. In Northern Europe, foods imported from Asia contained 111 distinct pesticides and in some cases concentration exceeded the Maximum Residue Levels with leafy vegetables particularly concerned (chives, thai basil) (Skretteberg, 2015). In 2010, among 245 plant foods from Phnom Penh markets, 15% of the long beans and 95% of the kale contained noticeable levels of organophosphate and carbamate pesticides (Neufeld et al., 2010).

It is true that, apart from the war inheritances like agent orange which still results in daily intakes of dioxins far above the WHO recommendation in some parts of Vietnam (Tuyet-Hanh, Minh, Vu-Anh, Dunne, Toms, Tenkate, et al., 2015), South-East Asian cultures can be potentially contaminated by chemicals and metals. Several studies have highlighted the poisoning of agriculture workers (Thetkathuek & Jaidee, 2017; Thetkathuek, Suymbros, Daniell, Meepradit, & Jaidee, 2014) and of the environment (Harnpicharnchai, Chaiear, & Charerntanyarak, 2014) but the main concern for fermented food products is related to pesticides encountered in raw materials. A survey in the Red river delta showed that pesticides used in agriculture were frequently detected in biota, leading to repeated analyses above the acceptable daily intakes in fishes and vegetables (Hoai, Sebesvari, Minh, Viet, &
Renaud, 2011). Even banned organochlorine pesticides still persist in these environments. Among vegetables reaching the residue limits established by the European Union, some vegetables used for fermentation like Chinese cabbage and some herbs are cited (Sapbamrer & Hongsibsong, 2014; Wanwimolruk, Kanchanamayoon, Phopin, & Prachayasittikul, 2015) while some fruits (watermelon and durian) despite the presence of chemicals, were considered as safe (Wanwimolruk, Kanchanamayoon, Boonpangrak, & Prachayasittikul, 2015). The fate of pesticides in food products depends on the specific physicochemical properties of the compounds as well as on the conditions of preparation of food (presence of water, temperature and pH etc). During fermentation, the concentration of pesticides usually decreases significantly, giving rise to degradation products. In addition to non-fermented products, fermented products are characterized by the presence of microorganisms. The presence of pesticides as well as of their degradation products tend to limit the activity of microorganisms and modify the sensorial properties of the product but in the mean time, microorganisms can degrade these products and help decreasing the contamination of fermented products (Regueiro, López-Fernández, Rial-Otero, Cancho-Grande, & Simal-Gándara, 2015). Studies on pesticides in food are still at the preliminary level and their degradation, the risk related to their degradation products, the potential catalysis by microorganisms, thought of paramount importance, need to be further studied.

5. Antibiotics resistance of microbes from traditional fermented foods from South-East Asia

Antibiotics are either microbial secondary metabolites or the analogous compounds synthesized or semi-synthesized chemically, that could inhibit the growth and survival of other bacteria. These compounds are used as therapeutic agents against infectious disease in
humans, livestock and aquaculture. However, haphazard and extensive use of antibiotics may
select antibiotic resistant bacteria (Ben et al., 2019). Bacteria can develop antibiotic resistance
by several mechanisms via enzymatic degradation; antibiotic target modification; changing
the bacterial cell wall permeability and alternative pathways to escape the activity (Verraes et
al., 2013). Antibiotic resistance can be inherited or acquired. Inherited antibiotic resistance is
exhibited by all isolated of the same species while acquired antibiotic resistance occurs when
susceptible bacteria gain the genes encoding a resistance mechanism via mutation or the
transfer of genetic material from other bacteria (MacGowan & Macnaughton 2017).

Foodborne diseases not only affect people’s well-being, but also cause hospitalization and
economic loss. Approximately 22.8 million cases of diarrheal illness caused by Salmonellosis
outbreak annually, with 37,600 deaths in South-East Asia (Van et al., 2012). Generally, food
contributes as an important part for transfer of antibiotic resistance in terms of antibiotic
residues or resistant genes from food microflora to pathogenic bacteria (Akbar & Anal, 2013).
It is important to monitor the prevalence of pathogenic bacteria along with antibiotic resistant
foodborne pathogens in food chain to improve and implement food safety (Chanseyha et al.,
2018). For instance, for the contamination of raw products by pathogenic bacteria as
discussed above, the resistance of bacteria to antibiotic is thus also an important issue. The
resistance of *E. coli* to antibiotic isolated from pork collected in pig farm, supermarket and
wet market from Hochiminh city and Tien Giang province was reported. The resistance to
tetracycline, sulphafurazole, ampicillin/amoxicillin, trimethoprim, chloramphenicol,
streptomycin, nalidixic acid, ciprofloxacin, gentamicin, colistin and ceftazidime were 100, 70,
55, 60, 50, 65, 30, 42.2, 73.3, 22.2 and 1.1%, respectively (N. T. Nguyen, Nguyen, Nguyen,
Nguyen, Thai, et al., 2016; Van, Chin, Chapman, Tran, & Coloe, 2008). Nguyen et
al. (2016a) described for the first time a strain – isolated from pork – resistant against colistin
(a last-resort antibiotic). Multi-resistance of *E. coli* to at least 3 different classes of antibiotics was observed with rates up to 75% in pork (Van, Chin, Chapman, Tran, & Coloe, 2008). *Campylobacter* and *Salmonella* spp. from pork meat showed high resistance rate (>50%) against streptomycin and tetracycline in addition, with different levels of antimicrobial susceptibility to ciprofloxacin, nalidixic acid, ampicillin, chloramphenicol, erythromycin and streptomycin (0-<50%) (T. N. M. Nguyen, et al., 2016; Vo, van Duijkeren, Gaastra, & Fluit, 2010). Moreover, 52.2% of *Salmonella* strains from pork, beef and chicken meat showed multidrug resistance (Nguyen Thi Nhung, et al., 2018).

Traditional fermented foods and beverages are popular for their nutritional balance and food security. In many Asian countries, techniques for fermenting cereals, vegetables and meat products are well developed. Such fermented foods are highly priced for improved nutritional and organoleptic quality as well as for beneficial microorganisms (Anal, 2019). Several studies have indicated that along with beneficial microorganism, fermented foods can act as vehicles of antibiotic resistant bacteria (see Table 4). Therefore, through the food chain involving traditional fermented food, antibiotic resistant genes may be transferred to other bacteria including pathogens and commensals and into the gastrointestinal tract (Abriouel et al., 2017).

South-East Asia region is rapidly developing, and food products are exported globally. Since this region is a hotspot of antibiotic resistant bacteria, there is a risk of dissemination of antibiotic resistant bacteria and genes to consumers worldwide (Nhung et al., 2016). In Asia, numerous fermented foods are categorized into five groups including fermented soybean; fish; vegetable; bread and porridges; and alcoholic beverage. Lactic acid bacteria (LAB) are the commonly involved bacteria in these products to a varying extent, having either positive or negative effects (Rhee et al., 2011). Some of the antibiotic resistant LAB isolated from traditionally fermented foods are summarized in the Table 4.
6. Analysis and main recommendations

Despite huge differences between South-East Asian countries, concerns about risk of pathogens in fermented meat product such as nem chua, due to the contamination in raw meat material, are common (Hoang & Vu, 2017). The high level of contaminations in farms can be related to hygiene (Dang-Xuan, Nguyen-Viet, Pham-Duc, Unger, Tran-Thi, Grace, et al., 2019). However, several studies have highlighted an increase in the level of contaminations in slaughterhouses. These contaminations were likely to come from faeces to carcasses (Dang-Xuan, et al., 2019; Le Bas, et al., 2008). Cross contaminations between species have also been observed as shown in Table 1: although infections by Campylobacter concerned mostly poultry and poultry products, this species was also found in swine carcasses and retail products as the meat could be contaminated with faeces at the slaughterhouse and processing facilities during the evisceration process, leading to the contamination of food products (T. N. M. Nguyen, et al., 2016). Taking into account that pigs are still mainly slaughtered in small structures in Vietnam despite the existence of big modern structures, one axis of improvement could be the improvement of hygiene conditions in those small slaughterhouses in a way sustainable for small structures. These recommendations for good hygiene practices could be:

(1) separate gut rinsing and carcass dressing, (2) separate lairage and carcass dressing, (3) use specific working surface for the carcass during slaughter, (4) cleaning and disinfection of these surfaces after work, (5) give clean water to the pigs at lairage (well water, not tank water), (6) clean and disinfect tanks and tools after work, (7) waste management avoiding contamination (Le Bas, et al., 2008). Other steps can be causes of contaminations such as handling in pork shops where management of flies and handling avoiding contact between meat and worker clothes could be improved (Dang-Xuan, et al., 2019). Finally, although the original load of raw pork meat is certainly the main contributor to the pathogen contamination
in the sausage, some additional contaminations may also result from the processing, especially during the forming of the sausages into the guava and banana leaves, usually done by hand. Leaves being usually considered as the source of inoculation of fermenting lactic acid bacteria, a maintained spontaneous fermentation would require an improvement of the leave production while another perspective would be the use of starters. Recommendation could also target consumers and a Thai study recommended also to cook nahm before eating (Paukatong & Kunawasen, 2001), however, such a step would introduce a completely new way of consumption in Vietnam.

For vegetables, basic hygiene could improve significantly the situation concerning pathogens. Contrary to the general consumer perception, hygienic problems are not limited to wet markets but are also present in supermarkets. For instance, a Thai study detected almost no significant contamination differences between open markets and supermarkets however, it could not take into account differences concerning fermented products as they were only available in open markets at that time (Ananchaipattana, et al., 2012). It is likely that a training of producers and handlers to good practices could improve greatly the hygienic quality of fermented products. One particular care should be taken to cross contaminations which have also been observed in vegetables as mixed vegetables are far more contaminated than fermented monoproduc

The problem of mycotoxin comes mainly from conditions of mold development, which can be decreased through the respect of good practice, and from the high stability of concerned molecules that can stay in the environment a long time after the production by molds. One concern is the price of analyses, which makes difficult any actions for basic farmers. There are however also some solutions to decrease the level of contamination by using adsorbant
materials like bentonite clays for piglet farming (Thieu, Ogle, & Pettersson, 2008) or microbial catalysts able to degrade the toxins (Petchkongkaew, Taillandier, Gasaluck, & Lebrihi, 2008).

The fluctuations in the BAs concentration suggest the lack of standardized processes. Improvements in this direction could be useful. In this context, it is essential to implement control strategies and develop methods to reduce BAs content in fermented products in order to face consumers demand for healthier and safe foods.

Food contamination by pesticides is a world-wide problem but, concerning specific contaminations in the region, the agricultural practices are obviously a way to improve results as, for mangosteen, 97% of the fruits for local market are exceeding the MRLs whereas no problems are detected for the GAP production of fruits intended for the European Union (Wanwimolruk, Kanchanamayoon, Phopin, & Prachayasittikul, 2015). Organic agriculture could also be a mean to improve this point but some steps are still required to secure production especially in less controlled area. Indeed, the safety of organic foods is still unclear as the use of untreated irrigation or washing water or inappropriate organic fertilizers (i.e manure or composts) is possible (Taban et al., 2011; Nguyen-the et al, 2016). Data related to the microbial communities associated to the surface of fresh fruits and vegetables have shown significant differences, quantitatively and qualitatively, between conventional and organic products (Leff & Fierer, 2013; Bigot et al., 2015). Using E. coli, Salmonella and Listeria which are the most contaminating pathogen bacteria for leafy vegetables as indicator, different studies have been carried out to evaluate the contamination level of organic vs conventional vegetables, notably leafy ones (Tango et al., 2014; Karp et al., 2016). Results are contrasted with no real trend or a slight impact on organically-grown vegetables (Leff & Fierer, 2013; Tango et al., 2014). Studies on the mycotoxin contamination of agricultural products have mainly been carried out on cereals or fruits and rarely on leafy vegetables (van
Mycotoxin contaminations in organic cereal crops were variable and inconclusive but their levels were sometimes higher than those observed in conventional samples (Baert et al., 2006; Magkos et al., 2006; Piqué et al., 2013). In this field, more studies are needed before establishing precise recommendations. In all cases, training of farmers, retailers and transformers would greatly improve the situation.

7. Conclusion

Fermented foods from South-East Asia exhibit several safety risks in a similar way to raw agriculture products (Figure 1). The presence of pathogens is one of the main and immediate risk as it contaminates many clean samples during slaughter and handling. However, the presence of chemicals, biogenic amins, mycotoxins and parasites can be a more difficult risk to take into account as it can be more hidden with a long-term effect. Risks could be greatly diminished by the use of good agriculture/manufacturing practice, especially concerning pathogen and chemical contamination and antibiotic resistance. For mycotoxin, good producing and storage practice could also help a lot and, for biogenic amines, a survey of strains present during fermentation might be required as a first step before strategies to avoid their development. For all food safety concerns, starters can also be used for biopreservation and bioremediation purposes and thus decrease risks (Ho, Nguyen, Petchkongkaew, Nguyen, Chu-Ky, Nguyen, et al., in minor revision).

This validates the drivers of food unsafety as cited above (Kendall, et al., 2018). Among the various ways to improve safety, training of all actors of the production/transformation chain may be one of the main active ones. This was the subject of the AsiFood Erasmus+ project which just finished recently (Anal et al., in press). and, in the future, it would be interesting to evaluate the impact of training on food safety in the different partner countries. It should also
be added that the level of food safety in the various ASEAN countries is very diverse as a result of economic development, culture, motivation (export to world region exerting a big control) etc.

Acknowledgements: This work was funded by the Erasmus+ AsiFood «Universities as key partners for the new challenges regarding food safety and quality in ASEAN» project, the Bualuang ASEAN chair professorship of Thammasat University, the Investissement d’Avenir ISITE BFC ANR-15-IDEX-0003 and the French Embassy in Thailand. The author are thankful to Dr Guillaume Da for his precious help to establish the network.

References


Sriraj, P., Boonmars, T., Aukkanimart, R., Songsri, J., Sripan, P., Ratanasuwan, P.,
fluke infection and traditional northeastern Thai foods associated with cholangiocarcinoma


Antibiotic-Resistance Genes from Lactic Acid Bacteria in Indonesian Fermented Foods.
*HAYATI Journal of Biosciences*, 21, 144–150.

Microbiology*, 6, 472


Takeshi, K., Itoh, S., Hosono, H., Kono, H., Tin, V. T., Vinh, N. Q., Thuy, N. T., Kawamoto,
K., & Makino, S. (2009). Detection of *Salmonella* spp. Isolates from specimens due to pork

Vegetables from Organic and Conventional Production in Different Areas of Korea. *Journal
of Food Protection*, 77, 1411–1417.


**Table 1** Contamination of raw and fermented products in Vietnam, Thailand, Cambodia and Northeast India.

<table>
<thead>
<tr>
<th>Species</th>
<th>Samples</th>
<th>Origin</th>
<th>Place</th>
<th>Positive samples</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>In raw products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>meat</td>
<td>HCMc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>Hanoi</td>
<td>25%</td>
<td>Toan et al. (2013)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>Wet market</td>
<td>Hung Yen</td>
<td>32.8%</td>
<td>Takeshi et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td>Wet market</td>
<td>Hue</td>
<td>44%</td>
<td>Dang-Xuan et al. (2017)</td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td></td>
<td></td>
<td>11.6%</td>
<td>Nguyen et al. (2016)</td>
</tr>
<tr>
<td></td>
<td>meat</td>
<td>Open markets</td>
<td>Bangkok /Pathum Thani</td>
<td>83%</td>
<td>(Ananchaipattana, et al., 2012)</td>
</tr>
<tr>
<td></td>
<td>meat</td>
<td>supermark ets</td>
<td>Bangkok /Pathum Thani</td>
<td>67%</td>
<td>(Ananchaipattana, et al., 2012)</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>Poultry</td>
<td>Factories, school, hospital canteens</td>
<td>Hanoi</td>
<td>45%</td>
<td>(Dao &amp; Yen, 2006)</td>
</tr>
<tr>
<td>Raw meat (beef, pork)</td>
<td></td>
<td></td>
<td></td>
<td>21.3%</td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td></td>
<td></td>
<td></td>
<td>6.6%</td>
<td></td>
</tr>
<tr>
<td>Veg.</td>
<td></td>
<td></td>
<td></td>
<td>18.5%</td>
<td></td>
</tr>
<tr>
<td><em>Campylobacter</em></td>
<td>Vietnam</td>
<td></td>
<td></td>
<td>10%</td>
<td>Nguyen et al. (2016)</td>
</tr>
<tr>
<td></td>
<td>Vietnam</td>
<td></td>
<td></td>
<td>15-32%</td>
<td>Carrique-Mas et al. (2014)</td>
</tr>
</tbody>
</table>
In fermented products

<table>
<thead>
<tr>
<th>Organism</th>
<th>Product</th>
<th>Location</th>
<th>BAs (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterococcus sp.</td>
<td>vegetables</td>
<td>5 wet markets</td>
<td>34%</td>
<td>Chrun, Hosotani et al. (2017)</td>
</tr>
<tr>
<td>Bacillus sp.</td>
<td></td>
<td>Phnom Penh</td>
<td>31%</td>
<td></td>
</tr>
<tr>
<td>E. coli</td>
<td>cucumber</td>
<td>22 sellers from 11 wet markets</td>
<td>4/11 markets</td>
<td>Tan Reasme (unpublished data)</td>
</tr>
<tr>
<td>E. coli</td>
<td>pork and fish</td>
<td>Open markets</td>
<td>18%</td>
<td>Ananchaipattana et al. 2012</td>
</tr>
<tr>
<td>S. aureus</td>
<td></td>
<td></td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Salmonella</td>
<td></td>
<td></td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Staphylococcus</td>
<td></td>
<td></td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Listeria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacillus cereus</td>
<td>soybean</td>
<td>markets</td>
<td>100%</td>
<td>Keisam et al. 2019</td>
</tr>
<tr>
<td>Clostridium botulinum</td>
<td>Soybean</td>
<td>North-east India</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bamboo</td>
<td></td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish</td>
<td></td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Milk</td>
<td></td>
<td>44%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td></td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>74%</td>
<td></td>
</tr>
<tr>
<td>E. coli</td>
<td>Soybean</td>
<td></td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Proteus mirabilis</td>
<td>soybean</td>
<td></td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>milk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pork</td>
<td></td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Salmonella</td>
<td>Nem chua</td>
<td>Along chain</td>
<td>35.2%</td>
<td>(Le Bas, et al., 2008)</td>
</tr>
<tr>
<td>Salmonella</td>
<td>Nahm</td>
<td>Bangkok</td>
<td>20%</td>
<td>(Osiriphun, Pongpoolponsak, &amp; Tuitemwong, 2004)</td>
</tr>
</tbody>
</table>

Table 2: Minimum and maximum BAs content in some fermented soybean product. BAs concentration is expressed in mg/kg. Modified from Mah et al. (2019)

<table>
<thead>
<tr>
<th>Fermented soybean product</th>
<th>TRP</th>
<th>PHE</th>
<th>PUT</th>
<th>CAD</th>
<th>HIS</th>
<th>TYR</th>
<th>SPD</th>
<th>SPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheonggukjang</td>
<td>236.4</td>
<td>40.8</td>
<td>121.3</td>
<td>20.2</td>
<td>755.4</td>
<td>2539</td>
<td>59.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Chunjang</td>
<td>13.3-31.35</td>
<td>11.8</td>
<td>2.2-28.59</td>
<td>6.6</td>
<td>1.85-272.55</td>
<td>19.78-131.27</td>
<td>0.24-12.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Doenjiang</td>
<td>2808.1</td>
<td>8704</td>
<td>4292.3</td>
<td>3235.5</td>
<td>2794.8</td>
<td>6616.1</td>
<td>8804</td>
<td>9729.5</td>
</tr>
<tr>
<td>Douchi</td>
<td>62.43</td>
<td>143-185.61</td>
<td>1.15-129.17</td>
<td>0.17</td>
<td>59</td>
<td>2.1-126.8</td>
<td>14.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Gochujang</td>
<td>440</td>
<td>239</td>
<td>596</td>
<td>191</td>
<td>808</td>
<td>529</td>
<td>6616.1</td>
<td>242</td>
</tr>
<tr>
<td>Gochujang</td>
<td>36.6</td>
<td>0.7-24.8</td>
<td>2.5-36.4</td>
<td>18.1</td>
<td>0.6-59</td>
<td>2.1-126.8</td>
<td>14.5</td>
<td>18</td>
</tr>
<tr>
<td>Miso</td>
<td>762</td>
<td>11.76</td>
<td>23.2</td>
<td>201</td>
<td>221</td>
<td>95.3</td>
<td>95.3</td>
<td>216</td>
</tr>
<tr>
<td>Natto</td>
<td>301</td>
<td>51.5</td>
<td>43.1</td>
<td>42</td>
<td>457</td>
<td>300.2</td>
<td>478.1</td>
<td>80.1</td>
</tr>
<tr>
<td>Soy sauce</td>
<td>45.8</td>
<td>1.5-121.6</td>
<td>2.5-1007.5</td>
<td>0.7-32.3</td>
<td>3.9-398.8</td>
<td>26.8-794.3</td>
<td>1.5-53.1</td>
<td>16.1</td>
</tr>
</tbody>
</table>

Table 3 Range of histamine concentrations found in Asian fish products

<table>
<thead>
<tr>
<th>Product</th>
<th>Origin</th>
<th>HIS (mg/kg)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish sauce</td>
<td>Taiwan</td>
<td>45–1220</td>
<td>Tsai et al. 2006</td>
</tr>
<tr>
<td>Fish paste</td>
<td></td>
<td>0.1–760</td>
<td></td>
</tr>
<tr>
<td>Shrimp paste</td>
<td></td>
<td>20–1180</td>
<td></td>
</tr>
<tr>
<td>Anchovy sauces</td>
<td>Malaysia</td>
<td>63–393</td>
<td>Saaid et al. 2009, Zaman et al. 2010</td>
</tr>
<tr>
<td>Thai fish sauce (Som-fug)</td>
<td>Thailand</td>
<td>55.1–291</td>
<td>Riebroy et al. 2004</td>
</tr>
<tr>
<td>Ikan pekasam from black tilapia</td>
<td>Malaysia</td>
<td>18.8–71.3</td>
<td>Ezzat et al., 2015</td>
</tr>
<tr>
<td>Ikan pekasam from javanese carp</td>
<td>Malaysia</td>
<td>12.7–109.1</td>
<td></td>
</tr>
</tbody>
</table>
Table 4 Antibiotic resistance of LAB isolated from Asian traditional fermented food products

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Country</th>
<th>Product</th>
<th>LAB</th>
<th>Phenotypic antibiotic resistance</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>China</td>
<td>Yogurt</td>
<td><em>Lb. acidophilus, Lb. brevis, Lb. fermentum, Lb. plantarum, S. thermophilus</em></td>
<td>ERY, TET</td>
<td>Nawaz et al. (2011)</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Dadih</td>
<td></td>
<td><em>Lb. fermentum, Lb. plantarum, P. acidilactici</em></td>
<td>CHL, ERY</td>
<td>Sukmarini et al. (2014)</td>
</tr>
<tr>
<td>Meat</td>
<td>Indonesia</td>
<td>Bekasam or tempoyak</td>
<td><em>Lb. fermentum, Lb. plantarum, P. acidilactici</em></td>
<td>CHL, ERY</td>
<td></td>
</tr>
<tr>
<td>Vegetable</td>
<td>China</td>
<td>Jiang shui</td>
<td><em>Lb. plantarum</em></td>
<td>TET</td>
<td>Nawaz et al. (2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pickle</td>
<td><em>Lb. salivarius</em></td>
<td>ERY, TET</td>
<td></td>
</tr>
<tr>
<td>Cereal</td>
<td>India</td>
<td>Idli batter, dosa batter</td>
<td><em>E. casseliflavus, E. faecium, E. durans, E. lactis, Lb. fermentum, Lb. plantarum, P. pentosaceus, Ln. mesenteroides</em></td>
<td>ERY, TET</td>
<td>Thumu and Halai (2012)</td>
</tr>
<tr>
<td>Rice + ragi</td>
<td>Indonesia</td>
<td>Tape ketan</td>
<td><em>Lb. fermentum, Lb. plantarum, P. acidilactici</em></td>
<td>CHL, ERY</td>
<td>Sukmarini et al. (2014)</td>
</tr>
</tbody>
</table>

CHL, chloramphenicol; ERY, Erythromycin; TET, tetracycline
Future challenges

- Organic agriculture
- Standards and certifications
- Crop rotation and intercropping with nitrogen
- Fixing leguminous crops
- Integrated pest management using biological controls
- Good practices
- Training

Figure 1°: Pre-processing

Pathogen

Lactic acid bacteria

Antibiotics

Pesticides

Mycotoxin

Future challenges
Figure 1B: Processing and post-processing

- Biogenic amines
- Fermentation
- Cross contamination
- Market
- Consumer
- Future challenges
  - Hurdle technologies
  - Biopreservation
  - Starter cultures
  - Adsorbant materials
  - Microbial catalysts
  - Good hygienic practice
  - Cold storage