CHEMICAL AND MICROBIOLOGICAL CHANGES DURING FERMENTATION OF *NONSOM*, AN INDIGENOUS FERMENTED FISH IN SABAH.

WONG YIN FAR

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE DEGREE BACHELOR OF FOOD SCIENCE WITH HONOURS IN THE FIELD OF FOOD TECHNOLOGY AND BIOPROCESS

SCHOOL OF FOOD SCIENCE AND NUTRITION
UNIVERSITI MALAYSIA SABAH
2007

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL: CHEMICAL AND MICROBIOLOGICAL CHANGES DURING FERMENTATION OF NONSOM, AN INDIGENOUS FERMENTED FISH IN SABAH.

IJAZAH: SARJAN MUDA

SESI PENGAJIAN: 2004 / 2005

Saya WONG YIN FAR
(HURUF BESAR)

mengaku membenarkan tesis (LPS/ Sarjana/ Doktor Falsafah) ini di simpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. ** Sila tandakan (/)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[/]	TIDAK TERHAD	

Disahkan oleh

(TANDATANGAN PENULIS)

(TANDATANGAN PUSTAKAWAN)

Alamat Tetap: NO. 24, KAMPUNG BEMBAN, 31000 BATU GAJAH, PERAK

DR. CHYE FOOK YEE
Nama Penyelia

Tarikh: 11 / 05 / 07

Tarikh: 11 / 05 / 07

CATATAN: * Potong yang tidak berkenaan.
* Jika tesis ini SULIT atau TERHAD, sila lampiran surat daripada pihak berkuasa/organsasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (LPSM).

DECLARATION

The materials in this thesis are original except for quotations, excerpts, summaries and references, which have been duly acknowledged.

WONG YIN FAR

HN 2004-2385

26 MARCH 2007

VERIFICATION

1. SUPERVISOR

(DR. CHYE FOOK YEE)

2. EXAMINER 1

(MS. HO AI LING)

3. EXAMINER 2

(DR. MUHAMMAD IQBAL HASHIMI)

Mlltashmi

4. DEAN

(PROF. MADYA DR. MOHD ISMAIL ABDULLAH)

ACKNOWLEDGEMENTS

This study has been supported by School of Food Science and Nutrition (SSMP), UMS. I would like to thank Profesor Madya, Dr. Mohd. Ismail Abdullah, Dean of SSMP. I also sincerely thank Dr.Chye Fook Yee, who is my supervisor for this study for spending his time and giving a great amount of guidance and helpful discussion towards the completion of my dissertation. Without him, this study would not have completed in time. Besides that, I would like to thank my family, friends and other lecturers who support and help me for this study. I would also like to express my appreciation to the lab assistants Encik Othman, Encik Taipin, and Puan Marni for being there for me when I needed them. Their contributions are important for smooth operation of my research.

ABSTRACT

The physicochemical, proximate properties and microbiological changes of *nonsom*, which is traditionally produced fermented fish with rice in Sabah, were studied during fermentation. Value of pH dropped significantly at first 5 days. Reversely, the value of titratable acidity rapidly increased at that period. The correlation between pH, titratable and salt content was studied throughout fermentation. The value of crude fat and crude fiber were gradually increased, while crude protein content of sample decreased in this spontaneous fish fermentation. There are no significant changes in ash content, moisture content, carbohydrate and salt content. Total aerobic mesophile, proteolytic bacteria, halotolerant bacteria, lactic acid bacteria, yeast and mould were included in microbiological counting. Total aerobic mesophiles was varied in 10^7 and 10^8. Lactic acid bacteria comprised the dominant microbial group in *nonsom* compared to other microbial groups except total aerobic mesophiles. The LAB strains isolated namely *Lactobacillus brevis, Lactobacillus sakei, Lactobacillus plantarum, Lactobacillus hilgardii, Leuconostoc* spp., *Pediococcus* spp., which exhibiting starch-fermenting characteristic.

ABSTRAK

PERUBAHAN KIMIA DAN MIKROBIOLOGI SEMASA FERMENTASI NONSOM, SEJENIS IKAN FERMENTASI DI SABAH.

Perubahan fizikokimia, proksimat dan mikrobiologi bagi nonsom, sejenis ikan fermentasi di Sabah, dikaji sepanjang masa fermenatasi. Nilai pH menurun dengan nyata dalam 5 hari pertama. Sebaliknya, keasidan titrat meningkat dengan cepat pada masa itu. Korelasi antara pH, keasidan titrat dna kandungan garam juga dikaji sepanjang masa fermentasi. Nilai bagi lemak kasar dan serabut kasar meningkat beransur-ansur, manakala protin kasar menurun semasa fermentasi semulajadi ini berlaku. Perubahan bagi nilai kandungan abu, kandungan air, karbohidrat dan garam tiada perubahan yang nyata. Jumlah mesofilik aerobik, bakteria proteolitik (LAB), bakteria halotolerant, bakteria asid laktik, yis dan mould termasuk dalam perhitungan mikrobiologi untuk menentukan kuantiti setiap kumpulan mikroorganisma. Jumlah mesofilik aerobik berbeza antara 10^7 and 10^8. Bakteria asid laktik didapati merupakan kumpulan dominan dalam nonsom berbandingan dengan kumpulan lain selain total aerobic mesophiles. Strains LAB yang dipencilkan merupakan Lactobacillus brevis, Lactobacillus sakei, Lactobacillus plantarum, Lactobacillus hilgardii, Leuconostoc spp., Pediococcus spp., yang berupaya mefermentasikan karbohodrat.

CONTENTS

LIST OF FIGURE

LIST OF TABLE

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

Fermentation has been used for several thousand years as an effective and low cost means to preserve the quality and safety of foods. Animals and plant tissues subjected to the action of microorganisms and/or enzymes to give desirable biochemical changes and significant modification of food quality are referred to as fermented food (Campbell-Platt, 1994). Food fermentation is the oldest known form of biotechnology. The traditional fermented foods contain high nutritive value and developed a diversity of flavors, aromas, and texture in food substrates (Steinkraus, 1995).

As food expand and diversify, there is a growing interest in traditional fermented products manufactured at the farm level due to the uniqueness of such foods and the difficulties in mimicking them on an industrial scale(Souza *et al.*, 2003). Besides, it may also help to alleviate the nutritional problems that face the developing world. Food fermentation is especially important for developing countries where the lack of resources limits the use of techniques such as vitamin enrichment of foods, and the use of energy and capital intensive processes for food preservation. Examination of the indigenous fermented foods may, therefore, provide clues as to how food production and preservation can be expanded and thereby contribute to improved nutrition in the developing world in the future.

The so-called 'fermented' products can be divided into two main categories: the first is a high salt (20-30%) product in which the microbial count decreases during curing, and the second has a lower salt content to which fermentable carbohydrates are added (Cooke *et al.*, 1993). The latter category is characterized by an increase in microbial count during fermentation with a dominance of LAB (Tanasupawat & Komagata, 1995; Steinkraus, 1996). During fermentation, there are physical, microbiological and biochemical changes, involving tissue enzymes as well as microbial enzyme take place in food. The fermentation process depends on different parameters, such as the proportions and the quality of raw material, the use of starter cultures, temperatures and relative humidity and microbial flora (Rosello *et al.,* 1995).

Some important indigenous foods include Indonesian kocap (fermented vegetables proteins), Malaysian tempe kedela (fermented cereal), Korean kimchi (fermented cabbage), fish sauce in South-east Asia and so on. In South-East Asia, the fermented fish normally produced for condiments. However there are some indigenous fermented fish that are lightly salted fermented fish products (Ishige, 1993; Adams *et al.*, 1985). They are typically composed of freshwater fish species, salt, a carbohydrate source (boiled/ roasted rice, millet, sugar or fruit) and spices (garlic, ginger, chilli, pepper) (Paludan-Müller *et al.*, 1998). There is closely product called burong dalog in Philippine which is the raw fish are mixed with boiled rice and solar salt and allowed to ferment (Steinkraus, 1994). Besides, Som-fak is another Thai product composed of minced fish fillet, salt, ground boiled rice and minced garlic (Paludan-Müller *et al.*, 1998). In Som-fak, rapid growth of lactic acid bacteria (LAB) causing pH to decrease below 4.5

in 2 days is essential to prevent spoilage (Østergaard *et al.*, 1986) and to ensure safety of the product.

In Sabah, Malaysia, one type of fermented fish known as *Nonsom* among the Kadazan society was found. Traditionally, almost every Kadazan household in Sabah makes their own *nonsom* for domestic consumption. It is manufactured with fresh fish, rice, salt, seed of *Pangium edule* and no commercial starters are used in its production, fermentation occurring, therefore, by a natural process. Ripening depends entirely on natural microflora. These home-made techniques, acidification by the indigenous microbial group in raw material and the absence of control of temperature and relative humidity during ripening period, result in a lack of uniformity and quality of the final product. However there is a lack of knowledge is particularly critical, specially the microbiological quality. Such lack of knowledge is particularly critical, specially the microbiological quality as the spontaneous fermentation of fish.

The knowledge of microbiological and biochemical reactions in *nonsom* can help to introduce process modifications necessary to improve the quality of products, without any loss in its characteristics. The aims of the present study were investigate the changes in levels of the main microbial groups and in the physicochemical characteristics as well as proximate composition throughout the ripening process of *nonsom*. The result from this study is expected to study the beneficial microbial groups involved in fermentation of *nonsom*, as well as to provide further scientific basis for the understanding of ripening process, which is necessary to improve home-made processing.

Specific objectives

1. To determine physico-chemical and proximate composition changes during the fermentation of nonsom.
2. To enumerate the count of microbial groups at various stages of fermentation.
3. To characterize and identify the microorganisms isolated based on biochemical tests.

CHAPTER 2

LITERATURE REVIEWS

2.1 Food Fermentation

Fermentation is one of the oldest forms of food preservation as well as being a precursor of modern biotechnology (Cook, 1994). It is a process dependent on the biological activity of microorganisms for production of a range of metabolites which can suppress the growth and survival of undesirable microflora in foodstuffs (Ross *et al.*, 2002) in which depend on the principle of oxidation of carbohydrates and related derivatives to generate end-products such as generally acids, alcohol and carbon dioxide. Besides, chemical definition of the term of fermentation is applied to describe a strictly anaerobic process; however, the general understanding of the term now encompasses both aerobic and anaerobic carbohydrate breakdown processes (Caplise & Fitzgerald, 1999).

The raw materials traditionally used for fermentation are as diverse as: fruits, cereals, honey, vegetables, milk, meat and fish. It is possible to obtain a large variety of different food products by selecting different raw materials, starter cultures and fermentation conditions (Cook, 1994). Fermented foods are food substrates that are invaded or overgrown by edible microorganisms whose enzymes, particularly amylases, proteases and lipase, hydrolyze the polysaccharides, proteins and lipids to nontoxic products with flavors, aromas and textures pleasant and attractive to the human consumer (Steinkraus, 2002). A variety of fermented foods can be found throughout the world, such as beer, bread, sauerkraut, pickles, cheese, yoghurt and sausages in which their principles offer a wealth of possibilities for new product development (Giraffa, 2004). The fermentation process may be conducted either naturally or by adding starter culture. In a spontaneous fermentation, the conditions are set so that the desirable microorganisms grow preferentially and produce metabolic by products, which give the unique characteristic of the product (Hansen, 2002). The process is unpredictable and uncontrollable as it depends on the natural microflora on the raw material is inefficient. Thus the indigenous microflora is very important in determining quality of the fermented food.

2.2 Fermentation as a method of food processing

Generally, food fermentation plays important role in enrichment of the human dietary through development of a wide diversity of flavors, aromas, colors and textures in foods. It also contributes in enrichment of food substrates biologically with protein, essential amino acids, essential fatty acids and vitamins. The nutritional impact of fermented foods on nutritional diseases can be direct or indirect. Food fermentation which raise the protein content or improve the balance of essential amino acids or their availability will have a direct curative effect and also for that increase the content or the availability of vitamins such as thiamine, riboflavin, niacin or folic acid can have profound direct positive effects on the health of the consumers (Steinkraus, 1994).

Besides, microorganisms from fermented foods may be are potential sources of useful components including uncommon lipids, antimicrobial agents and biopolymers help in preservation of substantial amounts of foods. Through the soaking or hydration that raw substrates undergo in various fermentation processes ot enzymatic hydrolysis, some natural toxic like trypsin inhibitor, phytate and hemagglutinin exist in food may be detoxified. For example, aflatoxin that frequently found in peanut and cereal grain substrates is reduced in the Indonesian *ontjom* fermentation (Steinkraus, 1983). Fermented foods are also a potential source of microorganisms for biotechnology although relatively few have been exploited by industry. The production of fermented foods is also important in adding value to agriculture raw materials, thus providing income and generating employment (Hansen, 2002).

2.3 Indigenous fermented food

Indigenous food fermentations are one of the oldest forms of biotechnology, although the potential of associated microorganisms has probably not yet been fully realized. The indigenous fermented foods constitute a group of foods that are produced in homes, villages, and small cottage industries at prices within the means of the majority of consumers (Steinkraus, 1985). In most cases, the methodologies and knowledge associated with the production of these products were handed down from generation to generation within local communities, monasteries and feudal estates (Caplise & Fitzgerald, 1999). They can be produced and distributed at a relatively low cost but generally high nutritious, providing calories, protein, vitamins and minerals (Steinkraus, 1994). With the increasing population and the benefits aspects of fermented foods, there is starting of the concentration of studies related to indigenous fermented foods so that the indigenous fermented foods will be contribute in ensuring the extensive food supplies needed to feed mankind when world population rises in the future.

2.3.1 Classification of indigenous fermented food

There are a number of ways to classify the indigenous fermented foods according to different researchers. Major food preservations by fermentation include lactic acid bacteria fermentation, alcoholic fermentation, acetic acid fermentation and alkaline fermentation. Besides, it is also classified according to the following categories (Steinkraus, 1983): (1) Fermentation producing textures vegetable protein meat substitutes in legume or cereal mixtures. Examples are Indonesian *tempe* and *ontjom*; (2) High salt or savory meat-flavored or amino acid or peptide sauce and paste fermentation. For instance, Chinese soy sauce, Japanese *shoyu* and others in which are predominantly Oriental fermentation; (3) Lactic acid fermentation. Examples are vegetable lactic acid fermentation, fermented milk and leavened bread; (4) Alcoholic fermentation; an example is grape wine; (5) acetic acid or vinegar fermentation: examples are apple cider and wine vinegars in the West; (6) Alkali fermentation, examples are Japanese *natto* and Thai *thua-nao*; (7) Leavened bread, example is sourdough breads; and (8) Flat unleavened bread.

2.3.2 Indigenous fermented food in Malaysia

There are a number of indigenous fermented foods have been industrialized in Malaysia, such as product of high salt/savory meat-flavored/ amino acid/ peptide sauce and pasta fermentation: *belachan*; lactic acid fermentation: pickled vegetables, *tempoyak* and *tairu* (soy-bean milk); as well as alcoholic fermentation: *tapai* (Steinkraus, 1983). However, there are many of the indigenous fermented foods have not been studied and developed especially those produced at household level in rural areas. It is also considered as traditional food from different ethic groups in Malaysia. It may represent a cultural and lifestyle of certain groups of people from different regions in Malaysia besides preserved over many years in order to maintain the uniqueness and identities of these foods.

For instance, *montoku* is a traditional alcoholic beverage in Sabah among Kadazandusun. They drink *montoku* in conjunction with harvest celebrations and social or communal gatherings. Besides, *sasad* is a traditional starter culture produced at home scale production by local Sabah community as well as fermented *bambangan*. It have been consumed by people in Sabah and Sarawak and due to its high yield of production, it have been preserved through fermentation by ancestors and handed through generations. Some of them are similar to the fermented foods from other Orient countries and they are recognized in different name. For example, *sasad* is also can be known as *ragi* and *montoku* is one type of rice wine. Malaysian rice wine or tapai is lighter in colour, ranging from red to pink. It is made from cooked gelatinized rice and red pulverized ragi (yeast cake, or jui-piang) (Aidoo *et al*, 2005).

2.4 Fermented fish

Many fermented fish products are prepared in different parts of the world, and the method of processing depends upon various factors, such as availability of raw materials, consumer preference and the climatic conditions of the region. Microbial fermentation of fish has precedents in the production of various fish sauces and pastes (Mackie *et al.*, 1971; Beddows, 1985; Adams *et al.*, 1985; Saono *et al.*, 1986) and in the production of fish silages (Raa & Gildberg, 1982). There are some popular fermented fish products in Southeast Asia and is known by various names according to the country of origin (for example, *Nam-pla* in Thailand and Laos; *Budu* in Malaysia, *Patis* in the Philippines; *Ngampi-pya-ye* in Burma; *Ketjap-ikan* or *Bakasang* in Indonesia; or *Nuoc-mam* in Vietnam) (Beddows, 1985). Besides this region, fermented fish sauce also produced in other Asia and Europe countries. It is called *Shottsuru* or *Ika-shoyu* in Japan; *yu lu* in China; *Jeot-kal* in Korea; *Colombo-cure* in India and Pakistan; *Mehiawah* in Middle East and anchovy in France. Table 2.1 shows the acid-fermented fish of different countries (Lee, 1994).

Table 2.1 Examples of acid-fermented seafood and cereal mixtures (Lee, 1994).

Product name	Country	Major ingredients	Microorganisms	Usage
Sikhae	Korea	Sea-water fish, cooked millet, salt	*L.mesenteroides, L. plantarum*	Side-dish
Narezushi	Japan	Sea-water fish, cooked millet, salt	*L.mesenterioides. L. plantarum*	Side-dish
Burong-isda	Philippines	Fresh-water fish, rice, salt	*L.brevis, Streptoccus sp.*	Side-dish
Pla-ra	Thailand	Fresh-water fish, salt, roasted rice	*Pediococcus*	Condiment
Balao-balao	Philippines	Shrimp, rice, salt	*L.mesenteroides, P.cerevisiae*	Side-dish
Kungchao	Thailand	Shrimp, salt, sweetened rice	*P.cerevisiae*	Side-dish

There are another types of low salt fermented fish in which other sources of carbohydrate like rice, millet and garlic would be added and mixed with fish. Preservation of fermented fish products obviously depends on lactic acid and possibly bacteriocin production; however, other factors may also contribute to the overall keeping quality of low-salt fermented fish products. These products are often produced using freshwater fish, where addition of salt may have a significance inhibitory effect on mesophilic spoilage flora (Gram, 1991). Similarly, the addition of spices (e.g. garlic) may have an important role in ensuring product safety (Souance *et al.*, 1987; Beuchat, 1994). In addition, salt and spices (such as garlic, pepper or ginger) may add to the safety of products. Also, in some products garlic may serve as a carbohydrate source for the fermentation (Paludan-Müller *et al.*, 1999). In addition, this fermented fish also depend on proteolytic enzymes to hydrolyze the proteins in the substrate to the constituent amino acids and peptides.

2.4.1 Low salt fermented fish in South East Asia

There are a few examples of low salt fermented fish products. For instance, *plaa som* in Thailand in which the whole fish is mixed with salt (ratio 8:1 by weight) and left overnight. Cooked rice and minced garlic are added (ratio 20 fish/salt: 4 rice: 1 garlic by weight), then the mixture is packed in jars and fermented at ambient temperature for 5-7 days. The shelf life is reportedly 3 weeks (Phithakpol *et al.*, 1995).

In addition there is another type of low salt fermented fish in Thailand called *som-fug* which is a highly nutritious and served as an excellent source of protein. It varies in color from white to brownish or reddish, depending on the type of fish and the methodology used in its production. The ripened product is slightly sour and salty in flavor, and is of a relatively firm and springy texture, and consumed either in the raw or cooked state (Valyasevi & Rolle, 2000). Besides, there is another closely related product which categorized in boiled rice/ raw shrimp/ raw fish mixtures: Philippine *balao- balao,*

REFERENCES

Adam, M.R., Cooke, R.D. & Rattagool, P. 1985. Fermented Fish Products of South East Asia. *Tropical Scienc.* **25**: 61-73.

Adams, M.R. 1986. Fermented flesh foods. *In* Adams, M.R. (Ed.). *Progress in Industrial Microbiology, Vol. 23. Microorganisms in the Production of Food.* Amsterdam: Elsevier.

Aidoo, K.E., Rob Nout, M. J. & Sarkar P. K. 2005. Occurrenceand function of yeasts inAsian indigenous fermented foods. *FEMS Yeast Res.* **6**: 30–39

Anihouvi, V.B., Ayernor, G.S., Hounhouigan, J.D., Sakyi-Dau, E. 2006. Quality characteristics of *Lanhouin*: a traditionally processed fermented fish product in the Republic of Benin. *Journal of Africa.*

Ardhana, M.M. & Fleet, G.H. 1989. The microbial ecology of tape ketan fermentation. *International Journal of Food Microbiolog.* **9**: 157 - 165

Aryanta, R.W., Fleet, G.H. & Buckle, K.A. 1991. The occurrence and growth of microorganisms during the fermentation of fish sausage.*Internation Journal of Food Microbiology.* **13**: 143-156.

Ashenafi,M., & Busse,M. 1991. Growth potential of Salmonella infantis and *Esherichia coli* in fermenting tempeh made from horsebean, pea and chickpea and their inhibition by Lactobacillus plantarum. *Journal of Science and Food Agriculture.* **55**: 607–615.

Aymerich, M.T., Garriga, M., Monfort, J.M., Nes, I., & Hugas, M. 2000. Bacteriocin-producing lactobacilli in Spanish-style fermented sausages: characterization of bacteriocins. *Food Microbiology.* **17**: 33-45.

Beddows, C.G. 1985. Fermented Fish and Fish Products. *In* Woods, B.J. (Ed.). *Microbiology of Fermented Foods.* **2**. London: Elsevier Applied Science Publication.

Campbell-Platt, G. 1994. Fermented Foods- A World Perspective. *Food Research International.* **27**: 253.

Caplise, E. & Fizgerald, G.F. 1999. Food fermentation: role of microorganisms in food production and preservation. *International Journal of Food Microbiolog.* **50**: 131-139.

Chavan, J.K. & Kadam, S.S. 1989. Nutritional improvement of cereals by fermentation. *Critical Reviews in Food Science and Nutrition.* **28**: 349-393.

Conner, D.E. & Beauchat, R. 1984. Effects of essential oils from plants on growth of food spoilage yeasts. *Journal of Food Science.* **49**: 429-434.

Cook, P.E. 1994. Fermented foods as biotechnological resources. *Food Reseaarch International.* **27**: 309-316.

Cooke, R.D., Twiddy, D.R. & Reilly, P.J.A. 1993. Lactic fermentation of fish as a low-cost means of food preservation. *In*: Lee, C.-H., Steinkraus, K.H., Reilly, P.J.A. (Eds.). *Fish Fermentation Technology.* Tokyo: United Nations University Press. pp. 291-300.

Crisan, E.V. & Sands, A. 1975. Microflora of four fermented fish sauces. *Applied Microbiology.* **29**: 106-108.

Drosinos, E.H., Paramithiotis, S., Kolovos, G., Tsikouras, I. & Metaxopoulos, I. 2007. Phenotypic and technological diversity of lactic acid bacteria and staphylococci isolated from traditionally fermented sausages in Southern Greece. *Food Microbiology.* **24**: 260-270.

Eka, O. U. 1980. Effect of fermentation on the nutrient status of locust beans. *Food Chemistry.* **5**:303-308

Fleet, G.H. 1999. Microorganisms in food ecosystem. *International Journal of Food Microbiology* **50**: 101-117.

Fontán, M.C.G., Lorenzo, J.M., Parada, A., Franco, I., & Carballo, J. 2006. Microbiological characteristics of "androlla", a Spanish traditional pork sausage. *Food Microbiology.* Article In Press.

Gelman, A., Drabkin, V. & Glatman, L. 2001. Evaluation of lactic acid bacteria, isolated from lightly preserved fish products, as starter cultures for new fish-based food products. *Innovative Food Science and Emerging Technologies.* **1**: 219-226.

Giraffa, G. 2004. Studying the dynamics of microbial populations during food fermentation. *FEMS Microbiology Reviews.* **28**: 251-260.

Gotcheva, V., Pandiella, S. S., Angelow, A., Roshkova, Z. & Webb, C. 2000. Monitoring the fermentation of the traditional Bulgarian beverage boza. *International Journal of Food Science and Technology*, **36**: 129-134.

Gram, L. 1991. Inhibition of mesophilic *Acremonas spp.* by chilling, salt, smoke and sorbate. *Journal of Food Protection.* **54**: 436-442.

Hammes, W.P. & Tichaczek, P.S. 1994. The potential of lactic acid bacteria for the production of safe and wholesome food. *Zeitschrift fuer Lebensmotted-Untersuchung und Forschung.* **198**: 193-201.

Hansen, E.B. 2002. Commercial bacterial starter cultures for fermented foods of the future. *International Journal of Food Microbiology.* **78**: 119-131.

Harrigan, W.F. 1998. *Laboratory Methods in Food Microbiology.* 3rd Edition. London: Academic Press Limited.

Helander, I.M.von Wright, A. & Mattila-Sandjolm, T. M. 1997. Potential of lactic acid bacteria and novel antimicrobials against Gram-negative bacteria. *Trend in Food Science and Technology.* **8**: 146-150.

Ijong, F.G. & Ohta, Y. 1995. Amino Acid Compositions of Bakasang, A Traditional Fermented Fish Sauce from Indonesia. *Lebensm.-Wiss. u.-Technology.* **28**: 236-237.

Ishige, N. 1993. Cultural Aspects of Fermented Fish Products in Asia, *In* Lee, C.-H., Steinkraus, K.H., Reilly, P.J.A. (Eds.). *Fish Fermentation Technology.* Tokyo: United Nations University Press. pp. 13–32.

Jeppesen, V. F. & Huss, H. H. 1993. Caharateristic and antagonistic activity of lactic acid bacteria isolated from chilled fish products. *International Journal of Food Microbiology*. **18**: 305-320.

Kalchayanand, N., Hanilin, M.B., & Ray, B. 1992. Sublethal injury makes Gram-negative and resistant Gram-positive bacteria sensitive to the bacteriocins pediocin Ac H and nisin. *Applied Microbiology*. **15**: 239-243.

Khetarpaul, N. & Chauhan, B.M. 1989. Effect of fermentation on protein, fat, minerals and thiamine content of pearl millet. *Plant Foods for Human Nutrition*. **39**: 169-177.

Krieg, N.R. 1981. Enrichment and Isolation. *In* Gerhardt, P., Murray, R.G.E., Costilow, R., Nester, E.W., Wood, W.A., Krieg, N.R., & Phillips, G.B. (Eds). *Manual of Methods for General Bacteriology*. Washington: American Society for Microbiology, pp. 112-142.

Lee, C.H. 1997. Lactic acid fermented foods and their benefits in Asia. *Food control*. **8:** 259-269.

Lucke, F.K. 1996. Lactic acid bacteria involved in food fermentation and their present and future uses in food industry. *In* Bologlu, F. & Ray, B. (Eds). Currents Advances in Metabolism, Genetics and Applications. Heideberg: Springer- Verlag.

MacKay, L. & Baldwin, K. 1990. Application for biotechnology: present and future improvements in lactic acid bacteria: a review. *FEMS Microbiology Reviews*. **87**: 3-14.

Mackie, I.M., Hardy, R. & Hobbs, G. 1971. *Fermented Fish Products. FAO Fisheries Report No.100*. Food and Agriculture Organization of the United Nations, Rome.

Moat, A.G., 1979. Carbohydrate metabolism and energy production. In *Microbial Physiology*. New York: John Wiley and Sons Inc. pp: 123-189.

Nambudiry, D.D. 1986. Mixed culture fermentation as a predominant biology phenomenon in the production of fermented fish products. *Proceedings of the Symposium on Coastal Agriculture*. **6**: 1474.

Olympia, M., Ono, H., Shinmyo, A. & Takano, M. 1992. Lactic acid bacteria in a fermented fishery product, " Burong bangus". *Journal of Fermentation Bioengineering.* **73**:193-197.

Ordóñez, J.A., Hierro, E.M., Bruna, J.M. & de la Hoz, L. 1999. Changes in the components of dry-fermented sausages during ripening. *Critical Review of Food Science and Nutrition.* **34** (9): 329-367.

Orejana, F.M. 1983. Fermented fish products. *In* Chan, H.T. (Ed). *Handbook of Tropical Foods.* New York: Marcel Dekker.

Owens, J.D. & Mendoza, L.S. 1985. Enzymatically hydrolyzed and bacterially fermented fisheries products. *Journal of Food Technology.* **20**: 273-293.

Østergaard, A., Embarek, P.K.B., Wedel-Neergaarrd, C., Huss, H.H. & Gram, L. 1986. Fermentation and Spoilage of *Som-fak*, a Thai Low Salted Product. *Tropical Science.* **38**: *105-112.*

Østergaard, A., Embarek, P.K.B., Wedel-Neergaarrd, C., Huss, H.H. & Gram, L. 1998. Characterisation of anti-listerial lactic acid bacteria isolated from Thai fermented fish products. *Food Microbiology.* **15**: 223-233.

Pandey, N. K. & Bhaskaran, S. 1987. Biotechnological approaches for augmenting supply of edible oils. *Proceeding of the Nutrition Society of India.* **33**:19-32

Phithakpol, B., Varanyanond, W., Reungmancepaitoon, S. & Wood, H. 1995. *The Traditional Fermented Foods of Thailand.* University, Bangkok: Institute of Food Research and Products Development.

Paludan-Müller, C., Huss, H.H. & Gram, L. 1999. Characterization of Lactic Acid Bacteria Isolated from a Thai Low-salt Fermented Fish Product and the Role of Garlic as Substrate for Fermentation. *International Journal of Food Microbiology.* **46**(3): 219-229.

Raa, J.D. & Mendoza, L.S. 1985. Enzymatically hydrolyzed and bacterially fermented fisheries products. *Journal of Food Technology.* **20**: 273-293.

Riebroy, S., Benjakul, S., Visessanguan, W., Kijrongrojana, K. & Tanaka, M. 2004. Some characteristics of commercial Som-fug produced in Thainland. *Food Chemistry.* **88** (4): 527-535.

Ringø,E. & Gatesoupe, F. 1998. Lactic acid bacteria in fish: a review. *Aquaculture.* **160**: 177–203.

Rosello, C., Barbas, J.I., Berna, A. & Lopez, N. 1995. Microbial and Chemical Changes in Sobrassada during Ripening. *Meat Science.* **40**: 379-385.

Ross, R.P., Morgan, S. & Hill, C. 2002. Preservation and fermentation: past, present and future. *International Journal of Food Microbiology.* **79**: 3-16.

Rukayah Aman. 1999. *Buah-buahan Malaysia.* Kuala Lumpur: Dewan Bahasa dan Puastaka.

Saisithi, P., Yongmanitchai, P., Chimanage, P., Wongkhalaung, C., Boonyaratanakornkit, M., & Maleehuan, S. 1996. Improvement of a Thai traditional fermented fish product: Som Fug. *Report to the Food and Agricultural Organisation of the United Nations.* November 1986.

Saisithi, P. 1987. Traditional fermented fish products with special reference to Thai products. *ASEAN Food Journal.* **3**: 3-10.

Sakai, H., Caldo, G.A. and Kozaki, M. 1983. A numerical taxonomic study of lactic acid bacteria from vacuum- packed beef, pork, lamd and bacon. *Journal of Applied Bacteiology.* **56**: 25-40.

Salminen, S., Deighton, M., Benno, Y. & Gorbach, S. L. 1998. Lactic acid bacteria in health and disease. *In* Salminen, S. (Ed). *Lactic acid bacteria: Microbiology and Functional Aspect* (2nd Edition). New York: Marcel Dekker, Inc.

Samelis, J., Metaxopoulos, J., Vlassi, M. & Pappa, A..1998. Stability and safety of traditional Greek salami — a microbiological ecology study. *International Journal of Food Microbiology.* **44**: 69–82.

Sands, A. & Crisan, E.V. 1974. Microflora of fermented Korean seafoods. *Journal of Food Science.* **39**: 1002-1005.

Saono, S., Hull, R.R. & Dhamcharce, B. 1986. *A Concise Handbook of Indigenous Fermented Foods in the ASCA Countries*. Indonesian Institute of Science, Jakarta.

Schillinger, U. & Lücke, F.K. 1990. Lactic acid bacteris as protective cultures in meat products. *Fleischwirtschaft*. **70:** 1296-1299.

Seman, D.L., Olson, D.G. &Mandigo, R.W. 1980. Effect of reduction and partial replacement of sodium on bologna characteristics and acceptability. *Journal of Food Science*. **45**: 1116-1121.

Souane, M., Bae Kim, Y. & Lee, C.H. 1987. Microbial characterization of gajami sik-hae fermentation. *Korean Journal of Applied Microbiology and Bioengineering*. **15**: 150-157.

Souza, C.F.V., Rosa, T.D., & Ayub, M.A.Z. 2003. Changes in the microbiological and physicochemical characteristics of Serrano cheese during manufacture and ripening. *Brazilian Journal of Microbiology*. **34**(3).

Steinkraus, K.H. 1966. *Handbook of Indigenous Fermented Foods*. New York: Marcel Dekker, Inc.

Steinkraus, K.H. 1983. *Handbook of Indigenous Fermented Foods*. New York: Marcel Dekker, Inc.

Steinkraus, K.H. 1985. Indigenous fermented food technologies for small scale industries. *Food and Nutrition Bulletin*. **7**(2).

Steinkraus, K.H. 1994. Nutritional Significance of Fermented Foods. *Food Research International*. **27**: 256-267.

Steinkraus, K.H. 1995. *Handbook of Indigenous Fermented Foods*. New York: Marcel Dekker, Inc.

Suma, K., Misra, M. & Varadaraj, M. 1998. Plantacin LP84, a broad spectrum heat-stable bactriocin of Lactobacillus plantarum NCIM 2084 produced in a simple glucose broth medium. *International Journal of Food Microbiology*. **40**: 17- 25.

Steinkraus, K.H. 2002. Fermentations in World Food Processing. *Food Science and Food Safety*. **1**: 22-25.

Tamer, C.E., Kumral, A., Asan, M. & Sahin, I. 2006. Chemical composition of traditional Tarhana having different formulations. *Journal of Food Processing and Preservation*. **31**: 116–126.

Tanasupawat, S. & Komagata, K.. 1995. Lactic acid bacteria in fermented foods in Thailand. *World Journal of Microbiology and Biotechnology* ***11***: 253-256.

Tannock,G.W. 1997. Probiotic properties of lactic acid bacteria: plenty of scope for fundamental R & D. *Tibtechnology*. **15**: 270–274.

Terzic-Vidojevic, A., Vukasinovic, M., Veljovic, K., Ostojic, M. & Topisirovic, L. 2007. Characterization of microflora in homemade semi-hard white Zlatar cheese. *International Journal of Food Microbiology*. **114**: 36-42.

Valyasevi, R. & Rolle, R.S. 2002. An overview of small-scale food fermentation technologies in developing countries with special reference to Thailand: scope for their improvement. *International Journal of Food Microbiology*. **75**: 231– 239.

Visessanguan, W., Benjakul, S., Riebroy, S. & Thepkasikul, P. 2004. Changes in composition and functional properties of proteins and their contributions to Nham characteristics. *Meat Science*. **64**: 579-588.

Yoon, H.D., Lee, D.S., Ji, C.I. & Suh, S.B. 1997. Studies on the utilization of wastes form fish processing: characterization of lactic acid bacteria for preparing skipjack tuna viscera silage. *Journal of the Korean Fish Society*. **30**:1-7.