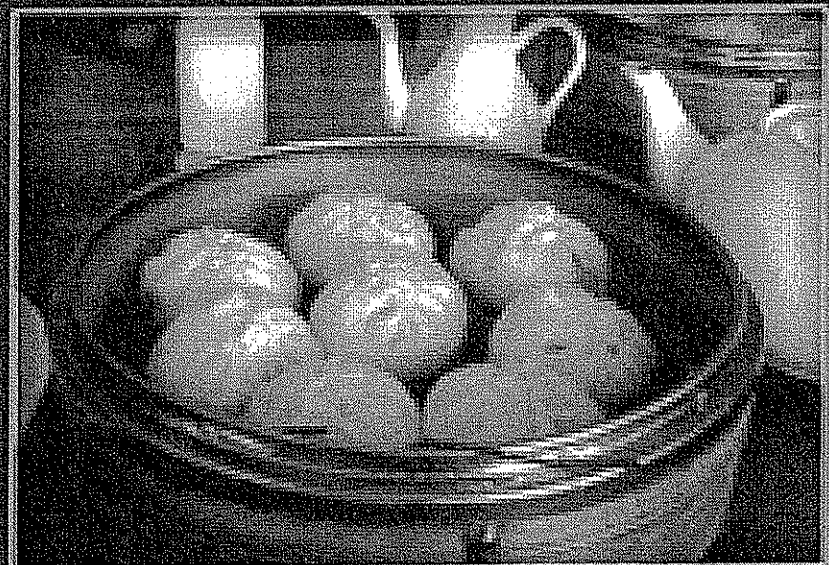


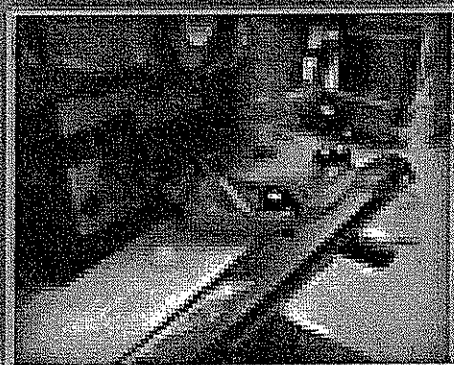
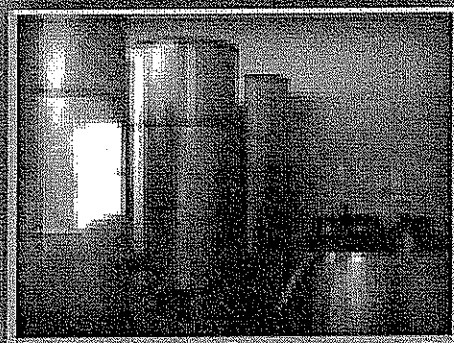
Handbook of Plant-Based Fermented Food and Beverage Technology

Edited by Y. H. Hui



Administrative Associate Editor
E. Özgül Evranuz

Associate Editors
Francisco Noel Arroyo-López
Lihua Fan
Åse Solvej Hansen
M. Eugenia Jaramillo-Flores
Marica Rakin
Rosane Freitas Schwan
Weihao Zhou




☐ Full Access Content Only

[Mobile](#) [Register](#) [Log In](#)

 Search
[Advanced Search](#)
[Home](#) [Browse Content](#) [Advanced Search](#) [About CRCnetBASE](#) [Subject Collections](#) [How to Subscribe](#) [Librarian Resources](#) [News & Events](#) [Free Trial](#)

About this Book


[Recommend Title](#)
[Purchase E-book](#)

Search

Simple Search

[Advanced Search](#)
☐ All books
☐ This book

Handbook of Plant-Based Fermented Food and Beverage Technology, Second Edition

Citation Information

Handbook of Plant-Based Fermented Food and Beverage Technology, Second Edition
 Y. H. Hui and E. Özgül . Evranuz
 CRC Press 2012
 Print ISBN: 978-1-4398-4904-0
 eBook ISBN: 978-1-4398-7069-3

Table of Contents

[Download to Citation Mgr](#) [View Abstracts](#) [Add to Bookshelf](#) [Email](#)
[Permalink](#)

☐	Access	Page	Title
☐	FREE	I	Front Matter
			Abstract - Hi-Res PDF (650 KB) - PDF w/links (651 KB)
☐		1	Part I. Introduction
			Abstract - Hi-Res PDF (65 KB) - PDF w/links (66 KB)
☐		3	Chapter 1. Fermented Plant Products and Their Manufacturing Y. H. Hui
			Abstract - Hi-Res PDF (489 KB) - PDF w/links (491 KB)
☐		23	Chapter 2. Flavors and Food Fermentation Shao Quan Liu
			Abstract - Hi-Res PDF (498 KB) - PDF w/links (528 KB)
☐		35	Chapter 3. Fermentation and Biopreservation of Plant-Based Foods with Lactic Acid Bacteria Lihua Fan, Lisbeth Truelstrup Hansen
			Abstract - Hi-Res PDF (2770 KB) - PDF w/links (2799 KB)
☐		49	Chapter 4. Plant-Based Fermented Foods and Beverages of Asia Jyoti Prakash Tamang
			Abstract - Hi-Res PDF (728 KB) - PDF w/links (807 KB)
☐		91	Part II. Soy Products
			Abstract - Hi-Res PDF (66 KB) - PDF w/links (66 KB)
☐		93	Chapter 5. Soy Sauce Hanifah Nuryani Lioe, Anton Apriyantono, Masaaki Yasuda
			Abstract - Hi-Res PDF (403 KB) - PDF w/links (421 KB)
☐		103	Chapter 6. Synbiotic Soy Beverages Olga Lucia Mondragón-Bernal, Francisco Maugerli Filho, José Guilherme Lembi Ferreira Alves, Maria Isabel Rodrigues
			Abstract - Hi-Res PDF (2793 KB) - PDF w/links (2834 KB)
☐		131	Chapter 7. Thua Nao Ekachai Chuksatiroe, Katekan Dajanta, Arunee Apichartsrangkoon
			Abstract - Hi-Res PDF (558 KB) - PDF w/links (573 KB)
☐		139	Chapter 8. Soy milk and Tofu Manufacturing Sam K. C. Chang, Zhisheng Liu
			Abstract - Hi-Res PDF (1109 KB) - PDF w/links (1165 KB)
☐		163	Part III. Fruits and Fruit Products
			Abstract - Hi-Res PDF (67 KB) - PDF w/links (68 KB)
☐		165	Chapter 9. Sensory Analysis of Fruit and Fermented Fruit Product Flavors Soo-Yeun Lee, Lisa Allgeyer, Erika Neely, Joseph Kreger
			Abstract - Hi-Res PDF (421 KB) - PDF w/links (457 KB)
☐		179	Chapter 10. Wine Fermentation and Production Juan José Rodríguez-Bencomo, M. Ángeles Pozo-Bayón, M. Victoria Moreno-Arribas
			Abstract - Hi-Res PDF (520 KB) - PDF w/links (528 KB)
☐		201	Chapter 11. Fermentation of Caper Products Rubén Pérez Pulido, Nabil Benomar, Magdalena Martínez Cañamero, Hikmate Abriouel, Antonio Gálvez
			Abstract - Hi-Res PDF (329 KB) - PDF w/links (342 KB)
☐		209	Chapter 12. Apple Cider Fermentation Alessandro Nogueira, Gilvan Woslacki
			Abstract - Hi-Res PDF (2247 KB) - PDF w/links (2275 KB)
☐		237	Chapter 13. Fermentation and Cashew Apple Juice Ana Lúcia Fernandes Pereira, Suelli Rodrigues
			Abstract - Hi-Res PDF (476 KB) - PDF w/links (495 KB)
☐		249	Chapter 14. Production and Characterization of Wine from Mango (Mangifera indica L.) Fruit Juice Lebaka Veeranjanya Reddy, Obulam Vijaya Sarathi Reddy
			Abstract - Hi-Res PDF (2695 KB) - PDF w/links (2728 KB)

Thua Nao: A Traditional Thai Fermented Soy Product

Ekachai Chukeatirote, Katekan Dajanta, and Arunee Apichartsrangkoon

CONTENTS

7.1	Introduction.....	131
7.2	<i>Thua Nao</i> and Related Products	131
7.3	<i>Thua Nao</i> Fermentation Process.....	132
7.4	<i>Bacillus</i> Species as Predominant in <i>Thua Nao</i> Fermentation	133
7.5	Proximate Composition of <i>Thua Nao</i>	134
7.6	Amino Acid Profiles of <i>Thua Nao</i>	134
7.7	Isoflavones of <i>Thua Nao</i>	134
7.8	Aroma and Flavoring Agents of <i>Thua Nao</i>	135
7.9	Conclusion.....	135
	Acknowledgments.....	135
	References.....	135

7.1 Introduction

Fermented soybeans constitute a key part of the diet in many parts of the world, especially in Asia and Africa. Although the main raw materials (i.e., soybeans) and fermentation processes are very similar, they come in various forms and names. The widely known examples of food products in this group are the Japanese *natto*, the Korean *chungkukjang*, and the Indian *kinema* (Steinkraus 1996). The major microorganisms responsible for fermentation are the *Bacillus* bacteria, in which their proteases cause protein hydrolysis and ammonia liberation. The release of ammonia provides an alkaline condition; hence, these products are often termed *alkaline-fermented soybeans*. Among these, *natto* is probably best characterized with comprehensive scientific data. In contrast, there is little scientific information on *thua nao*. This chapter is therefore introduced to document the current status of *thua nao* in terms of manufacture, fermenting microbes, and nutritive quality.

7.2 *Thua Nao* and Related Products

Thua nao is a traditional fermented soybean food widely consumed in Northern Thailand (i.e., Chiang Mai, Chiang Rai, Mae Hong Son, Lam Phun, and Lam Pang). It is not only an important food/condiment but also serves as a low cost protein supplement for the local people. Traditional *thua nao* has a strong unpleasant ammoniacal smell, dark grayish or brownish color, and slightly slime matter (Figure 7.1). This is different from *natto*, which are a white mucous substance that has a unique flavor and a palatably soft texture, are light yellow, and are able to generate silky and sticky mass (Wei et al. 2001). Some features of *thua nao* and other traditional *Bacillus*-fermented soybeans are summarized in Table 7.1.

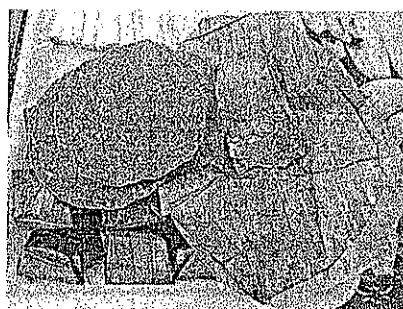


FIGURE 7.1 *Thua nao* products in the local market of Chiang Rai. Left, dried form known as *thua nao kab*; right, roasted *thua nao* covered in banana leaf. (Courtesy of Mr. Pichitchai Nantararat.)

TABLE 7.1

Some Features of Traditional *Bacillus*-Fermented Soybeans

Product	Country	Uses	Reference
<i>Thua nao</i>	Thailand	Flavor enhancer in local dishes Main dish: mashed fresh <i>thua nao</i> in combination with salt, chili, lemongrass, onion, and garlic, packed in banana leaves into small pocket and cooked by steaming or roasting, eaten with sticky rice	Chukeatirote et al. (2010)
<i>Natto</i>	Japan	Eaten directly with rice Flavor enhancer in local dishes, i.e., miso soup and sushi Accompaniments to drinks, i.e., sake and tea Main dish: mixed with miso, salt, sugar, garlic, and other ingredients, mashed together and stored in chinaware for few days to produce a pickled dish	Kiuchi and Watanabe (2004)
<i>Kinema</i>	India	Fried in vegetable oil for 3 to 5 minutes and tomato, onion, spices, salt, and a little amount of water are added to produce a thick curry	Tamang et al. (1988); Nout et al. (1998)
<i>Dawadawa</i>	Nigeria and Ghana	Flavor enhancer in local dishes	Omafuvbe et al. (2002)
<i>Chungkukjang</i>	Korea	Flavor enhancer in local dishes	Kwak et al. (2007)

7.3 *Thua Nao* Fermentation Process

Three major raw ingredients for *thua nao* production are as follows: soybeans, water, and mixed natural bacterial culture. In general, four major steps are involved in the conventional *thua nao* manufacturing process consisting of soaking, boiling, fermenting, and incubating (Chantawannakul et al. 2002; Chukeatirote et al. 2010). For detailed descriptions, it typically begins with soaking of soybean for overnight and then boiling of soybean seeds for 3 to 4 hours until soft. The cooked soybeans are then packed in bamboo baskets lined and covered with banana leaves and allowed to undergo spontaneous fermentation at ambient temperature for 2 to 3 days. However, there are differences in the procedures and equipment used in different areas and communities. For example, in the production of *thua nao* at Fang

District in Chiang Mai, dry soybeans are cooked in boiling water for 7 hours after being washed twice with clean water, fermented in woven bamboo baskets lined with fern leaves, and then covered with the plastic bags and placed outside the building exposed to sunlight for 3 days (Leejeerajumnean et al. 2001). According to the production process of Muang Chiang Mai District, soybean seeds are soaked overnight (12–14 hours) in water before being boiled for a shorter time (4–6 hours). Besides, the fermentation conditions are also different, as cooked seeds are packed in bamboo basket lined and covered with banana leaves and left to stand at ambient temperature in the household for 2 to 3 days. The production of *thua nao* in Lam Phun and Lam Pang follows closely the method of Fang District, except for omitting the soaking step of the seeds; instead, dry soybean seeds are immediately cooked by boiling in water for 3 to 4 h, and the banana leaves are used to enclose the cooked soybeans in bamboo baskets and allowed to spontaneously ferment at ambient temperature in the household for 3 to 4 days (Sundhagul et al. 1972). The diversity of soaking and cooking steps including the variation of equipment and fermentation conditions leads to the inconsistency and safety qualities of the product. The complete fermented soybean is indicated by the grayish brown color of soybean seeds and the appearance of a slight mucilaginous substance and is dominated by a strong ammonia-like odor. *Thua nao* is regarded as spoiled when they liberate putrid or rancid smell or appeared contaminated with mold or yellow-pigmented slimy material on the beans. A major problem of cooked *thua nao* is a short shelf life, approximately 2 days, if stored under ambient conditions. Hence, to extend the shelf life of this product, a sun-dried process of *thua nao* is developed and widely known among the locals as *thua nao kab* (see Figure 7.1), which could be kept for several months.

7.4 *Bacillus* Species as Predominant in *Thua Nao* Fermentation

As mentioned earlier, *thua nao* is still produced conventionally by natural microflora. It should be noted, however, that *Bacillus* species are always present in high numbers. According to Chukeatirote et al. (2006), *Bacillus* species, especially *Bacillus subtilis*, predominated from the beginning to the end of the fermentation. The occurrence of *B. subtilis* as the predominant species in *thua nao* product was also reported by Chantawannakul et al. (2002) and Leejeerajumnean (2000). Other *Bacillus* species were also found including *Bacillus cereus*, *Bacillus licheniformis*, *Bacillus megaterium*, and *Bacillus pumilus* (Chukeatirote et al. 2006; Leejeerajumnean 2000). Apart from dominant *Bacillus* species, a few bacterial groups (i.e., lactic acid bacteria and unidentified Gram-positive cocci) were also identified only at the onset, and thus their involvement in fermentation is possibly limited (Boontim et al. 2003; Chukeatirote et al. 2006; Table 7.2).

TABLE 7.2

Predominant Bacteria Involved in Alkaline-Fermented Soybeans

Product	Microorganisms Involved	References
<i>Thua Nao</i>	<i>B. subtilis</i> , <i>B. licheniformis</i> , <i>B. pumilus</i> , <i>B. megaterium</i> , <i>B. cereus</i> , <i>Lactobacillus</i> sp., Gram-positive cocci	Chukeatirote et al. (2006); Sundhagul et al. (1972); Leejeerajumnean (2003)
<i>Kinema</i>	<i>B. subtilis</i> , <i>B. licheniformis</i> , <i>B. cereus</i> , <i>Bacillus</i> <i>circulans</i> , <i>B. thuringensis</i> , <i>B. sphaericus</i> , <i>Enterococcus faecum</i> , <i>Candida parapsilosis</i> , <i>Geotrichum candidum</i> , <i>Escherichia coli</i> , <i>coliform</i> , and <i>Enterobacteriaceae</i>	Tamang (1993); Sarkar et al. (1994, 2002); Nout et al. (1998)
<i>Daddawa</i>	<i>B. subtilis</i> , <i>B. licheniformis</i> , <i>B. pumilus</i> , <i>B. cereus</i> , <i>B. firmus</i> , <i>B. circulans</i> , <i>Bacillus</i> <i>metaterium</i> , <i>Staphylococcus saprophysicus</i> , <i>Staphylococcus epidermidis</i> , <i>Micrococcus</i> <i>luteus</i> , <i>Pseudomonas aeruginosa</i>	Omafuvbe et al. (2000); Dakwa et al. (2005); Dike and Odunfa (2003); Iideani and Okeke (1991)
<i>Chungkukjang</i>	<i>B. subtilis</i>	Kwak et al. (2007)
<i>Natto</i>	<i>B. subtilis</i> (<i>natto</i>)	Kiuchi and Watanabe (2004)

TABLE 7.3

Proximate Composition of *Bacillus*-Fermented Soybeans

Chemical Composition	<i>Kinema</i> ^a	<i>Thua Nao</i> ^b	<i>Dawadawa</i> ^{c,d}	<i>Chunglukjang</i> ^e	<i>Natto</i> ^f
Protein (%)	48	38.76	31.25	15.70	42.51
Fat (%)	17	16.97	19.90	9.0	21.11
Ash (%)	7	5.73	1.72	5.2	4.38
Carbohydrate (%)	28	26.38	22.86	16.1	30.80
Fiber (%)	—	11.93	3.47	—	—
Reducing sugar (%)	—	—	—	—	8.20
Ammonia (mg/100 g)	—	—	—	—	240.49
Moisture (%)	62	—	59.40	54.00	59.30
pH	7.89	8.0–8.6	8.2–8.9	8.49	6.83

Note: —, data not available.

^a Source: Sarkar, P. K. et al., *Food Microbiol*, 11, 47–55, 1994. With permission.

^b Source: Sundhagul, M. et al., *Thai J Agric Sci*, 5, 43–56, 1972. With permission.

^c Source: Jeff-Agboola, Y. A., O. S. Oguntuase, *J Nutr*, 5, 606–7, 2006. With permission.

^d Source: Omafuvbe, B. O. et al., *Food Microbiol*, 19, 561–6, 2002. With permission.

^e Lee, M. Y., et al., *J Food Sci*, 70, M191–6, 2005. With permission.

^f Source: Wei, Q., and S. K. C. Chang, *J Food Process Preserv*, 28, 251–73, 2004. With permission.

7.5 Proximate Composition of *Thua Nao*

It is expected that there exist some differences of these proximate values between *thua nao* product and raw soybean because of biochemical changes during fermentation. As described by Chukeatirote and Thakang (2006), the content of protein, fat, and reducing sugar of fresh *thua nao* appeared to be slightly higher than unfermented soybean. These changes are possibly caused by several extracellular enzymes produced during fermentation (Chukeatirote et al. 2006). The overall data of proximate analysis of *thua nao* products are as follows: 64.91% moisture, 1.65% ash, 7.69% crude fiber, 14.33% crude protein, and 1.83% fat, whereas those features of *thua nao kab* were 11.88%, 4.94%, 13.46%, 36.43%, and 17.96%, respectively (Chukeatirote and Thakang 2006). Table 7.3 summarizes proximate composition data of *thua nao* compared with other fermented soybeans. Please note that the data of *thua nao* in Table 7.3 are from Sundhagul et al. (1972) in which some variations in these values are also observed compared with the data mentioned previously.

7.6 Amino Acid Profiles of *Thua Nao*

Thua nao products seem to be a good protein source based on the amino acid profiles. Available data show that all amino acids are present in *thua nao* with quantities of total free amino acids ranging from 11.03 to 61.23 g/kg, as dry basis. The major amino acids are Trp, followed by Glu, Cys, Lys, and Leu. All essential amino acids are also present in considerable amounts. It should be noted interestingly that there exist a large proportion of bitter amino acids accounting for more than 50% of total free amino acids (Dajanta et al. 2011a,c).

7.7 Isoflavones of *Thua Nao*

Isoflavones, a type of phenolic compounds, exhibit estrogen-like activity, which has been reported to exhibit several health beneficial effects (Wiseman 2006). Similar to other fermented soybeans, *thua nao* products contain high amounts of isoflavone compounds. Besides, the use of pure starter culture to prepare *thua nao* has showed to increase the content of aglycone isoflavones (Dajanta et al. 2009). Aglycone compounds are of great interest because of their bioavailability, high rate of absorption in animals and

humans (Izumi et al. 2000; Kano et al. 2006), and high antiproliferative activity on human cancer cells (Peterson et al. 1998).

7.8 Aroma and Flavoring Agents of *Thua Nao*

The microbial fermentation of soybeans causes biochemical changes including organoleptic properties. Such changes affect texture, odor, and flavors of the products. Traditionally produced *thua nao* is typically described as a fish sauce-like product due to a strong ammoniacal smell. In contrast, *natto* produced by a pure starter culture has a fruity/nutty aroma. Leejeerajumnean et al. (2001) reported that *thua nao* products contain aldehydes, aliphatic acids, esters, and sulfur compounds, whereas *natto* condiments are devoid of these chemicals. Besides, several pyrazine compounds found in *natto* are proposed to be the main contributors to *natto* odor characteristics (Sugawara 1985; Owens et al. 1997).

As part of the program to improve *thua nao* quality, the use of pure starter culture of *B. subtilis* strain TN51 isolated from commercial *thua nao* product has been shown to improve the organoleptic quality of the product (Dajanta et al. 2011b). The profile of volatile compounds responsible for the aroma of *thua nao* produced with pure and mixed cultures was determined using gas chromatography–mass spectrometry. In total, 85 volatile compounds were identified as follows: pyrazines (10), aldehydes (6), ketones (17), esters (8), alcohols (15), acids (4), aromatics (4), furans (5), sulfur-containing compounds (2), and other compounds (14). Generally, the predominant volatiles in fermented *thua nao* products were 2-methylbutanoic acid, 2,3,5-trimethylpyrazine, 2-methylpropanoic acid, acetic acid, 2,5-dimethylpyrazine, benzaldehyde, 5-methyl-3-hexanone, 2-butanone, and 3-methyl-2-pentanone, whereas those in cooked nonfermented products were ethanol, 2,3-butanedione, 3-hydroxy-2-butanone, acetone, benzaldehyde, and 2,5-dimethylpyrazine. It is therefore evident that there was a shift in volatile profiles from the cooked nonfermented to fermented products. Besides, a different pattern of the volatile compounds was also observed in the *thua nao* samples prepared with pure and mixed starter culture (Dajanta et al. 2011b).

7.9 Conclusion

Thua nao is an indigenous alkaline-fermented soybean of Thailand. This condiment plays a key role as dietary culture of local Thai people. In terms of nutrition, the product is acceptable as a good source of protein supplement in which other health benefits must be further explored. At present, scientific data of Thai *thua nao* are increasing. This chapter, which is a focus of *thua nao*, is our attempt to update its information currently available with an anticipation to attract researcher's attention on this local food product. Several issues are open for further experiment to study and to improve the product's quality. For instance, the use of pure starter culture is a good start and potential for product improvement. An alternative research relevant to nutritional quality (i.e., enhancement of amino acids and flavoring agents), health benefits (i.e., anticancer, antimicrobial, and antioxidant activities), and fermentation process would provide a new image of this indigenous food to the Thai and world community.

ACKNOWLEDGMENTS

The authors acknowledge the Royal Golden Jubilee PhD Research Scholarship and the Thailand Research Fund for financial support.

REFERENCES

- Boontim N, Lumyong S, Moriguchi M. 2003. Characterisation of thai fermented foods by organic acid contents. *ScienceAsia* 29:301–6.
- Chantawannakul P, Oncharoen A, Klanbut K, Chukeatirote E, Lumyong S. 2002. Characterisation of proteases of *Bacillus subtilis* strain 38 isolated from traditionally fermented soybean in Northern Thailand. *ScienceAsia* 28:241–5.

- Chukeatirote E, Chainun C, Siengsubchart A, Moukamnerd C, Chantawannakul P, Lumyong S, Boontim N, Thakang P. 2006. Microbiological and biochemical changes in *thua nao* fermentation. *Res J Microbiol* 1:38–44.
- Chukeatirote E, Dajanta K, Apichartsrangkoon A. 2010. Thua nao, indigenous thai fermented soybean: A review. *J Biol Sci* 10:581–3.
- Chukeatirote E, Thakang P. 2006. Chemical composition of *thua nao*—A fermented soybean food of northern Thailand. *Chiang Mai J Sci* 33:243–5.
- Dajanta K, Apichartsrangkoon A, Chukeatirote E. 2011a. Free-amino acid profiles of *thua nao*, a Thai fermented soybean. *Food Chem* 125:342–7.
- Dajanta K, Apichartsrangkoon A, Chukeatirote E. 2011b. Volatile profiles of *thua nao*, a Thai fermented soy product. *Food Chem* 125:464–70.
- Dajanta K, Chukeatirote E, Apichartsrangkoon A. 2011c. Analysis and characterisation of amino acid contents of *thua nao*, a traditionally fermented soybean food of Northern Thailand. *Int Food Res J* 18:588–92.
- Dajanta K, Chukeatirote E, Apichartsrangkoon A, Frazier RA. 2009. Enhanced aglycone production of fermented soybean products by *Bacillus* species. *Acta Biol Szeged* 53:93–8.
- Dakwa S, Sakyi-Dawson E, Diako C, Annan NT, Amoa-Awua WK. 2005. Effect of Boiling and Roasting on the Fermentation of Soybeans into Dawadawa (soy-dawadawa). *Int J Food Microbiol* 104:69–82.
- Dike EN, Odunfa SA. 2003. Microbiological and biochemical evaluation of a fermented soyabean product—Soy-dadawadwa. *J Food Sci Technol* 40:606–10.
- Izumi T, Piskula MK, Osawa S, Obata A, Tobe K, Saito M, Kataoka S, Kubota Y, Kikuchi M. 2000. Soy isoflavone aglycones are absorbed faster and in higher amounts than their glucosides in humans. *J Nutri* 130:1695–9.
- Jeff-Agboola YA, Oguntuase OS. 2006. Effect of *Bacillus sphaericus* on proximate composition of soybean (*Glycine max*) for the production of soy iru. *Pakistan J Nutri* 5:606–7.
- Jideani IAO, Okeke CR. 1991. Comparative study of microorganisms and sensory attributes of condiments from the fermentation of different seeds. *Plant Foods Human Nutri* 41:27–34.
- Kano M, Takayanagi T, Harada K, Sawada S, Ishikawa F. 2006. Bioavailability of isoflavones after ingestion of soy beverages in healthy adults. *J Nutri* 136:2291–6.
- Kiuchi K, Watanabe S. 2004. Industrialization of Japanese natto. In: Steinkraus KH, editor. *Industrialization of indigenous fermented foods*. 2nd ed. New York: Marcel Dekker. p 193–246.
- Kwak CS, Lee MS, Park SC. 2007. Higher antioxidant properties of chungkukjang, a fermented soybean paste, may be due to increased aglycone and malonylglycoside isoflavone during fermentation. *Nutri Res* 27:719–27.
- Lee MY, Park SY, Jung KO, Park KY, Kim SD. 2005. Quality and functional characteristics of Chungkukjang prepared with various *Bacillus* sp. isolated from traditional Chungkukjang. *J Food Sci* 70:M191–6.
- Leejeerajumnean A. 2000. *Bacillus* fermentation of soybeans: Characterisation of traditional *thua nao* manufacture. [DPhil thesis]. Reading, UK: The University of Reading.
- Leejeerajumnean A. 2003. *Thua nao*: Alkali fermented soybean from *Bacillus subtilis*. *Silpakorn Univ Int J* 3:277–92.
- Leejeerajumnean A, Duckham SC, Owens JD, Ames JM. 2001. Volatile Compounds in *Bacillus*-fermented soybeans. *J Sci Food Agric* 81:525–9.
- Nout MJR, Bakshi D, Sarkar PK. 1998. Microbiological safety of kinema, a fermented soya bean food. *Food Control* 9:357–62.
- Omafuvbe BO, Abiose SH, Shonukan OO. 2002. Fermentation of soybean (*Glycine max*) for soy-daddawa production by starter cultures of *Bacillus*. *Food Microbiol* 19:561–6.
- Omafuvbe BO, Shonukan OO, Abiose SH. 2000. Microbiological and biochemical changes in the traditional fermentation of soybean for soydaddawa—Nigerian food condiment. *Food Microbiol* 17:465–74.
- Owens JD, Allagheny N, Kipping G, Ames JM. 1997. Formation of volatile compounds during *Bacillus subtilis* fermentation of soya beans. *J Sci Food Agric* 74:132–40.
- Peterson TG, Ji GP, Kirk M, Coward L, Falany CN, Barnes S. 1998. Metabolism of the isoflavones genistein and daidzein in human breast cancer cell lines. *Amer J Clin Nutri* 68:1505–11.
- Sarkar PK, Hasenack B, Nout MJR. 2002. Diversity and functionality of *Bacillus* and related genera isolated from spontaneously fermented soybeans Indian kinema, and locust beans African Soumbala. *Int J Food Microbiol* 77:175–86.

- Sarkar PK, Tamang JP, Cook PE, Owens JD. 1994. Kinema—A traditional soybean fermented food: Proximate composition and microflora. *Food Microbiol* 11:47–55.
- Steinkraus KH. 1996. *Handbook of indigenous fermented foods*. 2nd ed. New York: Marcel Dekker.
- Sugawara E, Ito T, Odagiri S, Kubota K, Kobayashi A. 1985. Comparison of compositions of odour components of *natto* and cooked soybeans. *Agric Biol Chem* 49:311–7.
- Sundhagul M, Smanmathuroj P, Bhodacharoen W. 1972. Thua-Nao: A fermented soybean food of Northern Thailand: I. Traditional processing method. *Thai J Agric Sci* 5:43–56.
- Tamang JP. 1993. Studies on the microflora of some traditional fermented foods of darjeeling hills and sikkim. [DPhil thesis]. Siliguri: University of North Bengal, India.
- Tamang JP, Sarkar PK, Hesseltine CW. 1988. Traditional fermented foods and beverages of darjeeling and sikkim—A review. *J Sci Food Agric* 44:375–85.
- Wei Q, Chang SKC. 2004. Characteristics of fermented natto products as affected by soybean cultivars. *J Food Process Preserv* 28:251–73.
- Wei Q, Wolf-Hall C, Chang KC. 2001. Natto characteristics as affected by steaming time, *bacillus* strains, and fermentation time. *J Food Sci* 66:167–73.
- Wiseman H. 2006. Isoflavonoids and human health. In: Andersen OM, Markham KR, editors. *Flavonoids, chemistry, biochemistry and applications*. Florida: CRC Press. p 371–96.

