# 4

# *Plant-Based Fermented Foods and Beverages of Asia*

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**CONTENTS**

## 4.1 Introduction

There are several definitions for fermented foods in the literature. The most recent definition of fermented foods and beverages is given by Tamang (2010b). Ethnic fermented foods are defined as foods produced by ethnic people using their native knowledge from locally available raw materials of plant or animal sources either naturally or by adding starter culture(s) containing functional microorganisms which modify the substrates biochemically and organoleptically into edible products that are culturally and socially acceptable to the consumers (Tamang 2010a). Asian people consume vegetables, both domesticated and wild, in a variety of recipes. Perishable and seasonal leafy vegetables, radish, cucumbers, including young edible tender bamboo shoots, are traditionally fermented into edible products using the indigenous knowledge of biopreservation (Table 4.1). The knowledge of the art of pickling vegetables, which is basically fermentation, might have developed in Asia (Pederson 1979). Soybeans are the most common among the legumes used for fermentation of soybean foods in the South East, Far Asia, and the Himalayan regions of India, Nepal, and Bhutan. Cooked rice is a staple food in Asia. Wheat and barley are also important staple diets in the Indian subcontinent and in western and middle eastern Asia. Production of ethnic fermented cereal products is mostly restricted to the Indian subcontinent. Comparable to the African and European dietary cultures, Asia has a limited number of ethnic nonalcoholic fermented cereal products. Cereals are commonly fermented into several ethnic alcoholic drinks in Asia. Tea, the second most popular beverage in the world after water, originated in China and two common species of tea are *Camellia sinensis* var. *sinensis* and *C. sinensis* var. *assamica* (Schillinger et al. 2010). Although normal black tea is drunk everywhere, some ethnic Asian communities, however, have special fermented teas such as *miang* from Thailand, *puer* tea and *fuzhuan brick* and *kombucha* from China.

In addition to being a recreational beverage, ethnic alcoholic drinks have strong ritualistic importance among the ethnic people in Asia where social activities require the provision and drinking of alcohol. Drinking of alcohol in India has been mentioned in the *Ramayana* during 300 to 75 BC (Prakash 1961). Interestingly, the malting process for alcohol production is rare or unknown in Asia. Wine making is not a tradition in Asia because fruits are eaten directly without extracting into juice or fermenting into wines. Dry mixed starters containing a consortia of microorganisms are traditionally used in the fermentation of alcoholic beverages in many countries in Asia (Table 4.2). In general, three types of amylolytic mixed cultures or inocula are traditionally used in Asia as a starter to convert cereal starch to sugars and, subsequently, to alcohol and organic acids (Tamang and Fleet 2009):

Type I: A consortium of mycelial or filamentous molds, amylolytic, and alcohol-producing yeasts, and lactic acid bacteria (LAB) with rice or wheat as the base in the form of dry, flattened, or round balls of various sizes. The starter is inoculated with material from a previous batch. This mixed flora is allowed to develop for a short time, then dried and used to make either alcohol or fermented foods from starchy materials. Ethnic starters, which are used for a number of fermentations based on rice and cassava or other cereals in Asia, have different vernacular names such as *marcha* in India and Nepal, *ragi* in Indonesia, *bubod* in the Philippines, *chiu/chu* in China and Taiwan, *loogpang* in Thailand, *nuruk* in Korea, and *men* in Vietnam (Tamang 2010c).

Type II: A combination of *Aspergillus oryzae* and *Aspergillus sojae* is used in the form of a starter called *koji* in Japan to produce alcoholic beverages, including *saké*. Koji also produces amylases that convert starch to fermentable sugars, which are then used for the second stage of yeast fermentation to make a nonalcoholic fermented soybean product called *miso* and *shoyu*, whereas proteases are formed to break down the soybean protein.

Type III: Whole wheat flour is moistened and made into large compact cakes that are incubated in culture yeasts and filamentous molds and used to ferment starchy material to produce alcohol. This type is mainly used in China for alcohol production.

The Indian and Chinese communities have the most diverse variety of ethnic fermented foods and alcoholic beverages among Asians (Tamang 2010b). Plant-based fermented foods from Asia are categorized into fermented vegetables, fermented bamboo shoots, fermented legumes, fermented cereal, fermented tea, and fermented beverages.

**TABLE 4.1**

Plant-Based Fermented Foods of Asia

| Country | Plant Source | Fermented Food | Nature and Use |
|---|---|---|---|
| Afghanistan | Wheat flour | *Nan* | Leaved bread, baked; staple |
| Bangladesh | Fruits, vegetables | *Chatney* | Acidic, hot and sour; pickles |
| Bhutan | Leafy vegetable | *Gundruk* | Acidic, sour, dry; soup, pickle |
| Bhutan | Radish taproot | *Sinki* | Acidic, sour, dry; soup, pickle |
| Bhutan | Soybean | *Kinema* | Alkaline, sticky; curry, soup |
| Bhutan | Rice-wheat flour | *Selroti* | Pretzel-like, deep fried; staple |
| China | Vegetables | *Suan-cai* | Acidic, sour, wet; pickle |
| China | Vegetables | *Paocai* | Acidic, sour, wet; pickle |
| China | Soybean | *Chee-fan* | Cheese-like, solid; salad |
| China | Soybean | *Chiang* | Alkaline, paste; soup |
| China | Soybean | *Dauchi* | Alkaline, paste; condiment, soup |
| China | Soybean | *Furu* | Mild acidic; savory |
| China | Soybean | *Meitauza* | Liquid drink |
| China | Soybean | *Sufu* | Mild-acidic, soft; side dish |
| China | Soybean | *Tofu si* | Alkaline, liquid; seasoning |
| China | Rice | *Ang-kak* | Powder colorant |
| China | Wheat gluten | *Minchin* | Solid; condiment |
| China | Tea liquor | *Kombucha* | Flavored; drink |
| China | Tea | *Fuzhuan brick* | Fermented tea; drink |
| China | Tea | *Puer* | Fermented tea; drink |
| Cambodia | Soybean | *Sieng* | Alkaline, sticky; side dish |
| India | Taro leaves | *Anishi* | Acidic, wet; curry |
| India | Bamboo shoot | *Bastanga* | Acidic, soft; curry |
| India | Bamboo shoot | *Ekung* | Acidic, sour, soft; soup |
| India | Bamboo shoot | *Eup* | Acidic, sour, dry; curry, soup |
| India | Bamboo shoot | *Hirring* | Acidic, sour, wet; curry, soup |
| India | Bamboo shoot | *Mesu* | Acidic, sour, wet; pickle |
| India | Bamboo shoot | *Lung-siej* | Sour-acidic, soft; curry |
| India | Bamboo shoot | *Soibum* | Acidic, sour, soft; curry |
| India | Bamboo shoot | *Soidon* | Acidic, sour, soft; curry |
| India | Leafy vegetable | *Gundruk* | Acidic, sour, dry; soup, pickle |
| India | Wild vegetable | *Goyang* | Acidic, sour, wet; condiment, soup |
| India | Mustard leaves | *Inziang-sang* | Acidic, sour, dry; curry, soup |
| India | Mustard leaves | *Inziang-dui* | Acidic, sour, liquid; condiment |
| India | Cucumber | *Khalpi* | Acidic, sour, wet; pickle |
| India | Radish taproot | *Sinki* | Acidic, sour, dry; soup, pickle |
| India | Soybean | *Kinema* | Alkaline, sticky; curry, soup |
| India | Soybean | *Hawaijar* | Alkaline, sticky; side dish |
| India | Soybean | *Aakhone* | Alkaline, sticky, paste; side dish |
| India | Soybean | *Tungrymbai* | Alkaline, sticky; curry, soup |
| India | Soybean | *Bekang* | Alkaline, sticky, paste; side dish |
| India | Soybean | *Peruyaan* | Alkaline, sticky; side dish |
| India | Bengal gram | *Dhokla* | Mild acidic, spongy; snack |
| India | Black gram | *Bhallae* | Mild acidic, fried patties; snack |
| India | Bengal gram | *Khaman* | Mild acidic, spongy; breakfast food |
| India | Black gram | *Vadai* | Paste, fried patties; snack |
| India | Black gram | *Wari* | Ball-like, brittle; condiment |
| India | Rice and black gram | *Idli* | Mild-acidic, soft, moist, spongy; breakfast food |

(*continued*)

**TABLE 4.1 (Continued)**

Plant-Based Fermented Foods of Asia

| Country | Plant Source | Fermented Food | Nature and Use |
|---|---|---|---|
| India | Rice and black gram | *Dosa* | Thin, crisp pancake; shallow-fried, staple |
| India | Maize, Bengal gram | *Puda/Pudla* | Solid food, pancake; snack food |
| India | Wheat flour | *Bahtura* | Bread; deep-fried bread |
| India | Wheat flour | *Nan* | Leaved bread, baked; staple |
| India | Wheat, barley, buckwheat | *Chilra* | Like *dosa;* staple |
| India | Wheat flour | *Marchu* | Baked bread; staple |
| India | Wheat flour | *Jalebi* | Crispy sweet, doughnut-like, deep-fried; snacks |
| India | Millet, rice | *Ambali* | Acidic, pan cake shallow-fried; staple |
| India | Black gram | *Maseura* | Dry, ball-like, brittle; condiment |
| India | Black gram | *Papad* | Circular wafers; snack |
| India | Cereals, pulses, milk | *Rabadi* | Mild-acidic, thick slurry-like product; drink |
| India | Wheat grains | *Seera* | Dried; sweet dish |
| India | Rice-wheat | *Selroti* | Pretzel-like, deep fried; staple |
| India | Wheat flour, opium seeds | *Siddu* | Steamed bread, oval-shaped; staple |
| India | Fruits, vegetables, oil, salt | *Achar/chatney* | Acidic, hot and sour; pickles |
| India | Fruits | *Chuk* | Sour, dark-brown paste; therapeutic uses |
| India | Rice | *Hakua* | Strong off-flavor; therapeutic uses |
| India | Tea liquor | *Kombucha* | Flavored; drink |
| Indonesia | Soybean, wheat | *Kecap* | Liquid; condiment, seasoning |
| Indonesia | Soybean (black) | *Ketjap* | Syrup; seasoning agent |
| Indonesia | Mustard leaves, cabbage | *Sayur asin* | Acidic, sour, wet; salad, side dish |
| Indonesia | Peanut | *Ontjom* | Alkaline, solid cake, roasted or fried; snack |
| Indonesia | Soybean | *Tauco* | Alkaline, paste; soup |
| Indonesia | Soybean | *Tempe* | Alkaline, solid; fried cake; snack |
| Indonesia | Coconut | *Bongkrek* | Solid, roasted or fried in oil; snack |
| Indonesia | Cassava roots | *Peujeum* | Acidic, solid; snack |
| Japan | Soybean | *Natto* | Alkaline, sticky; breakfast |
| Japan | Soybean | *Miso* | Alkaline, paste; soup |
| Japan | Soybean | *Shoyu* | Alkaline, liquid; seasoning |
| Japan | Turnip | *Sunki* | Acidic, sour, wet; pickle |
| Korea | Rice | *Kichudok* | Steamed cake; side dish |
| Korea | Cabbage, radish | *Kimchi* | Acidic, mild-sour, wet; salad |
| Korea | Soybean | *Doenjang* | Alkaline, paste; soup |
| Korea | Soybean | *Chungkokjang* | Alkaline, sticky; condiment, soup |
| Korea | Soybean, rice | *Kochujang* | Alkaline, paste; condiment, soup |
| Korea | Soybean | *Kanjang* | Alkaline, paste; condiment |
| Korea | Soybean | *Meju* | Alkaline, paste; seasoning |
| Laos | Soybean | *Sieng* | Alkaline, sticky; side dish |
| Malaysia | Fruits, vegetables | *Jeruk* | Acidic, wet; salad |
| Myanmar | Soybean | *Pepok* | Alkaline, sticky; side dish |
| Nepal | Leafy vegetable | *Gundruk* | Acidic, sour, dry; soup, pickle |
| Nepal | Wild vegetable | *Goyang* | Acidic, sour, wet; condiment, soup |
| Nepal | Cucumber | *Khalpi* | Acidic, sour, wet; pickle |
| Nepal | Radish | *Sinnamani* | Acidic, sour, wet; pickle |

(*continued*)

**TABLE 4.1 (Continued)**

Plant-Based Fermented Foods of Asia

| Country | Plant Source | Fermented Food | Nature and Use |
|---|---|---|---|
| Nepal | Radish taproot | *Sinki* | Acidic, sour, dry; soup, pickle |
| Nepal | Bamboo shoot | *Mesu* | Acidic, sour, wet; pickle |
| Nepal | Soybean | *Kinema* | Alkaline, sticky; curry, soup |
| Nepal | Black gram | *Maseura* | Dry, ball-like, brittle; condiment |
| Nepal | Rice | *Hakua* | Strong off-flavor; therapeutic uses |
| Nepal | Fruits, vegetables, oil, salt | *Achar* | Acidic, hot and sour; pickles |
| Nepal | Rice-wheat | *Selroti* | Pretzel-like, deep fried bread, staple |
| Pakistan | Wheat flour | *Marchu* | Baked bread; staple |
| Pakistan | Wheat flour | *Nan* | Leaved bread, baked; staple |
| Pakistan | cereals, pulses-milk | *Rabadi* | Mild-acidic, thick slurry-like product; drink |
| Pakistan | Wheat grains | *Seera* | Dried; sweet dish |
| Pakistan | Fruits, vegetables, oil, salt | *Chatney* | Acidic, hot and sour; pickles |
| Philippines | Rice | *Puto* | Steamed cake; breakfast or snack |
| Philippines | Mustard | *Burong mustasa* | Acidic, wet; salad |
| Philippines | Coconut water or coconut skim milk | *Nata de coco* | Thick white or cream-colored, candied; Ice cream, fruit salads |
| Philippines | Juice from pineapple | *Nata de piña* | Thick white or cream-colored, insoluble gelatinous film of polysaccharides; ice cream, fruit salads |
| Taiwan | Mustard | *Suan-tsai* | Acidic, sour, dry; soup, stew |
| Taiwan | Mustard | *Fu-tsai* | Acidic, sour; soup, stew |
| Taiwan | Soybean | *Meitauza* | Liquid; drink |
| Taiwan | Soybean curd | *Sufu* | Mild-acidic, soft; side dish |
| Taiwan | Bamboo shoots | *Jiang-sun* | Acidic, sour; side dish |
| Thailand | Mustard leaf | *Dakguadong* | Acidic, wet; salad |
| Thailand | Bamboo shoots | *Naw-mai-dong* | Acidic, wet; side dish |
| Thailand | Leafy vegetable | *Pak-gard-dong* | Acidic, wet; side dish |
| Thailand | Leaves of Gynandropis pentaphylla | *Pak-sian-dong* | Acidic, wet; side dish |
| Thailand | Soybean | *Thua nao* | Alkaline, paste, dry; soup |
| Thailand | Rice | *Khanom-jeen* | Noodle; staple |
| Thailand | Tea | *Miang* | Fermented tea, flavored; drink |
| Sri Lanka | Rice and black gram | *Dosa* | Thin, crisp pancake, shallow-fried; staple |
| Sri Lanka | Rice and black gram | *Idli* | Mild-acidic, soft, moist, spongy; beakfast food |
| Sri Lanka | Rice, coconut water | *Hopper* | Steak-baked, pancake; staple |
| Vietnam | Cabbage | *Dhamuoi* | Acidic, wet; salad |
| Vietnam | Rice | *Me* | Acidic, sour; condiment |
| Southeast Asia | Soybean | Soy sauce | Alkaline, liquid; seasoning |
| Southeast Asia | Sugar-containing substrates | Vinegar | Acetic acid flavored, liquid; condiment, seasoning |

**TABLE 4.2**

Plant-Based Fermented Beverages of Asia

| Country | Plant Source | Mixed Starter | Beverage | Nature and Use |
|---|---|---|---|---|
| Bhutan | Finger millet/ barley | *Poo* | *Chyang* | Mild alcoholic, slightly, sweet-acidic |
| Bhutan | Barley, millet | *Poo* | *Aarak* | Distilled from *chyang*, clear liquor |
| China | Sorghum | *Daqu* | *Maotai* | Distilled, clear liquor (national drink) |
| China | Finger millet/ barley | *Phab* | *Chyang* | Mild alcoholic, slightly sweet-acidic |
| China | Barley, millet | *Phab* | *Aarak* | Distilled from *chyang*, clear liquor |
| China | Rice | *Chiu yueh* | *Lao chao* | Sweet-sour, mild alcoholic paste |
| China | Rice | *Chiu-yueh* | *Tien-chiu-niang* | Mild alcoholic, sweet |
| India | Finger millet | *Marcha* | *Kodo ko jaanr* | Mild alcoholic, sweet-acidic |
| India | Rice | *Marcha* | *Bhaati jaanr* | Mild alcoholic, sweet-sour, paste |
| India | Rice | *Hamei* | *Atingba* | Mild alcoholic, sweet-sour |
| India | Rice | *Humao* | *Judima* | Mild alcoholic, sweet-sour |
| India | Maize-rice/barley | *Phab* | *Bhang-chyang* | Extract of *mingri* |
| India | Rice | *Phab* | *Apong* | Mild alcoholic |
| India | Barley | *Phab* | *Buza* | Thick liquor |
| India | Apricot | Yeast | *Chulli* | Filtrate, clear |
| India | Buck wheat | *Marcha* | *Faapar ko jaanr* | Mild acidic, alcoholic |
| India | Cereal | Yeast, LAB | *Daru* | Alcoholic beverages; filtrate |
| India | Red rice | Yeast, LAB | *Duizou* | Fermented rice beverage |
| India | Rice, paddy husk | Yeast, LAB | Ennog | Black rice beverage |
| India | Wheat | *Marcha* | *Gahoon ko jaanr* | Mild acidic, alcoholic |
| India | Rice | *Thiat* | *Kiad lieh* | Distilled liquor, clear |
| India | Barley | *Marcha* | *Jao ko jaanr* | Mild acidic, alcoholic |
| India | Rice | Yeasts, LAB | Jou | Mild alcoholic beverage |
| India | Carrot/beetroots | *Torani* (starter) | *Kanji* | Strong flavored |
| India | Finger millet/ barley | *Phab* | *Chyang/Chee* | Mild alcoholic, slightly sweet-acidic |
| India | Maize-rice/barley | *Phab* | *Mingri* | Sweet, mild alcoholic, thick |
| India | Coconut palm | Yeasts, LAB | *Nareli* | Sweet, milky, effervescent, mild alcoholic |
| India | Red rice | *Khekhrii* | *Nchiangne* | Distilled liquor |
| India | Rice-millet | Unknown | Oh | Soft, mild alcoholic beverage |
| India | Palmyra and date palm sap | Yeasts, LAB | *Tari* | Sweet, effervescent, and mild alcoholic |
| India | Date palm | Yeasts, LAB | *Tari* | Sweet, alcoholic beverage |
| India | Finger millet, barley | Molds, yeasts | *Themsing* | Mild alcoholic, sweet |
| India | Rice | *Hamei* | *Yu* | Distilled from liquor from *atingba*, alcoholic drink |
| India | Barley | Yeasts | *Sing sing* | Beverage |
| India | Cassava tuber | *Marcha* | *Simal tarul ko jaanr* | Mild alcoholic, sweet-sour |
| India | Rice | Yeasts, LAB | *Zu* | Distilled from fermented rice; clear liquor |
| India | Rice | *Khekhrii* | Zutho | Milky white, sweet-sour, mild alcoholic |
| India | Finger millet | *Dhehli* | *Sura* | Alcoholic |
| India | Maize-rice, barley | Unknown | *Lohpani* | Alcoholic liquor |

(*continued*)

**TABLE 4.2 (Continued)**

Plant-Based Fermented Beverages of Asia

| Country | Plant Source | Mixed Starter | Beverage | Nature and Use |
|---|---|---|---|---|
| India | Barley | *Phab* | *Lugri* | Sweet-sour, mild alcoholic, thick liquid |
| India | Rice | Yeast, mold | *Madhu* | Distilled liquor |
| India | Maize | *Marcha* | *Makai ko jaanr* | Mild alcoholic, sweet-sour |
| India | Rice | Molds, yeast, LAB | *Pona* | Mild alcoholic, sweet-sour, paste |
| India | Cereals | *Marcha* | *Raksi* | Clear distilled liquor |
| India | Rice | Yeasts | *Ruhi* | Distilled liquor |
| Indonesia | Rice | *Ragi* | *Brem* | Dried, sweet-sour, mild alcoholic product |
| Indonesia | Rice, cassava, maize, millet | *Ragi* | *Tapé kekan* | Sweet-sour alcoholic paste |
| Japan | Rice | *Koji* | *Saké* | Nondistilled, clarified and filtered liquor (national drink) |
| Japan | Rice | *Koji* | *Shochu* | Distilled spirit |
| Japan | Sugar cane | *Koji* | *Shoto saké* | Liquor |
| Korea | Rice | *Nuruk* | *Soju* | Distilled liquor |
| Korea | Rice | *Nuruk* or commercial starter | *Makgeolli* | Sweet-acidic, mild alcoholic drink (national drink) |
| Korea | Rice, wheat, barley, maize | *Nuruk* | *Takju* | Alcoholic |
| Korea | Rice | *Nuruk* | *Ewhaju* | Nondistilled, filtered, and clarified, clear liquor |
| Korea | Rice, wheat, barley, maize | *Nuruk* | *Yakju* | Alcoholic |
| Korea | Rice | *Nuruk* | *Soju* | Distilled liquor |
| Malaysia | Rice | *Ragi* or *jui-piang* | *Tapai pulut* | Sweet, sour, mild alcoholic |
| Malaysia | Cassava | *Ragi* or *jui-piang* | *Tapai ubi* | Sweet, sour, mild alcoholic |
| Mongolia | Millet | LAB, yeasts | *Darassun* | Liquid |
| Nepal | Rice | *Marcha* | *Bhaati jaanr* | Mild alcoholic, sweet-sour, paste |
| Nepal | Buck wheat | *Marcha* | *Faapar ko jaanr* | Mild acidic, alcoholic |
| Nepal | Wheat | *Marcha* | *Gahoon ko jaanr* | Mild acidic, alcoholic |
| Nepal | Barley | *Marcha* | *Jao ko jaanr* | Mild acidic, alcoholic |
| Nepal | Maize | *Marcha* | *Makai ko jaanr* | Mild alcoholic, sweet-sour |
| Nepal | Finger millet | *Marcha* | *Kodo ko jaanr* | Mild alcoholic, sweet-acidic |
| Nepal | Rice | *Manapu* | *Poko* | Sweet-acidic, mild-alcoholic |
| Nepal | Cereals | *Marcha* | *Raksi* | Clear distilled liquor |
| Nepal | Cassava tuber | *Marcha* | *Simal tarul ko jaanr* | Mild-alcoholic, sweet-sour |
| Philippines | Sugar cane | *Bubod, binubudan* | *Basi* | Clear or cloudy liquid |
| Taiwan | Rice | *Chiu-yueh* | *Tien-chiu-niang* | Mild-alcoholic, sweet |
| Thailand | Rice | *Loogpang* | *Ou* | Distilled liquor |
| Thailand | Rice | *Loogpang* | *Khao maak* | Juicy, white colored, sweet taste, mild alcoholic |
| Thailand | Rice | *Loogpang* | *Nam khao* | Distilled liquor |
| Thailand | Rice | *Loogpang* | *Krachae* | Nondistilled and filtered liquor |
| Thailand | Rice | *Loogpang* | *Sato* | Distilled liquor |
| Philippines | Rice | *Bobod* | *Tapuy* | Sweet, sour, mild alcoholic |
| Vietnam | Rice | *Men* | Ruou de | Distilled liquor, clear |
| Vietnam | Rice | *Men* | Ruou nep | Distilled liquor, clear |
| Vietnam | Rice (purple) | *Men* | Ruou nep than | Nondistilled, viscous, thick |
| Vietnam | Rice, maize, cassava | *Men* | Ruou nep chan | Nondistilled, viscous, thick; or distilled |

## 4.2 Fermented Vegetables

### 4.2.1 Gundruk

*Gundruk* is an ethnic fermented vegetable of the Himalayan regions of India, Nepal, and Bhutan. Daily per capita consumption of gundruk is 1.4 g with an annual production of 3.2 kg/house in the Indian state of Sikkim (Tamang et al. 2007a). Gundruk is prepared from the fresh leaves of a local vegetable called *rayo-sag* (*Brasicca rapa* subspecies *campestris* variety *cuneifolia*), mustard, and cauliflower. This mixture is wilted and shredded, crushed mildly, and pressed into an airtight earthen jar or container. The container is kept in a warm place and allowed to ferment naturally for approximately 7 to 10 days. Unlike kimchi and sauerkraut, freshly fermented gundruk is sun-dried for 3 to 4 days before consumption whereas dried gundruk can be preserved for more than 2 years at room temperature. Gundruk is eaten as a soup or pickle.

*Lactobacillus fermentum*, *Lactobacillus plantarum*, *Lactobacillus casei*, *Lactobacillus casei* subsp. *pseudoplantarum*, and *Pediococcus pentosaceus* have been isolated from gundruk (Tamang et al. 2005). Gundruk fermentation is initiated by *Lb. fermentum*, followed by *P. pentosaceus* and, finally, by *Lb. plantarum*, *Lb. casei*, and *Lb. casei* subsp. *pseudoplantarum* (Karki et al. 1983d; Tamang and Tamang 2010). *Lb. plantarum* MTCC 9483 and *P. pentosaceus* MTCC 9484 have been selected as starters for the production of gundruk (Tamang and Tamang 2010). Some LAB isolated from gundruk showed strong acidification, antimicrobial properties, and the ability to degrade antinutritive factors and probiotic character (Tamang et al. 2009a). Gundruk contains organic acids such as lactic, acetic, citric, malic, and acetic acids (Karki 1986), and is considered as a good appetizer (Tamang 2010a). Cyanides and isothiocyanates are the main flavor components, followed by alcohols, esters, and phenyl acetaldehyde in gundruk (Karki et al. 1983a). Increases of palmitic, oleic, linoleic, and linolenic acids and free amino acids, mostly glutamic acid, alanine, leucine, lysine, and threonine have been observed in gundruk (Karki et al. 1983b,c).

### 4.2.2 Kimchi

*Kimchi* symbolizes the rich food culture of Korea, and is one of the most popular ethnic fermented vegetables in Korea. Kimchi is a generic term used to denote a group of fermented cabbage, radish, and garlic foods in Korea. Per capita consumption of kimchi is 50 to 200 g per day (Kim and Chun 2005). More than 106 tons of kimchi is consumed annually in South Korea using not less than100 types of vegetables to prepare kimchi (Wacher et al. 2010). Chinese cabbage, radish, cucumber, a mixture of red pepper powder, garlic, ginger, and green onion are the ingredients for the production of kimchi (Nam et al. 2009). During the traditional method of preparation of kimchi, cabbage and radish are cut into small chunks, salted, mixed with chopped hot red pepper, garlic, dropwort, leaf mustards, and some seaweed. Water is added to the mixture which is kept in a closed earthen pot until it is fermented. The freshly fermented product, kimchi, is taken out and is eaten directly as a side dish. Three major types of kimchi are commonly prepared in Korea—whole cabbage kimchi (*jeotgukji*), diced-radish kimchi (*kakdug*i), and water kimchi (*yeolmu*).

Several species of LAB have been identified from kimchi, including *Leuconostoc kimchii*, *Leuconostoc mesenteroides*, *Leuconostoc pseudomesenteroides*, *Leuconostoc lactic*, *Lactobacillus brevis*, *Lactobacillus kimchii*, *Lb. plantarum*, *Lactococcus inhae*, *Weisella kimchi*, *Weisella koreensis*, *Tetragenococcus koreensis* (Yoon et al. 2000; Lee et al. 2002, 2005; Choy et al. 2002; Kim et al. 2003; Kim and Chun 2005). Several species of non-LAB and yeasts have also been reported from kimchi—*Halococcus*, *Natronococcus*, *Natrialba*, *Haloterrigena*, *Lodderomyces*, *Trichosporon*, *Candida*, *Saccharomyces*, *Pichia*, *Sporisorium*, and *Kluyveromyces* (Chang et al. 2008). Kimchi has several health-promoting benefits and is considered as a functional food. It has an antiobesity effect (Kong et al. 2008), probiotic properties (Lee and Lee 2006), and antioxidants (Sim and Han 2008; Sun et al. 2009). Consumption of kimchi prevents constipation, colon cancer, reduces serum cholesterol (Park et al. 2006), inhibits atherosclerosis (Kim et al. 2008), exerts antistress principles (Lee and Lee 2009), and helps in the reduction of depression, osteoarthritis, and liver disease (Lee et al. 2008). Nowadays, kimchi is no longer limited to the Korean diet and has been widely accepted by non-Korean consumers throughout the world as a popular salad due to its taste and functionality.

### 4.2.3 Sinki

*Sinki* is an ethnic fermented radish taproot commonly prepared in the Himalayan regions of India, Nepal, and Bhutan by pit fermentation. Pit fermentation of a *sinki* preparation is a unique type of biopreservation of perishable radish using lactic acid fermentation in the Himalayas (Tamang 2010a). A pit approximately 2 to 3 ft. with the same diameter is dug in a dry field, cleaned, plastered with mud, and warmed by burning. After removing the ashes, the pit is lined with bamboo sheaths and paddy straw. Radish taproots are wilted for 2 to 3 days, crushed, squeezed, and pressed tightly into the pit, then covered with dry leaves and weighted down by heavy planks or stones. The top of the pit is plastered with mud and left to ferment naturally for 22 to 30 days. Freshly fermented sinki is removed, cut into small pieces, sun-dried for 3 to 5 days, and stored at room temperature for future consumption. Dry sinki can be kept for several years in an airtight container. It is eaten as a soup or pickle. *Lb. plantarum*, *Lb. brevis*, *Lb. casei* and *Leuconostoc fallax* have been isolated from sinki (Tamang and Sarkar 1993; Tamang et al. 2005).

### 4.2.4 Sunki

*Sunki* is an ethnic nonsalted and fermented vegetable product of Japan prepared from the leaves and stems of red turnip (Wacher et al. 2010). Turnip is boiled, inoculated with *zumi* (a small, wild apple), and dried *sunki* from the previous year and allowed to ferment for 1 to 2 months. *Sunki* is eaten with rice and miso soup. *Lb. plantarum*, *Lb. brevis*, *Lactobacillus buchneri*, *Lactobacillus kisonensis*, *Lactobacillus otakiensis*, *Lactobacillus rapi*, *Lactobacillus sunkii*, *Enterococcus faecalis*, *Bacillus coagulans*, and *P. pentosaceus* have been isolated from *sunki* (Itabashi 1986; Watanabe et al. 2009).

### 4.2.5 Khalpi

*Khalpi* is an ethnic fermented cucumber product of Nepal and India. Ripened cucumber is cut into pieces and sun-dried for 2 days, then put into a closed bamboo vessel and fermented naturally at room temperature for 3 to 5 days. Khalpi is consumed as a pickle. *Leuc. fallax*, *P. pentosaceus*, *Lb. brevis*, and *Lb. plantarum* are the dominant LAB in khalpi fermentation (Tamang et al. 2005). *Lb. plantarum* MTCC 9485, *Lb. brevis* MTCC 9486, and *Leuc. fallax* MTCC 9487 were selected as a mixed starter for the commercial production of khalpi (Tamang and Tamang 2010).

### 4.2.6 Goyang

*Goyang* is an ethnic fermented wild plant food, generally prepared by the Sherpa women of high mountains in the Himalayan regions of India and Nepal (Tamang and Tamang 2007). The leaves of the wild edible plant (*Cardamine macrophylla* Willd), are collected, washed and cut into pieces, squeezed to drain off excess water, and tightly pressed into bamboo baskets lined with two to three layers of leaves from fig plants. The top of the baskets are then covered with fig plant leaves, and fermented naturally at room temperature for 25 to 30 days. Freshly fermented goyang is transferred into an airtight container which can be stored for 2 to 3 months. The shelf life of *goyang* can be prolonged by making the freshly fermented goyang into balls that are sun-dried for 2 to 3 days before being stored for several months. Goyang is eaten as a soup. *Lb. plantarum*, *Lb. brevis*, *Lactococcus lactis*, *Enterococcus faecium*, *P. pentosaceus*, and yeasts from *Candida* spp. have been isolated from goyang (Tamang and Tamang 2007).

### 4.2.7 Pao Cai and Suan Cai

*Pao cai* is an ethnic fermented cabbage from China, similar to Korean kimchi. It is most common in northern and western China. A similar form of pao cai, called *suan cai*, is prepared and eaten in northeast China. There are more than 11 major types of fermented vegetables or pickled vegetables in China. Pao cai is sweet and sour rather than spicy, and is eaten with congee as a breakfast food. The flavor and method of production of pao cai vary greatly across China. During production, vegetables are selected, cleaned, drained, cut into pieces, and seasonings (sugar, salt, vinegar, a little alcohol) are added before

being sealed in jars that are filled up with water and fermented for a week or more. The total annual production of pao cai in China is 2 million tons, fetching 150 million Chinese yuan annually (Lu 2010). *Lactobacillus pentosus*, *Lb. plantarum*, *Lb. brevis*, *Lb. lactis*, *Lb. fermentum*, *Leuc. mesenteroides*, and *P. pentosaceus* are the functional LAB in pao cai (Yan et al. 2008; Huang et al. 2009). *Lb. harbinensis* was isolated from suan cai (Miyamoto et al. 2005).

### 4.2.8 Fu-tsai and Suan-tsai

*Fu-tsai* and *suan-tsai* are ethnic fermented mustard products from Taiwan prepared by the Hakka tribes (Chao et al. 2009). Freshly harvested mustard is wilted, placed in a bucket in layers by alternating with 4% salt, sealed airtight, and left to ferment naturally for 7 days to 2 months at ambient temperature. If fermentation is continued for approximately 2 months, the fermented product is called suan-tsai. However, for the production of fu-tsai, partly fermented mustard is removed from the bucket after 7 days, and cleaned with water, sun-dried for 1 to 2 days, and then again fermented for at least 2 days. This step of sun-drying in the daytime and fermentation at night is repeated two or three times. The partly dried mustard is then divided into pieces and packed tightly into glass bottles or earthenware pots or plastic containers, before being sealed, and placed upside down for maturation for 3 months. The resulting product is called *fu-tsai*. Fu-tsai and suan-tsai are eaten as a soup, fried with shredded meat, or stewed with meat. LAB isolated from fu-tsai include *P. pentosaceus* and *Tetragenococcus halophilus* (Chen et al. 2006), *Lactobacillus farciminis*, *Leuc. mesenteroides*, *Leuc. pseudomesenteroides*, *Weisella cibaria*, and *Weisella paramesenteroides* (Chao et al. 2009).

### 4.2.9 Jeruk

*Jeruk* is an ethnic fermented vegetable from Malaysia, which is prepared from common fruits and vegetables (Merican 1996). Pickled vegetables are prepared like fresh vegetables; pickled fruit is eaten as a relish, especially by children and expectant mothers, because of the sweet-sour flavor. Species of *Leuconostoc*, *Lactobacillus*, *Pediococcus*, and *Enterococcus* are present in jeruk (Merican 1996).

### 4.2.10 Pak-gard-dong

*Pak-gard-dong* is an ethnic fermented vegetable product of Thailand prepared from mustard leaves (Boon-Long 1986). Black mustard leaves are collected (defective leaves are removed), washed, and wilted in the sun, and 2.5% salt is added to the wilted leaves which are then packed into a container and left for 12 hours. After removing the water, 3% sugar is added and fermented at room temperature for 3 to 5 days. *P. pentosaceus*, *Lb. brevis*, and *Lb. plantarum* as the major LAB involved in the fermentation of pak-gard-dong (Mingmuang 1974).

### 4.2.11 Pak-sian-dong

*Pak-sian-dong* is an ethnic fermented leafy vegetable product of Thailand (Dhavises 1972). It is prepared from the leaves of *pak-sian* (*Gynandropis pentaphylla* DC). Fresh vegetables are thoroughly cleaned with water and then spread out in the air or under the sun to dehydrate until the sample is distinctly flaccid. It is then mixed with water, salt, and sugar and kept in a tightly covered container for 2 to 3 days. *Leuc. mesenteroides*, *Lb. fermentum*, *Lb. buchneri*, *Lb. plantarum*, *Lb. brevis*, and *P. pentosaceus* are present in pak-sian-dong (Dhavises 1972).

### 4.2.12 Sayur Asin

*Sayur asin* is an ethnic, fermented mustard cabbage product from Indonesia (Puspito and Fleet 1985). Mustard cabbage leaves are wilted and rubbed or squeezed with 2.5% to 5% salt. Liquid from boiled rice is added to provide fermentable carbohydrate to assure that sufficient acid is produced during fermentation. Fermentation is initiated by *Leuc. mesenteroides* and *Lactobacillus confusus* and later dominated by *Lb. plantarum* and *P. pentosaceus* (Puspito and Fleet 1985).

## 4.3 Fermented Bamboo Shoots

### 4.3.1 Mesu

*Mesu* is an ethnic fermented bamboo shoot product of India, Nepal, and Bhutan. Young shoots of species of bamboo such as *Dendrocalamus sikkimensis*, *Dendrocalamus hamiltonii*, and *Bambusa tulda* are defoliated, finely chopped, and pressed tightly into a hollow, green bamboo stem. Any openings in the vessel are covered tightly with bamboo leaves and it is left to ferment under natural anaerobic conditions for 7 to 15 days. Mesu is eaten as a pickle. *Lb. plantarum*, *Lb. brevis*, *Lactobacillus curvatus*, *Leuconostoc citreum*, and *P. pentosaceus* have been isolated from mesu (Tamang and Sarkar 1996; Tamang et al. 2008).

### 4.3.2 Soibum

*Soibum* is an ethnic fermented bamboo shoot dish from India. Thin slices of young bamboo shoots are packed into this chamber, the upper surface is sealed with a polytethylene sheet, and weights are then put on top for proper pressing. The bottom of the chamber is perforated for draining any acidic juices before being left for 6 to 12 months for fermentation. After fermentation, soibum can be stored for 10 to 12 months. In Manipur, India, different dishes are prepared from soibum such as *ironba*, *athongba*, *kangou*, and *chagempomba* (Tamang 2010a). *Lb. plantarum*, *Lb. brevis*, *Leuc. fallax*, *Leuc. mesenteroides*, *Leuc. lactis*, and *Enterococcus durans* are present in soibum (Tamang et al. 2008). *Bacillus subtilis*, *Bacillus licheniformis*, *B. coagulans*, and *Micrococcus luteus* were also isolated from soibum (Sarangthem and Singh 2003). An increase in free amino acids has been observed during the fermentation of soibum (Giri and Janmejay 2000).

### 4.3.3 Soidon

*Soidon* is the fermented tip of mature bamboo shoot products commonly consumed in Manipur, India. The outer casings and lower portions of mature bamboo shoots are removed; entire tips are submerged in water in an earthen pot. Sour liquid from a previous batch is added as a starter in a 1:1 dilution. This mixture is covered and fermented for 3 to 7 days at room temperature. Leaves of *Garcinia pedunculata* Roxb., locally called *heibung*, may be added in the fermenting vessel during fermentation to enhance the flavor of soidon. After fermentation, soidon is removed from the pot and can be stored in a closed container at room temperature for 1 year. It is consumed as a curry as well as a pickle with steamed rice. *Lb. brevis*, *Leuc. fallax*, and *Leuc. lactis* have been isolated from soidon (Tamang et al. 2008).

### 4.3.4 Ekung

*Ekung* is an ethnic fermented bamboo shoot product of India, prepared in Arunachal Pradesh. A pit approximately 3 to 4 ft. is dug in the forest, bamboo baskets are laid into the pit and lined with leaves, and pieces of chopped bamboo shoots are put into the basket. When the basket is full, it is covered with leaves and then sealed. Heavy stones are used to weight and drain excess water from the bamboo shoots, which are then fermented for 1 to 3 months. Ekung can be kept for a year in an airtight container at room temperature. It is consumed raw or cooked with meat, fish, or vegetables. *Lb. plantarum*, *Lb. brevis*, *Lb. casei*, and *T. halophilus* have been isolated from ekung (Tamang and Tamang 2009).

### 4.3.5 Eup

*Eup* is a dry, fermented tender bamboo shoot food commonly prepared and consumed by different tribes from India. Bamboo shoots are chopped into small pieces and fermented in a similar manner to ekung. Fermentation is completed within 1 to 3 months. After fermentation, the product, now called *eup*, is again cut into smaller pieces and then dried in the sun for 5 to 10 days until its color changes from whitish

to chocolate brown. Eup is consumed as a side dish with steamed rice, meat, fish, or vegetables. *Lb. plantarum* and *Lb. fermentum* have been isolated from eup (Tamang and Tamang 2009).

### 4.3.6 Hirring

*Hirring* is the fermented topmost portion of the whole bamboo shoot product, commonly prepared in Arunachal Pradesh, India. The outer leaf sheaths of tender bamboo shoots are removed and the topmost tender edible portions are either cut longitudinally into two to three pieces or whole shoots are flattened by crushing before being put into bamboo baskets lined with leaves. The baskets are placed into the pit, covered with leaves, sealed and weighted down with heavy stones, and fermented for 1 to 3 months. Baskets are taken out from the pits after fermentation upon which time hirring is ready for consumption. Hirring can be kept for 2 to 3 months at room temperature. It is consumed as a side dish mixed with vegetables, meat, and fish along with steamed rice. *Lb. plantarum* and *Lc. lactis* are the functional LAB in hirring (Tamang and Tamang 2009).

### 4.3.7 Naw-mai-dong

*Naw-mai-dong* is an ethnic fermented bamboo shoot product of Thailand (Dhavises 1972). During preparation, young bamboo shoots are harvested, woody and defective portions are removed from the shoots by trimming. After washing, shoots are sliced and mixed with salt at 2% level. The bamboo shoots are boiled in water and the bitter liquor is discarded. These are then packed into earthen jars, covered with a plastic sheet, and weighted on top. Fermentation is complete in 3 to 4 weeks at room temperature. *Leuc. mesenteroides*, *Lb. fermentum*, *Lb. buchneri*, *Lb. brevis*, and *P. pentosaceus* are present in naw-mai-dong (Dhavises 1972; Phithakpol et al. 1995).

## 4.4 Fermented Legumes

### 4.4.1 Kinema

*Kinema* is an ethnic fermented soybean food from India, Nepal, and Bhutan, and is one of the oldest cultural foods from Asia (Tamang 2010a). Daily per capita consumption of kinema in Sikkim, India is 2.3 g (Tamang et al. 2007a). Soybeans are washed, soaked overnight, and placed into containers with fresh water and boiled for 2 to 3 hours until soft. Excess water is drained off and the cooked soybean seeds are placed into a wooden mortar and cracked lightly with a wooden pestle to split the cotyledons. This practice of cracking cooked soybean seeds has been observed only in kinema production, unlike natto and chungkokjang, probably to increase the surface area for speedy fermentation by aerobic spore-forming bacteria (Tamang 2001). Approximately 1% firewood ash is added directly to the cooked soybeans and mixed thoroughly to maintain the alkaline condition of the product. Soybean grits are placed in a bamboo basket lined with locally grown fresh fern (*Glaphylopteriolopsis erubescens*) or ficus (fig plant) and banana leaves. The basket is covered in a jute bag and left to ferment naturally at ambient temperatures (25–40°C) for 1 to 3 days above an earthen oven kitchen. During the summer, the required fermentation time may be 1 to 2 days, whereas in the winter, 2 to 3 days might be needed. Freshly prepared kinema remains viable for 2 to 3 days in the summer and for a maximum of 1 week in winter without refrigeration. Shelf life may be prolonged by drying in the sun for 2 to 3 days. Dried kinema can be stored for several months at room temperature.

A number of *Bacillus* species have been isolated from kinema, including *B. subtilis*, *B. licheniformis*, *Bacillus cereus*, *Bacillus circulans*, *Bacillus thuringiensis*, and *Bacillus sphaericus* (Sarkar et al. 1994, 2002). However, *B. subtilis* is the dominant functional bacterium in kinema (Sarkar and Tamang 1994; Tamang and Nikkuni 1996). Besides bacilli, *E. faecium* and two types of yeasts, *Candida parapsilosis* and *Geotrichum candidum*, were also isolated from kinema samples (Sarkar et al. 1994). It has been observed that rich microbial diversity from various sources, particularly the soybean, equipment, and

leaves as wrapping materials, harness microbiota for the spontaneous fermentation of kinema (Tamang 2003). With the decrease in protein nitrogen content, the nonprotein and soluble nitrogen contents increase during kinema fermentation (Sarkar and Tamang 1995). Tamang and Nikkuni (1998) found a significant increase in the relative viscosity of kinema during maturation at 5°C and 10°C. Keeping freshly prepared kinema below 10°C for 1 day stabilizes the quality of the product by preventing further biological activity of microorganisms and showing improved stickiness, which is a very important sensory property of kinema (Tamang and Nikkuni 1998). Organoleptically, the monoculture fermentation of soybeans by *B. subtilis* MTCC 2756 produces the best kinema because of a pleasant nutty flavor and highly sticky texture, minimizing the conventional fermentation time, maintaining better hygienic conditions, consistency, and increasing the levels of soluble protein (Tamang 1999).

Instead of discarding the soybean extract after autoclaving, an inexpensive soybean extract broth can be prepared, after adjusting the pH to 7, as a medium for the enrichment of *B. subtilis* spores (Tamang 1999). Moreover, the nutrient broth, conventionally used for the enrichment of *B. subtilis* spores, is composed of expensive beef extract, which is not acceptable to most of the Hindi population in the Himalayas. Kinema prepared by using the *B. subtilis* KK2:B10 strain, which is harvested from soybean extract broth, is dried in an oven at 70°C for 10 hours and ground aseptically to make a pulverized starter. Instead of *B. subtilis*, 1% of the pulverized starter is added aseptically to the autoclaved soybeans and fermented to obtain kinema. Consumers' preference trials show that kinema prepared by using pulverized starter under optimized conditions is more acceptable than kinema bought from local market (Tamang 1999). Water-soluble nitrogen and formol nitrogen contents are higher in kinema prepared by using the pulverized starter compared with store-bought kinema (Tamang 1999). Increased water-soluble nitrogen levels in kinema helps in digestibility, and high amounts of formol nitrogen, which contain free amino acid supplements, impart a better taste to kinema (Nikkuni et al. 1995). The application of ready-to-use pulverized starter seems appropriate in kinema production for marginal kinema producers in the Himalayas because it is cost-effective and easy to handle (Tamang 2010a).

Kinema has many health-promoting benefits, including having antioxidant activity, increased protein digestibility, essential amino acids, vitamin B complex, low cholesterol content, etc. (Tamang 2010a); therefore, kinema can be considered as a functional food. Kinema is the cheapest source of plant protein compared with milk and animal products on the basis of protein cost per kilogram. It contains all the essential amino acids (Sarkar et al. 1997), and is rich in linoleic acid, an essential fatty acid (Sarkar et al. 1996). Total amino acids, free amino acids, and mineral contents are increased during kinema fermentation (Sarkar and Tamang 1995; Nikkuni et al. 1995; Tamang and Nikkuni 1998). Phytosterols (cholesterol-lowering effect) are increased during kinema fermentation (Sarkar et al. 1996). Riboflavin and niacin levels increase in kinema during fermentation (Sarkar et al. 1998). Kinema has antioxidant activities (Tamang et al. 2009b). Because it contains large amounts of Group B saponins, kinema reportedly has health-promoting benefits (Omizu et al. 2011).

Many kinema-like sticky bacilli–fermented soybeans are consumed by different ethnic communities living in the northeastern part of India bordering Bhutan, China, and Myanmar, which include *hawaijar* in Manipur, *bekang* in Mizoram, *peruyaan* in Arunachal Pradesh, *aakhone* in Nagaland, and *tungrymbai* in Meghalaya (Tamang et al. 2009b).

#### 4.4.1.1 KNT Triangle Hypothesis

Nonsalted fermented soybean foods are concentrated in a triangle with three vertices: Japan (natto), India and Nepal (kinema), and Indonesia (tempe). Nakao (1972) named this the *natto triangle* and included both bacilli and mold-fermented soybean products, including tempe, and extended the triangle up to Indonesia. Tamang (2010a) renamed this hypothetical triangle the *kinema-natto-thua nao triangle* (KNT triangle), and included only nonsalty, bacilli-fermented soybean foods with three vertices in India and Nepal (kinema), Thailand (thua nao), and Japan (natto). Within the proposed triangle-bound countries, many fermented sticky, nonsalty soybean foods were consumed by different ethnic groups of people such as kinema (India, Nepal, and Bhutan), natto (Japan), tungrymbai, bekang, hawaijar, aakhone, and peruyaan (India), thua nao (Thailand), chungkokjang (Korea), pepok (Myanmar), and sieng (Cambodia and Laos). Beyond this hypothetical KNT triangle, there is no report of kinema-like

products with sticky and ammonia-flavored fermented soybean foods and the proposed KNT triangle does not include salted, nonsticky, and non–bacilli-fermented soybean products such as tempe, miso, sufu, soy sauce, etc. (Tamang 2010a). Although the method of production and culinary practices vary from product to product, all bacilli-fermented Asian soybean foods have a characteristic stickiness and typical flavor. Hara et al. (1995) reported that the plasmid of *B. subtilis* (*natto*) strain resembles that of *B. subtilis* isolated from thua nao and kinema. The phylogenetic relationships among bacilli isolated from kinema (India), chungkokjang (Korea), natto (Japan), and similar fermented sticky soybean foods from Asia reveal that all bacilli strains belonged to *B. subtilis* (Tamang et al. 2002). This suggests that *B. subtilis* strains responsible for the fermentation of sticky soybean food in Asia might have originated from the same stock. Another theory was proposed in which nonsalted fermented soybean foods originated in Yunnan Province of China, which was the center of the hypothetical triangle (Nagai and Tamang 2010).

### 4.4.2 Natto

*Natto* is an ethnic fermented soybean food from Japan, similar to kinema. In the traditional method of natto preparation, soybeans are soaked in water overnight, boiled, water is discarded, and the boiled beans are wrapped with tied rice straws which have been soaked in boiling water to sterilize the microorganisms, other than the heat-tolerant spores of *B. subtilis* (*natto*), which inhabit the surface of straws (Ohta 1986). A modern method to prepare natto is based on the classical method. After boiling, the soybeans are sprayed with a suspension of spores of *B. subtilis* (*natto*) and weighed out by 30 to 100 g in polystyrene paper packages instead of wrapping in rice straws. The packages are transferred into incubators. After 16 hours at approximately 40°C, the packages are cooled for 6 to 8 hours for maturation. Natto is eaten directly with boiled rice, without frying or cooking.

*Bacillus natto* was isolated from homemade natto by Sawamura (1906). The bacterium is different from *B. subtilis* at the points of biotin requirement, production of polyglutamate, possession of 5.7 and 60 kb plasmids (Hara et al. 1983; Nagai et al. 1997), and insertion sequences (Nagai et al. 2000; Kimura and Itoh 2007). *B. subtilis* (*natto*) produces nattokinase, which has a high fibrinolytic activity equal to those of urokinase and plasmin (Sumi et al. 1987). Actually, capsulated nattokinase showed a significant enhancement of fibrinolytic activity in plasma after being given to adults (Sumi et al. 1990). Gly m Bd 30K of raw soybeans was degraded by *B. subtilis* (*natto*) during fermentation (Yamanishi et al. 1995). Therefore, natto is a suitable soybean food for patients allergic to raw soybeans. Pyrazines are found to be the major flavor components contributing to the characteristic natto flavor (Sugawara et al. 1985).

### 4.4.3 Thua Nao

*Thua nao* is an ethnic fermented, nonsalty soybean food from Thailand. It is generally available as a dried paste, and is used as a flavoring agent in vegetable dishes. Dry, whole soybeans are washed, boiled for 3 to 4 hours, and the cooked beans are transferred to a bamboo basket lined with banana leaves. The basket is covered with banana leaves, left at room temperature for 3 to 4 days to undergo natural fermentation (Sundhagul et al. 1972). After fermentation, thua nao is mashed lightly into a paste and salt, garlic, onion, and red pepper are added. The resulting paste is wrapped in banana leaves and cooked by steaming before eating. Thua nao is used as a seasoning and as an ingredient in soups, curry, and stir-fried vegetables (Okada 2008). *B. subtilis* is responsible for the fermentation of thua nao (Sundhagul et al. 1972). *B. subtilis* produces protease, amylase, subtilisin nattokinase, and γ-polyglutamic acid (PGA) in thua nao (Inatsu et al. 2006). Visessanguan et al. (2005) reported that *B. subtilis*–inoculated thua nao showed an increased proteolysis of soybean. Enzyme γ-glutamyl hydrolase (28 kDa) purified from thua nao degraded PGA to a hydrolysate of only approximately 20 kDa (with D-glutamic and L-glutamic acid in a ratio of 70:30), suggesting that the enzyme cleaves the γ-glutamyl linkage between L- and L-glutamic acid of PGA (Chunhachart et al. 2006). PGA-producing *Bacillus* strains isolated from thua nao, including *B. subtilis* IFO 3022, does not require biotin for growth (Hara et al. 1986).

### 4.4.4 Chungkokjang

*Chungkokjang* (or *jeonkukjang*, *cheonggukjang*) is an ethnic fermented soybean food from Korea. Cooked soybeans covered with matting made of straws are put on an ondol (Korean under-floor heating). After 3 days of fermentation, the soybeans are broken, mixed with soybean powder, ground with salt and dried in the sun. In the modern method for preparation of chungkokjang, a starter of *Bacillus* is used (Lee 2008). It is eaten as soup. *B. subitilis* isolated from chungkokjang produce viscous polyglutamate and fibrinolytic activity (Lee et al. 1991). *B. licheniformis* B1, which was isolated from soil in Korea, is known to produce chungkokjang with a good quality (Lee et al. 1999; Choy 2007). Super-high molecular weight PGA has been reported to be synthesized by *B. subtilis* subsp. *chungkokjang*, isolated from chungkokjang (Park et al. 2005). An increase in total phenol content has also been reported in chungkokjang (Shon et al. 2007). *Bacillus megaterium* SMY-212 is a suitable fermenting strain to promote the antioxidant and free-radical scavenging activities in chungkokjang (Shon et al. 2007). Fibrinolytic enzyme purified from *Bacillus* sp. strain CK 11-4 shows thermophillic, hydrophilic, and strong fibrinolytic activity (Kim et al. 1996).

### 4.4.5 Pepok

*Pepok* is an ethnic, fermented soybean food from northern Myanmar (Tanaka 2008a). Soybeans are soaked in water overnight, dewatered, boiled, and wrapped in leaves. After fermentation for 2 to 4 days, fermented beans are mashed up with salt and hot pepper, rolled out into disks, and dried under the sun. Pepok is used as a seasoning or eaten after roasting.

### 4.4.6 Sieng

*Sieng* is a traditional fermented soybean food from Cambodia (Tanaka 2008b). After boiling, soybeans are spread on bamboo baskets and fermented naturally by bacteria adhering to the baskets or suspended in the atmosphere. The soybeans are soaked in saltwater for 5 to 7 days immediately after a 2-day fermentation. Tree sap or enzymes are occasionally added to the saltwater. Sieng is used as a seasoning with salt and spices.

### 4.4.7 Tempe

*Tempe* is an ethnic, mold-fermented soybean food from Indonesia. Soybeans are soaked in water, where the pH of the soybeans is lowered by LAB inhabiting the water (Nagai and Tamang 2010). After being dehulled and drained, the soybeans are inoculated with tempe starter, locally called *usar* (*Rhizopus* spores developed on hibiscus leaves) or *ragi tempe* (*Rhizopus* inoculated on starch pulp). The inoculated soybeans are packed in leaves of banana or, recently, plastic bags, and fermented in 30°C for 24 hours. In modern procedures, the acidification process by LAB is replaced by the addition of organic acid (lactic acid, acetic acid, or vinegar or malic acid). Pure culture of *Rhizopus* starter is used in some tempe factories. Tempe is fried and is eaten as a snack.

*Rhizopus microsporus* variety *oligosporus* is a major fungus for the fermentation of tempe, although some bacteria were isolated in natural tempe (Nagai and Tamang 2010). *Klebsiella pneumoniae*, *K. pneumoniae* subsp. *ozaenae*, *Enterobacter cloacae*, and Gram-positive bacteria were also isolated as vitamin $B_{12}$–producing bacteria in tempe (Okada et al. 1985). In homemade tempe in Indonesia, the second most important microorganisms are LAB. The role of the bacteria is in lowering the pH of soybeans, both to prevent contaminated bacteria from growing dominantly and to provide *R. oligosporus* with suitable environments to grow. *Lb. plantarum* and *Lb. lactis* were isolated from water in which soybeans were soaked. Tempe possesses several functional properties such as thrombolytic activity, contains γ-amino butyric acid that retards the elevation of blood pressure, contains dietary fiber, saponins, isoflavones, and superoxide dismutase which eliminates active oxygen, and has an anticarcinogenic effect (Sumi and Okamoto 2003; Aoki et al. 2003).

### 4.4.8 Douchi

*Douchi* is an ethnic fermented soybean product of China. Four types of douchi are produced in China: *Mucor*-fermented douchi, *Aspergillus*-fermented douchi, *Rhizopus*-fermented douchi, and *Bacillus*-fermented douchi. Among them, *Aspergillus*-type douchi is the earliest known, and has been the most popular type in China (Bao 1985). Douchi is prepared from soybeans by pretreatment in a two-step fermentation process (primary and secondary fermentation) as described by Kang (2001). Soybeans are soaked in water and boiled for approximately 1 hour, but for bacterial-type douchi, the beans only need to be boiled for 30 to 40 minutes. The second step is *qu*-making, in which the boiled beans are inoculated with *A. oryzae* (0.3%) or *Mucor* strain spores (0.5%), or simply incubated at high temperature (>25°C) for 3 to 4 days to harvest matured *qu*. In *Aspergillus*-type douchi preparations, koji is washed with water to remove the spores, mycelium, and part of the enzymes to avoid an astringent flavor in the final product (Zhang et al. 2007). Then, 18% (w/w, soybean base) salt, a little sugar, and flavoring such as capsicum paste are mixed with *qu* to obtain a desirable flavor. The mixture is packed into jars and sealed with plastic film. The *Aspergillus*-type douchi is fermented at 30°C to 35°C for 7 to 40 days, whereas *Mucor*-type douchi is fermented at approximately 20°C for 10 to 12 months. Douchi is consumed as a soup or side dish.

The presence of two biogenic amines, that is, cadaverine and putrescine, leads to histamine toxicity in douchi by inhibiting histamine-metabolizing enzymes such as diamine oxidase and histamine methyltransferase (Arnold and Brown 1978; Lehane and Olley 2000). Douchi produces angiotensin I–converting enzyme inhibitors, which lower the blood pressure (Zhang et al. 2006). It also shows antioxidative activity (Wang et al. 2007).

### 4.4.9 Sufu

*Sufu* is an ethnic fermented soybean food from China and Taiwan. It is a cheese-like product with a spreadable creamy consistency and a strong flavor (Han et al. 2001a). Soybeans are washed, soaked overnight, ground into a slurry, and pressed to obtain soymilk. It is then salted to coagulate, the excess water is removed by pressing with stones or wooden planks, and finally, a soft and firm cake-like *tofu* results (Steinkraus 1996). In the next step, *Pehtze* (*pizi*) is prepared from fresh bean curd overgrown with mold mycelia by natural fermentation. Cubes of *tofu* are placed in wooden trays made up of loosely woven bamboo strips and surrounded with straw for natural inoculation and fermentation at a temperature of 15°C to 20°C for 5 to 15 days. The prepared pehtze has white or light yellow-white mycelium for an attractive appearance. It is then placed into a big earthen jar for salting, in which salt is spread between the layers of pehtze for 6 to 12 days. Afterward, the pehtze is removed from the jar, washed, and salted. Various dressing mixtures are then added for different types of sufu. The most common dressing mixture used consists of *angkak*, alcoholic beverage, salt, sugar, bean paste, and spices and sometimes even essence for flavor. For ripening, alternate layers of pehtze and dressing mixture are packed into jars in a 2:1 ratio. The mouth of the jar is wrapped with sheath leaves of bamboo and sealed with clay and aged for 6 months for further maturation. Three types of sufu—red, white, and yellow are prepared in Taiwan (Yuan 1994). Sufu is consumed as a side dish.

Pure culture starters consisting mainly of molds—mucoraceae (*Actinomucor*, *Mucor*, and *Rhizopus*) or bacteria—*Micrococcus* and *Bacillus* spp. are used for the production of sufu. Most sufu contains considerable levels of antimicrobial NaCl (5–15%) and ethanol (1–7%) that could prevent the survival and growth of pathogens; it is also known that the endospore-forming rods such as *Bacillus* spp. and *Clostridium* spp. vary greatly in their salt tolerance (Brewer 2000). Chou and Hwan (1994) reported that the addition of ethanol to the brine solution for aging resulted in free fatty acids in the sufu product. *Actinomucor repens*, *Actinomucor taiwanensis*, *Mucor circinelloides*, *Mucor hiemalis*, *Mucor racemosus*, and *R. microsporus* variety *microsporus* have been isolated from starter cultures used in commercial pehtze fermentation for sufu production (Han et al. 2001b). The diversity of LAB was reported in fermented brines used to ferment *tofu* into sufu, which included *Enterococcus hermanniensis*, *Lactobacillus agilis*, *Lb. brevis*, *Lb. buchneri*, *Lactobacillus crispatus*, *Lb. curvatus*, *Lactobacillus*

*delbrueckii*, *Lactobacillus farciminis*, *Lactobacillus fermentum*, *Lactobacillus pantheris*, *Lactobacillus salivarius*, *Lactobacillus vaccinostercus*, *Lc. lactis* subsp. *lactis*, *Lc. lactis* subsp. *cremoris*, *Leuc. carnosum*, *Leuc. citreum*, *Leuc. fallax*, *Leuc. lactis*, *Leuc. mesenteroides*, *Leuc. pseudomesenteroides*, *P. acidilactici*, *Streptococcus bovis*, *S. macedonicus*, *W. cibaria*, *Weisella confusa*, *W. paramesenteroides*, and *Weisella soli* (Chao et al. 2008).

### 4.4.10 Miso

*Miso* is a semisolid fermented food made from soybeans, rice, or barley. Salt is mainly used for preparing miso soup in Japan. The original meaning of miso in Japanese is *immature shoyu* (Sugawara 2010). There are various types of miso in Japan: rice miso, barley miso, and soybean miso depending on the kind of koji used. The most popular miso in Japan is rice miso, which is prepared by mixing cooked soybeans with koji (steamed rice on which *A. oryzae* is cultured); salt and a small amount of water is added to control the moisture level (Ebine 1989). Miso koji is made from a single cereal or soybean, that is, steamed rice, barley, or soybean itself, by inoculating with a koji starter of *A. oryzae*. The main product is a red, salty rice miso (*akakei-karakuti-kome* miso), whose typical composition at pH 5.0 is as follows: NaCl content, 12 to 13 g/100 g; total nitrogen, 1.6 to 2.0 g/100 g; total sugar, 13 to 14 g/100 mL; alcohol, approximately 1.0 mL/100 g (Sugawara 2010). The manufacturing process basically consists of three stages: koji-making; mixing of koji, steamed soybean, and salt; and fermentation. In the first process, steamed rice is inoculated with a starter culture of *A. oryzae*. After 40 hours, a fungus grows over the culture mixture, which is called *rice koji*. In the second process, miso is prepared by mixing koji, steamed soybean, salt, and water, and then the halo-tolerant yeast, *Zygosaccharomyces rouxii* or *Candida versatilis* is added to the mixture. Salt is then added to facilitate the fermentation by yeast and LAB, and to preclude any undesirable fermentation. In the third process, the mixture is fermented for a longer period of 3 to 12 months. During this time, starch is changed to lactic acid, alcohol, and carbon dioxide by the conversion of simple sugars from starch as well as by enzymatic hydrolysis of protein to peptides and amino acids by yeast and LAB. Microbial composition in miso is almost the same as that for shoyu; however, the degree of hydrolysis is much lower in miso than in shoyu, and the product is a solid paste. At the same time, various kinds of volatile compounds are formed (Sugawara 2010).

### 4.4.11 Doenjang

*Doenjang* is a naturally fermented soybean paste of Korea similar to Japanese miso (Min and Kim 1990). Chinese *jiang* is believed to be the oldest form of doenjang. During the preparation of doenjang, cooked soybeans are pounded and mashed in a mortar, shaped into balls, wrapped in rice straw, and hung under the rafters until each ball is covered with a white bloom of natural mold. Next, the balls are crushed and mixed with salt and water to form *meju*, sometimes with the addition of sesame seeds or leaves, and placed in an earthenware container of 1- to 10-gallon capacity. The fermentation period generally lasts for 6 months. It is used as a seasoning or consumed as soup. *Leuc. mesenteroides*, *T. halophilus*, *E. faecium*, *B. subtilis* and *B. licheniformis*, *Mucor plumbeus*, *A. oryzae*, and *Debaryomyces hansenii* have been reported from doenjang (Kim et al. 2009). Doenjang has antiobesity and antiatherogenesis properties (Back et al. 2010).

### 4.4.12 Shoyu

*Shoyu* or soy (soya) sauce is a fermented soybean liquid from Japan made from fungal fermentation and is commonly used as a seasoning or condiment in Asian countries, except in the Indian continent and in middle east Asia (Sasaki and Nunomura 2003). There are many types of shoyu in Japan, although the main product is *koikuchi-shoyu*, a deep brown–colored shoyu, whose typical composition at pH 4.7 is as follows: NaCl content, 16.9 g/100 mL; total nitrogen, 1.57 g/100 mL; reducing sugar, 3.0 g/100 mL; alcohol, 2 to 3 mL/100 mL (Mizunuma 1991). The manufacturing process basically consists of three stages: koji-making, brine fermentation, and refining. In the first process, a mixture of steamed soybean

and roasted wheat is inoculated with a starter culture of *A. oryzae* or *A. sojae*. After 3 or 4 days, a fungus, which is called *koji*, grows over the culture mixture. Brine is then added to facilitate the fermentation by the halo-tolerant yeast, *Z. rouxii* and *C. versatilis* and LAB, and to preclude any undesirable fermentation. This fermentation is continued for 6 to 8 months, during which starch is changed to alcohol, lactic acid, and carbon dioxide by the conversion of simple sugars from starch as well as by enzymatic hydrolysis of protein to peptides and amino acids (Sugawara 2010). The two starting materials, soybean and wheat, are generally used in equal amounts in the mixture. Therefore, the average amino acid composition of these two should correspond to that of shoyu if there are no chemical changes to amino acids during the fermentation process to hydrolyze the protein into water-soluble peptides and amino acids. The palatability of shoyu is greatly enhanced by a high concentration (~7.5%) of amino acids and particularly by the presence of glutamic acid (Yamaguchi 1987). During the fermentation process, different types of volatile compounds are formed as fermented products. The refining process includes filtration and pasteurization, the latter involving heating to 70°C to 80°C to deve1op the flavor of shoyu (Sugawara 2010).

### 4.4.13 Tauco

*Tauco* is an ethnic fermented soybean product of Indonesia, similar to miso. It is a yellow-colored saline paste with a meat-like flavor. Tauco is prepared by mold fermentation for 3 to 5 days followed by brine (20%) fermentation for 20 to 30 days. The first stage of preparation consists of inoculating soybean with *R. oligosporus*, *R. oryzae*, and *A. oryzae.* Microorganisms which are active during brine fermentation are *Lb. delbruekii* and *Hansenula* sp. After the second phase of fermentation is completed, the brine is drained; palm sugar (25%) is added and the mixture is cooked and stored for 24 hours or placed directly into bottles. Tauco is available in viscous liquid form. It is also available in semisolid form which is obtained by sun-drying the liquid product to a final moisture content of 25%. Tauco is used as a flavoring agent. Microorganisms present in tauco are *A. oryzae*, *R. oligosporus*, *R. oryzae*, *Hansenula* sp., *Zygosaccharomyces soyae*, and *Lb. delbruckii* (Winarno et al. 1973).

### 4.4.14 Maseura

*Maseura* is an ethnic fermented black or green gram product of India and Nepal (Tamang 2010a). Dry seeds of black or green gram are cleaned, washed, and soaked overnight. Soaked seeds are split by pressing through the hands and the hulls are blown off, the beans are ground into a thick paste, water is added until the paste becomes sticky, and is hand-molded into small balls or cones. If rice bean is used, then boiled potato, squash, or yam is mixed with the paste to make it sticky. The mixture is placed on a bamboo mat and left for natural fermentation for 2 to 3 days, and then sun-dried for 3 to 5 days depending on the weather conditions. Maseura can be stored in a dry container at room temperature for a year or more (Dahal et al. 2003). It is commonly used as a condiment or adjunct to vegetables. Species of bacteria present in maseura include *Lb. fermentum*, *Lb. salivarius*, *Pediococcus pantosaceous*, *P. acidilactici*, *E. durans*, *B. subtilis*, *B. mycoides*, *B. pumilus*, and *B. laterosporous*; yeasts include *Saccharomyces cerevisiae*, *Pichia burtonii*, *Candida castellii*, and *C. versatilis*; and molds include species of *Cladosporium*, *Penicillium*, and *Aspergillus niger* (Dahal et at. 2003; Chettri and Tamang 2008). An increase in soluble protein, amino nitrogen, nonprotein nitrogen, thiamine, and riboflavin have been observed in maseura (Dahal et al. 2003).

### 4.4.15 Wari

*Wari* is an ethnic fermented black gram product of India and Pakistan, similar to maseura. It is a dry, hollow, brittle, spicy, and friable ball of 3 to 8 cm in diameter and 15 to 40 g in weight (Batra 1986). Seeds of black gram are soaked in water for 6 to 12 hours, dewatered, dehulled, and ground into a smooth, mucilaginous paste. The dough is mixed with inoculum from a previous batch, salt and spices including asafetida, caraway, cardamom, clove, fenugreek, ginger, and red pepper. The mixture is allowed to ferment at room temperature for 1 to 3 days and hand-molded into balls, and dried for 2 to 8 days on bamboo

or palm mats (Batra and Millner 1976). Wari is used as a condiment and is mixed with vegetables as a side dish. Yeasts species of *Candida krusei*, *C. vartiovaarai*, *Kluyveromyces marxianus*, *Trichosporon beigelii*, *Hansenula anomala*, *S. cerevisiae*, *Leuc. mesenteroides*, and *Lb. fermentum* have been isolated from wari (Batra and Millner 1974, 1976; Batra 1981, 1986; Sandhu and Soni 1989). An increase in total acids, soluble nitrogen, free amino acids, thiamine, riboflavin, and cyanocobalamine has been observed during wari fermentation (Soni and Sandhu 1990).

### 4.4.16 Dhokla and Khaman

*Dhokla* is an ethnic fermented spongy-textured product of India prepared from Bengal gram and rice product, and is similar to idli except that dehulled Bengal gram dhal is used in place of black gram. *Khaman*, similar to dhokla, is also an ethnic fermented spongy-textured product of Gujarat in India and is made solely from the seeds of Bengal gram. Dry seeds of Bengal gram and white polished rice are washed, soaked, and ground. Salt and water are then added to make a thick paste. The slurries are left for natural fermentation in a warm place (30–32°C) for 8 to 10 hours. Once the product develops a spongy texture, the dhokla is ready. It is steamed for 10 to 15 minutes and is eaten as a snack. *Leuc. mesenteroides* and *E. faecalis* are essential and responsible for leavening the batter and acid-producing microorganisms during dhokla fermentation (Joshi et al. 1989). Acetoin and volatile fatty acids, at their optimum concentrations, impart a characteristic flavor to dhokla (Joshi et al. 1989).

### 4.4.17 Oncom

*Oncom* is an ethnic fermented peanut or groundnut cake-like product of Indonesia. Peanut or groundnut seeds are soaked, and press-cakes, as the major ingredients, are cooked along with solid wastes of tapioca and tahu, using a mixed culture of microorganisms with *Rhizopus* or *Neurospora* species (Winarno et al. 1973). Traditionally, two kinds of oncom are produced in Indonesia, *oncom hitam* (black oncom) and *oncom merah* (orange oncom). When fermentation is carried out by strains of mold belonging to the genus *Neurospora*, the product is called red oncom; if *R. oligosporus* is used, the resulting product is called black oncom. *Neurospora intermedia*, *Neurospora crassa*, and *Neurospora sitophila* have been reported from oncom (Ho 1986).

## 4.5 Fermented Cereals

### 4.5.1 Idli

*Idli* is an ethnic fermented rice/black gram food from India and Sri Lanka. It is an acid-leavened and steamed cake made by natural fermentation of a thick batter made from coarsely ground rice and dehulled black gram. Idli cakes are soft, moist, and spongy, have a sour flavor, and are eaten for breakfast in South India. The predominant bacteria responsible for souring as well as the production of gas in idli fermentation is *Leuc. mesenteroides* (Mukherjee et al. 1965). Yeasts have also been reported in idli, mostly *S. cerevisiae*, *D. hansenii*, *H. anomala*, *Torulopsis candida*, and *T. beigelii* (Soni and Sandhu 1989b, 1991; Thyagaraja et al. 1992). Yeasts in idli fermentation contribute to leavening and flavor development and results in enhanced contents of thiamine and riboflavin (Soni and Sandhu 1989a). Idli batter obtained from hotels and restaurants showed yeasts' participation in the leavening process in addition to *Leuc. mesenteroides* (Venkatasubbaiah et al. 1984). Idli makes an important contribution to the diet as a source of protein, calories, and B complex vitamins compared with raw unfermented ingredients (Steinkraus et al. 1967; Reddy et al. 1981).

### 4.5.2 Dosa

*Dosa* is also an ethnic fermented rice/black gram food from India and Sri Lanka. It is a light, shallow-fried, thin crisp pancake, made from finely grounded rice and dehulled black gram (Steinkraus 1983).

*Dosa* batter is very similar to idli batter, except that both the rice and black gram are finely ground. Bacteria alone or in combination with yeasts were found to be responsible for the fermentation of dosa and, ordinarily, the microorganisms developed during the initial soak and fermentation are sufficient to bring about fermentation (Soni et al. 1986). Overall increase in batter volume, microbial load, total nitrogen, soluble proteins, reducing sugar, and decrease of pH have been noted after 30 hours of fermentation of dosa (Soni et al. 1985). The combination of *S. cerevisiae* and natural bacterial flora was found to be the best microbial factor for standardizing the dosa fermentation (Soni and Sandhu 1989a).

### 4.5.3 Selroti

*Selroti* is an ethnic fermented rice food from the Himalayan regions of India, Nepal, and Bhutan (Yonzan and Tamang 2009). Rice is soaked overnight, pounded into coarse powder, and larger particles of pounded rice flour are separated from the rest by winnowing in a bamboo tray. Then, the rice flour is mixed with nearly 25% refined wheat flour, 25% sugar, 10% butter or fresh cream, and 2.5% spices/condiments containing large cardamom, cloves, fennel, nutmeg, and cinnamon are added to the rice flour and mixed thoroughly. Milk (boiled/unboiled) or water is added, kneaded into a soft dough, and finally into an easy-flowing batter. The batter is left to ferment naturally at ambient temperature (20–28°C) for 2 to 4 hours during summer and at 10°C to 18°C for 6 to 8 hours during winter. Oil is heated in a cast iron frying pan, the fermented batter is squeezed by hand, deposited as continuous rings onto hot edible oil, fried until golden brown, and drained out from the hot oil with a poker. Selroti is served as a confectionary bread. It can be served hot or cold. *Leuc. mesenteroides*, *E. faecium*, *P. pentosaceus* and *Lb. curvatus*, *S. cerevisiae*, *Saccharomyces kluyveri*, *D. hansenii*, *P. burtonii*, and *Z. rouxii* have been isolated from selroti (Yonzan and Tamang 2010). Yeasts in selroti show high activity of phosphatase, advocating their phytic acid–degrading abilities in the product (Yonzan and Tamang 2010).

### 4.5.4 Rabadi

*Rabadi* is an ethnic fermented cereal-based food from India. It is prepared by mixing flour from wheat, barley, pearl millet, or maize with buttermilk in an earthen or metallic vessel, and then allowing the mixture to ferment in the open sun for 5 to 6 hours in the hot summer. After fermentation, it is boiled, salted to taste, and consumed (Gupta et al. 1992a). *P. acidilactici*, *Bacillus* sp., and *Micrococcus* sp. were reported from rabadi (Ramakrishnan 1979). Phytic acid content decreased during rabadi fermentation (Mahajan and Chauhan 1987; Gupta et al. 1992b). Single as well as mixed culture fermentation of pearl millet with yeast (*S. cerevisiae* or *S. diastaticus*) and LAB (*Lb. brevis* or *Lb. fermentum*) were developed to prepare rabadi using pearl millet (Khetarpaul and Chauhan 1990a,b). Pearl millet–based rabadi prepared with developed starters has been found to increase the bioavailability of minerals (Khetarpaul and Chauhan 1989), improve starch and protein digestibility (Khetarpaul and Chauhan 1990a), increase total soluble sugar with a decrease in starch (Khetarpaul and Chauhan 1990b), and degrade antinutrients (Khetarpaul and Chauhan 1991).

### 4.5.5 Jalebi

*Jalebi* is one of the most popular sweet dishes of India, Bangladesh, and Nepal. It is a crispy sweet, deep-fried pretzel made from wheat flour, and is eaten as a snack food (Chitale 2000). Jalebi is prepared by mixing wheat flour with *dahi* (curd), adding water, and leaving this mixture overnight at room temperature. The thick leavened batter is squeezed through an embroidered hole (~4 mm in diameter) on a thick and durable cotton cloth, deposited as continuous spirals into hot edible oil, and fried on both sides until golden crisp. After about a minute, these are removed from the fat with a sieved spatula and submerged for several seconds in hot sugar saffron–scented syrup, which saturates their hollow insides, although skill is required to master the uniform shapes of jalebi. Often, rose or *kewda* (*Pandanus tectorius*) water and orange food color are added to the syrup (Ramakrishnan 1979; Batra 1981). The rheological parameters of jalebi batter can be controlled by adjusting the moisture content of the batter system (Chakkaravarthi et al. 2009). It is eaten as a snack when hot. *Lb. fermentum*, *Lb. buchneri*, *Lactobacillus*

*bulgaricus*, *Streptococcus lactis*, *E. faecalis*, *S. thermophilus*, and yeasts *Saccharomyces bayanus*, *S. cerevisiae* and *H. anomala* have been isolated from Jalebi (Batra and Millner 1974, 1976; Soni and Sandhu 1990b).

### 4.5.6 Nan

*Nan* is an ethnic leavened bread of India, Pakistan, and Afghanistan, and is made from wheat flour. Wheat flour is thoroughly mixed with butter, baking powder, *dahi* (curd), milk, salt, sugar, and water are added to make a thick dough. The dough is fermented for 3 to 5 hours at room temperature. Fermented dough is sheeted between the palms of the hand to approximately 2 to 3 mm thickness, slightly wetted, and pasted on the inner wall of the tandoori oven. The baked product, called *nan*, has a typical soft texture and flavor. Nan is baked in a specially designed oven known as a *tandoori* with a temperature range of 300°C to 350°C. It is also baked over live coals or a flame for a short time. Nan is eaten as a staple food with vegetable or *dal* (legume soup), and meats. *S. kluyveri* is the dominant yeast in nan (Batra 1986).

## 4.6 Fermented Tea

### 4.6.1 Miang

*Miang* is an ethnic fermented tea from northern Thailand. Young tea leaves are collected, tied into small bundles, and steamed for 2 hours or more to inactivate the polyphenol oxidases (Phithakpol et al. 1995). After cooling, the leaf bundles are carefully packed in a cement tank lined with banana leaves, and covered with banana leaves or a plastic sheet. The leaves are pressed tightly and weighted down to remove oxygen and thus to discourage the growth of yeasts and aerobic spoilage bacteria (Phithakpol et al. 1995). Fermentation takes approximately 3 or 4 months. Miang is consumed as a snack with salt or with condiments such as roasted coconut or shredded ginger. Miang is traditionally used during religious ceremonies and funerals in Thailand (Sasaki et al. 2007). *Lactobacillus thailandensis*, *Lb. camelliae*, *Lb. plantarum*, *Lb. pentosus*, *Lb. vaccinostercus*, *Lb. pantheris*, *Lb. fermentum*, *Lactobacillus suebicus*, *Pediococcus siamensis*, *Enterococcus casseliflavus*, and *Enterococcus camelliae* are involved in the fermentation of miang production (Tanasupawat et al. 2007; Sukontasing et al. 2007).

### 4.6.2 Puer Tea

*Puer* tea is an ethnic fermented tea from China, mainly produced in Yunnan Province. Fresh leaves are heat-treated to inactivate polyphenol oxidases (Mo et al. 2008). There are two types of puer tea: raw puer tea and cooked puer tea. During the production of raw puer tea, the leaves are simply softened by steaming and compressed into different sizes before the natural fermentation starts. The production of cooked puer tea is a more complex and relatively recent process developed in the early 1970s. In this case, the fermentation is initiated artificially. The dry black leaves are laid out in thick piles in a well-heated room and are sprayed with water and covered with a canvas or tarpaulin for a few weeks. During this fermentation period, the tea polyphenols are more intensively oxidized by the action of microorganisms and environmental oxygen than in the black tea fermentation process (Abe et al. 2008; Mo et al. 2008). The color turns from green to brown or brownish red, and a particular fragrance is produced. Puer tea acquires a characteristic flavor and numerous health-beneficial properties. The aging of puer tea is an essential process allowing the tea's aromatic bouquet to develop while mellowing the tannins and reducing the astringency. *A. niger* was identified as the predominating microorganism; *Aspergillus glaucus*, species of *Penicillium*, and *Rhizopus*, *Blastobotrys adeninivorans*, and *Saccharomyces* were also isolated (Mo et al. 2005; Jeng et al. 2007; Abe et al. 2008). Bacterial strains belonging to species of *Actinoplanes* and *Streptomyces* were also isolated from puer tea (Jeng et al. 2007). Puer tea has hypolipidemic effects

(Sano et al. 1986) and antioxidative properties (Jie et al. 2006). The antimutagenic and antimicrobial activities of puer tea have also been reported (Wu et al. 2007).

### 4.6.3 Fuzhuan Brick Tea

*Fuzhuan* brick tea is an ethnic fermented tea from China. *Aspergillus*, *Penicillium*, and *Eurotium* are the major fungi for fermentation of fuzhuan brick tea (Mo et al. 2008).

### 4.6.4 Kombucha

*Kombucha* is a slightly carbonated tea beverage, consumed worldwide, but historically originated from China (Schillinger et al. 2010). It is typically prepared by fermenting black tea which has been sweetened with sugar. In general, black tea leaves are infused in boiling water sweetened with sucrose (50–150 g/L) for approximately 10 minutes. After removing the tea leaves, the tea is poured into a wide-mouthed clean vessel and is acidified by the addition of vinegar or the so-called tea fungus, which is actually a floating cellulose mat (cellulosic pellicle) formed by a symbiotic association of yeasts and acetic acid bacteria from a previous fermentation. The jar is carefully covered with a clean cloth and the preparation is allowed to incubate at room temperature for 10 to 12 days. The final product is composed of organic acids, vitamins, minerals, and tea components resembling the taste of cider (Greenwalt et al. 2000). The acetic acid bacteria and the yeasts present in kombucha form a powerful symbiosis that is able to inhibit the growth of potential contaminating bacteria (Dufresne and Farnworth 2000). *Acetobacter xylinum* has been shown to be the primary bacterium in the mat, which is able to produce acetic acid and gluconic acid. It also synthesizes the floating cellulose network which is the prerequisite for the close association with the yeasts. *Zygosaccharomyces kombuchaensis*, *Zygosaccharomyces bailii*, *Zygosaccharomyces bisporus*, *Zygosaccharomyces microellipsoides*, *Brettanomyces*, *Saccharomyces*, *Schizosaccharomyces pombe*, *Torulaspora delbrueckii*, *Rhodotorula mucilaginosa*, *Candida stellata*, and *Brettanomyces bruxellensis* have been reported from kombucha (Mayser et al. 1995; Kurtzman et al. 2001; Teoh et al. 2004). Kombucha has gained popularity because of the apparent health benefits resulting from regular consumption. Stimulation of the immune system, digestion and liver function improvement, some detoxification activity and reduction of obesity are some of the health claims reported (Schillinger et al. 2010).

## 4.7 Vinegar

Vinegar has been used as a condiment, preservative, and medicine since ancient times in Asia. Vinegar is prepared from any sugar-containing substrate and hydrolyzes starchy materials through alcoholic fermentation followed by acetic acid fermentation (Yokotsuka 1991). The typical vinegar fermented with koji mold is rice vinegar, which is popular in China, Japan, Thailand, and other oriental countries where rice wine is produced with koji mold. *Acetobacter pasteurianus*, *Acetobacter aceti*, *A. xylinum*, and *Acetobacter polyxygenes* are the dominant bacterium for vinegar fermentation (Entani and Mashai 1985). *Lactobacillus fructivorans*, *Lactobacillus acetotolerans*, and *Moniliella acetobutans* also supplement fermentation (Entani and Mashai 1985). Yeast species involved in the fermentation of vinegar are *Z. bailii*, *Z. rouxii*, *Zygosaccharomyces pseudorouxii*, *Zygosaccharomyces mellis*, *Z. bisporus*, *Zygosaccharomyces lentus*, *Hanseniaspora valbyensis*, *Hanseniaspora osmophila*, *Candida lactis-condensi*, *C. stellata*, *Saccharomycodes ludwigii*, and *S. cerevisiae* (Solieri and Giudici 2008). The fungal denaturing gradient gel electrophoresis profile indicated that the transition from *A. oryzae* to *Saccharomyces* sp. took place at the initial stage of vinegar fermentation during which alcohol production was observed (Haruta et al. 2006). The early stage was characterized by the coexistence of *Saccharomyces* sp. and LAB, and almost all of the LAB denaturing gradient gel electrophoresis bands were replaced by bands derived from *Lactobacillus acetotolerance* and *A. pasteurianus* at the stage during which acetic acid started to accumulate (Haruta et al. 2006).

## 4.8 Nata

*Nata* is the thick white or cream-colored, insoluble gelatinous film of cells and polysaccharides which is a delicacy of the Philippines (Steinkraus 1996). Fermentation is due to *A. xylinum*, which forms on the surface of an acidified medium containing sugar, ethyl alcohol, and other nutrients (Kozaki 1976). Two types of *nata* are well known: *nata de piña*, produced from the juice of pineapple trimmings, and *nata de coco*, produced from coconut water or coconut skimmed milk. It is often eaten with ice cream and in fruit salads. The process of cellulose formation in a nata de coco culture system has been investigated and it has been found that cellulose formation or the consumption of glucose is controlled by the diffusion of atmospheric oxygen (Budhiono et al. 1999).

## 4.9 Amylolytic Mixed Cultures

### 4.9.1 Koji

Koji is a mold culture and is prepared from steamed/cooked cereal in Japan. The term *koji* is Japanese meaning naturally, spontaneously, or artificially molded cereals and beans (Yokotsuka 1991). The Chinese name for koji is *chu*, *shi*, or *qu*. Rice is steamed, cooled on bamboo-made trays, stacked with gaps of approximately 10 cm in between to allow air circulation, inoculated with 0.1% mold spores (locally called *tane-koji*), and incubated at 23°C to 25°C. The increase in temperature due to the growth of mold is kept within the range of 35°C to 45°C by stirring and turning the koji from top to bottom on trays after approximately 20 to 40 hours, normally fermented for 3 days, when mold mycelium has spread throughout the mass, and before sporulation (Lotong 1985). *A. oryzae*, *A. sojae*, *Aspergillus kawachii*, *Aspergillus shirousamii*, and *Aspergillus awamori* have been widely used as starters in the preparation of *koji* in Japan for the production of saké, shoyu, miso, and shochu (Kitamoto 2002; Matsushita et al. 2009). Among these molds, *A. oryzae* is the most important and popular in Japan, and has been used as yellow koji (Suganuma et al. 2007). *A. oryzae* is used for starch saccharification in saké manufacture (Inoue et al. 1992). Because koji is not cultivated in a closed system, it is a mixture of several microorganisms. At an early stage of cultivation, yeast grows on steamed rice grain and, approximately 20 hours after inoculation of seed koji, mold begins to grow. Koji, besides being a saccharifying and diastatic agent, also contributes to the color, flavor, and aroma of the fermented foods that are important for their overall attributes (Kitamoto 2002). Antioxidant activity is observed in koji prepared with *A. awamori* (Lee et al. 2007) and with *Aspergillus candidus* (Yen et al. 2003).

### 4.9.2 Marcha

*Marcha* is an ethnic amylolytic starter to produce fermented beverages and alcoholic drinks in the Himalayan regions of India, Nepal, Bhutan, and Tibet in China (Tamang 2010a). Marcha is a dry, round to flattened, creamy white to dusty white, solid ball–like structure. Glutinous rice is soaked, crushed, ground, mixed with the roots of *Plumbago zeylanica*, the leaves of *Buddleja asiatica*, the flowers of *Vernonia cinerea*, ginger, red dry chili, and 1% to 2% of previously prepared marcha. The mixture is made into a paste by adding water and kneaded into flat cakes of varying sizes and shapes. This is then placed individually on the ceiling-floor, above the kitchen, made up of bamboo strips inlaid with fresh fronds of ferns (*G. erubescens*), covered with dry ferns and jute bags, and left to ferment for 1 to 3 days. A distinct alcoholic and ester aroma and puffy/swollen appearance of marcha indicate the completion of fermentation, and fresh cakes of marcha are sun-dried for 2 to 3 days (Tamang et al. 1996). Marcha is stored at room temperature and can be kept in a dry place for more than a year. Marcha is a Nepali word. The different ethnic communities of the Himalayas call it by their vernacular names, such as *phab* (Tibetan), *poo* (Drukpa), *khesung* (Limboo), *bharama* (Tamang), *bopkha* or *khabed* (Rai), *buth* or *thanbum* (Lepcha), *manapu* (Newar), *hamei* (Meitei), *thiat* (Khasi),

*humao* (Dimasa), *pham* and *ipoh* (Apatani), *bakhar* (people of Himachal Pradesh in India), and *balan* (people of Uttarakhand in India). Marcha-making technology reflects a native skill of ethnic people on subculturing of desirable inocula (microorganisms consisting of filamentous molds, amylolytic and alcohol-producing yeasts, and species of LAB) from a previous batch to a new culture using rice or wheat as a starchy base or medium. This indigenous technique of "microbiology" preserves the functional microorganisms necessary for the fermentation of starchy substrates to alcoholic beverages in the Himalayas (Tamang 2010a).

Species of mycelial molds present in marcha are *M. circinelloides* forma *circinelloides*, *Mucor* sp. close to *M. hiemalis*, *R. chinensis*, and *R. stolonifer* variety *lyococcus* (Tamang et al. 1988). Amylolytic and alcohol-producing yeasts isolated from marcha are *Saccharomycopsis fibuligera*, *Saccharomycopsis capsularis*, *S. cerevisiae*, *S. bayanus*, *Pichia anomala*, *P. burtonii*, and *Candida glabrata* (Tsuyoshi et al. 2005). *Sm. fibuligera* is the most dominant yeast in marcha (Tamang and Sarkar 1995). Saccharifying activities are mostly shown by *Rhizopus* spp. and *Sm. fibuligera*, whereas liquefying activities are shown by *Sm. fibuligera* and *S. cerevisiae* (Thapa and Tamang 2004). Among LAB, *P. pentosaceus*, *Lb. bifermentans*, and *Lb. brevis* are present in marcha (Tamang and Sarkar 1995; Tamang et al. 2007b). LAB imparts flavor, antagonism, and acidification of the substrates in marcha (Tamang et al. 2007a,b). Hesseltine et al. (1988) isolated *Mucor* and *Rhizopus* spp. in marcha samples from Nepal. Uchimura et al. (1990) reported yeast, *Saccharomycopsis*, and molds, *Penicillium* sp. and *Aspergillus* sp., in *poo* or *phab* (marcha of Bhutan).

### 4.9.3 Mana

*Mana* is a unique granular type of ethnic starter of Nepal prepared from wheat (Tamang 2010a). Wheat grains are soaked in water overnight, steamed for 30 minutes and transferred to a bamboo basket, drained, and ground into a lump. The floor is cleaned, straw is spread on the ground, and the wheat lump is placed over it, covered with paddy straw or straw mat, and fermented for 6 to 7 days. After 7 days, green mold appears on the wheat grains and is dried in the sun to obtain mana that is then stored. *A. oryzae* and *Rhizopus* spp. are present in *mana* (Nikkuni et al. 1996; Shrestha et al. 2002).

### 4.9.4 Ragi

*Ragi* is an amylolytic starter from Indonesia in the form of dry and flat cakes. Rice or millet or cassava or other starchy bases are milled, mixed with herbs and spices, roasted together, and then sieved. Water is added to the mixture along with 2% to 4% powder of old ragi, and then it is mixed thoroughly and shaped into balls, and fermented at 25°C to 30°C for 72 hours, sun-dried, and used as a starter for the production of alcoholic beverages and drinks in Indonesia. Microorganisms associated with ragi are species of *Rhizopus*, *Mucor*, *Amylomyces rouxii*, *Aspergillus*, *Saccharomycopsis*, *C. parapsilosis*, *C. melinii*, *C. lactosa*, *C. pelliculosa*, *S. cerevisiae*, *Hansenula subpelliculosa*, *H. anomala*, and *H. malanga*; *E. faecalis*, *Lb. Plantarum*, and *P. pentosaceus; B. coagulans*, *B. brevis*, and *Bacillus stearothermophilus* are associated with ragi (Dwidjoseputro and Wolf 1970; Saono et al. 1974; Hadisepoetro et al. 1979; Hesseltine et al. 1988; Hesseltine and Ray 1988; Ardhana and Fleet 1989; Yokotsuka 1991). Elegado and Fujio (1993) isolated two polygalacturonase-producing strains of *Rhizopus* spp. from ragi and studied the enzymes' stability in a wide range of pH values from 2 to 11, and tolerance at 50°C for 20 minutes. Uchimura et al. (1991b) reported that there is a higher variability rate of *P. pentosaceus* in older ragi than in younger ones and the results suggest that rod-shaped bacteria cannot survive for a long time under dry conditions in ragi.

### 4.9.5 Bubod

*Bubod* is an ethnic amylolytic starter from the Philippines. Rice and ginger are powdered, and mixed thoroughly with enough water to have a consistency that permits rolling the material into a ball and

flattening it (Tanimura et al. 1977). The discs are coated with 1- to 3-month-old bubod and incubated in rice straw for 36 hours at room temperature and sun-dried. *M. circinelloides*, *Mucor grisecyanus*, *Rhizopus cohnii*, *S. cerevisiae*, and *Sm. fibuligera* have been reported from bubod (Kozaki and Uchimura 1990); however, *Sm. fibuligera* is the dominant amylolytic yeast in bubod (Hesseltine and Kurtzman 1990). The activated starter for the production of *basi*, a mild alcoholic food beverage in the Philippines is called *binubudan* (Tanimura et al. 1978). Rice is cooked with water so that the grains remain separate, any lumps are broken down, and the rice is cooled to 40°C to 45°C. Then, it is inoculated with 300 g of powdered bubod for 4 kg rice. The rice and bubod are mixed in a clean basin and covered with banana leaves and then a clean cheese cloth. Fermentation continues for 24 hours to obtain a fresh, activated starter called binubudan.

### 4.9.6 Nuruk

*Nuruk* is an ethnic amylolytic starter from Korea. Traditionally, nuruk is prepared by moistening wheat flour, kneaded and molded into a ball, and fermented for 17 days at 30°C to 45°C, dried for 2 weeks, and cured for 1 to 2 months at room temperature (Park et al. 1977). *A. oryzae*, *A. niger*, *Rhizopus* sp., along with a few bacteria and yeast species have been isolated from nuruk (Kim 1968). Generally, nuruk is prepared by natural inoculation of molds, bacteria, and yeasts; however, it can be prepared by inoculation with *Aspergillus usamii* (Park et al. 1977).

### 4.9.7 Loogpang

*Loogpang* is an ethnic amylolytic starter from Thailand, which is commonly used to prepare alcoholic drinks and vinegar. The main ingredient of loogpang is rice flour with the addition of different types of spices and microorganisms from previous batches of loogpang (Vachanavinich et al. 1994). Species of molds present in loogpang are *Amylomyces*, *Rhizopus*, *Aspergillus*, *Mucor*, and *Absidia* (Pichyangkura and Kulprecha 1977); and yeasts and LAB including *Sm. fibuligera*, *Hansenula*, *Saccharomyces*, and *Pediococcus* (Dhamcharee 1982; Uchimura et al. 1991a). *Sm. fibuligera* of loogpang showed high glucoamylase activity (Sukhumavasi et al. 1975).

### 4.9.8 Men

*Men* or *banh men* is the ethnic amylolytic starter from Vietnam, which is used to produce traditional alcoholic beverages and drinks called *ruou* (Dung 2004). Rice flour is mixed with local herbs and spices and moistened with a small amount of water to form a dough, which is then made into small balls or flattened discs. The dough is spread on a bamboo tray and mixed with powdered men, and fermented at room temperature for a few days. Molds *Am. rouxii* and *Rhizopus* spp.; yeasts, *Saccharomycopsis fibuliger*, *Hyphopichia burtonii*, and *S. cerevisiae*; and LAB, have been found in men (Dung et al. 2005, 2006, 2007). *S. bayanus* has not been isolated from men, but the closely related species of *S. cerevisiae* has been isolated from banh men (Lee and Fujio 1999). *Rhizopus oryzae*, *R. microsporus*, *Absidia corymbifera*, *Amylomyces* sp., *Sm. fibuligera*, *S. cerevisiae*, *Issatchenkia* sp., *Pichia anomala*, *P. ranongensis*, *Candida tropicalis*, *Clavispora lusitaniae*, *P. pentosaceus*, *Lb. plantarum*, *Lb. brevis*, *W. confusa*, *W. paramesenteroides*, *B. subtilis*, *B. circulans*, *B. amyloliquefaciens*, *B. sporothermodurans*, *Acetobacter orientalis*, and *A. pasteurianus* have been isolated from banh men (Thanh et al. 2008).

### 4.9.9 Chiu-yueh

*Chiu-yueh* or *peh-yueh* is an ethnic Chinese amylolytic starter for *lao-chao*, a fermented rice product (Wang and Hesseltine 1970). It is a gray-white ball containing yeasts and fungi grown on rice flour, which is closely related to Indonesian ragi. Species of *Rhizopus*, *Amylomyces*, *Torulopsis*, and *Hansenula* are present in *chiu-yueh* (Wei and Jong 1983).

## 4.10 Fermented Beverages and Alcoholic Drinks

### 4.10.1 Saké

*Saké* is the most popular, ethnic nondistilled alcoholic drink of Japan. It is prepared from rice using koji and is clear, pale yellow, containing 15% to 20% alcohol (Tamang 2010c). Polished rice is washed, steeped in water, and steamed for 30 to 60 minutes, and then cooled, mixed with koji, water, and a selected yeast starter culture for alcoholic fermentation. Main fermentation takes place in open tanks in cool conditions, starting at approximately 10°C, increasing to approximately 15°C. After fermentation, the liquid material called *moromi* is separated from the solids to produce a clarified saké, which is settled, refiltered, pasteurized, and blended and diluted with water before bottling (Yoshizawa and Ishikawa 1989). Unique strains of *S. cerevisiae* have evolved to carry out those fermentations, generating products with high ethanol content (12–20%), attractive flavor and aroma, and odor (Kodama 1993). The first organisms developed in the mash, under traditional fermentation conditions, are nitrate-reducing bacteria such as *Pseudomonas*, *Achromobacter*, *Flavobacterium*, or *Micrococcus* spp. (Murakami 1972). These are followed by *Leuc. mesenteroides* variety *saké* and *Lb. saké* and yeasts (Kodama and Yoshizawa 1977). The highly refined saké brewed by the most skillful brewers using very highly polished rice at low temperatures of 9°C to 11°C for 25 to 30 days is known as *gonjoshu* (Kodama and Yoshizawa 1977). The difference in responses to osmotic stress between the laboratory and saké-brewing strains of *S. cerevisiae* at the translational level was compared and it was found that enhancement of glycerol formation due to enhancement of the translation of proteins Hor2p, is required for the growth of *S. cerevisiae* under high osmotic pressure conditions (Hirasawa et al. 2009). *S. cerevisiae* strains with disrupted ubiquitin-related genes produced more ethanol than the parental strain during saké brewing (Wu et al. 2009). Several researchers have reported on the industrial scale use of improved strains of *A. oryzae* for saké production (Hirooka et al. 2005; Kotaka et al. 2008; Hirasawa et al. 2009).

### 4.10.2 Kodo ko Jaanr

*Kodo ko jaanr* or *chyang* is one of the most popular ethnic fermented finger millet (*Eleusine coracana*) beverages of the Himalayan regions of India, Nepal, Bhutan, and China (Tibet) with a mild alcoholic (4.8%) and sweet taste (Tamang 2010c). Kodo ko jaanr has several synonyms as used by different ethnic groups of the Himalayan people such as *chyang* (Tibetan, Ladakhi, and Drupka), *mandokpenaa thee* (Limboo), and *mong chee* (Lepcha). During its production, finger millet seeds are cleaned, washed, and cooked for approximately 30 minutes, excess water is drained off and cooked millets are spread on a bamboo mat for cooling. Approximately 1% to 2% of powdered marcha is sprinkled over the cooked seeds, mixed thoroughly and packed in a bamboo basket lined with fresh fern (*Thelypteris erubescens*) and then covered with sackcloths, and fermented at room temperature for 2 to 4 days. The saccharified mass is transferred into an earthen pot or bamboo basket, made airtight, and fermented for 3 to 4 days during summer and 5 to 7 days in winter at room temperature for alcohol production. Freshly fermented kodo ko jaanr is filled into a bamboo-made vessel locally called *toongbaa*, and lukewarm water is added up to its edge and it is left for 10 to 15 minutes. Then, the milky white extract of jaanr is sipped through a narrow bamboo straw called *pipsing* which has a hole in a side near the bottom to avoid passing of grits. Water is added twice or thrice after sipping of the extract. Consumption of fermented finger millet beverages in exclusively decorated bamboo or wood-made vessels called *toongbaa* is unique in the Himalayas (Tamang 2010a). Kodo ko jaanr liquor is believed to be a good tonic for ailing persons and postnatal women. After consumption, residual or grits of kodo ko jaanr are used as fodder for pigs and cattle. This is a good example of total utilization of the substrate as food and fodder; the discarded grits also contain nutrient used as animal feed.

Marcha, used as an amylolytic starter, supplements all functional microorganisms in kodo ko jaanr fermentation (Thapa and Tamang 2004). Mycelial molds have roles only in the initial phase of fermentation, mostly in saccharification of the substrates. Yeasts *Pichia anomala*, *S. cerevisiae*, *Candida glabrata*, *Sm. fibuligera*, and LAB *P. pentosaceus* and *Lactobacillus bifermentans* have been recovered in kodo

ko jaanr samples. The population of filamentous molds, which originated from marcha, declines daily during *in situ* fermentation of kodo ko jaanr and finally disappears after the fifth day (Thapa and Tamang 2006). *Sm. fibuligera* and *R. chinensis* saccharify and liquefy millet starch into glucose and produce alcohol in *in situ* fermentation of kodo ko jaanr. Fermentation of finger millet enhances bioenrichment of minerals such as calcium, magnesium, manganese, iron, potassium, and phosphorus, contributing to mineral intake in the daily diet of the Himalayan rural people (Thapa and Tamang 2004). Because of the high calorie content, ailing persons and postnatal women consume the extract of kodo ko jaanr to regain strength. Chyang contains more riboflavin, niacin, and pantothenic acid and folic acid than the substrate (Basappa 2002). The essential amino acids also increase in chyang (Bassapa et al. 1997).

### 4.10.3 Bhaati Jaanr

*Bhaati jaanr* is the Himalayan sweet-sour, mild alcoholic food beverage paste prepared from rice and consumed as a staple food (Tamang 2010a). Rice is cooked, spread on a bamboo mat for cooling, 2% to 4% of powdered marcha is sprinkled over the cooked rice, mixed well, and kept in a vessel or an earthen pot for 1 to 2 days at room temperature. After saccharification, the vessel is made airtight and fermented for 2 to 3 days in the summer and 7 to 8 days in the winter. Bhaati jaanr is made into a thick paste by stirring the fermented mass with the help of a hand-driven wooden or bamboo stirrer. It is consumed directly as a food beverage. A similar product from Nepal is called *poko*. Occasionally, bhaati jaanr is stored in an earthenware crock for 6 to 9 days and thick yellowish-white supernatant liquor locally called *nigaar* is collected at the bottom of the earthenware crock. Nigaar is drunk directly with or without the addition of water. Alcohol content of bhaati jaanr is 5.9% (Tamang 2010a). Bhaati jaanr is an inexpensive high-calorie staple food/beverage for postnatal women and ailing old persons in the villages, who believe that it helps to regain their strength. Maximum activities of saccharification and liquefaction of rice are observed on the third day of fermentation (Tamang and Thapa 2006). *Sm. fibuligera*, *Rhizopus* ssp. and *Mucor* spp. contribute in saccharification and liquefaction of glutinous rice, breaking the starch of substrates into glucose for alcohol production and also in aroma formation in bhaati jaanr preparation. An increase in the mineral contents, mostly calcium, iron, sodium, potassium and phosphorus is also observed in bhaati jaanr due to fermentation (Tamang and Thapa 2006).

### 4.10.4 Lao-chao

*Lao-chao* is a popular ethnic fermented rice food of the Cantonese in China. It has a sweet taste and mild alcoholic flavor with a fruity aroma, made from rice by using *chiu-yueh* or *peh-yueh* as amylolytic starters (Wang and Hesseltine 1970). It is served as a dessert and is also a traditional diet for new mothers who believe that it helps them regain their strength (Wei and Jong 1983). The process of production is similar to Indonesian *tapé keatan*. *Rhizopus*, *Amylomyces*, *Torulopsis*, and *Hansenula* are found in lao-chao (Wei and Jong 1983). Pure culture fermentation of lao-chao was developed by Wang and Hesseltine (1970) and showed that good fermented rice was made when a mold, *Rhizopus chinensis* NRRL 3671, and yeast, *Saccharomycopsis* sp. NRRL Y7067, were used as inocula instead of a commercial starter.

### 4.10.5 Tapé

*Tapé* is a sweet and sour paste with an alcoholic flavor, prepared from glutinous rice or cassava or other cereals by using starter ragi in Indonesia (Campbell-Platt 1994). It is eaten as dessert or delicacy before meals in Indonesia. There are various starchy substrates used to prepare tapé, such as cassava (*tapé ketala*), glutinous rice (*tapé ketan*), maize (*tapé jagung*), and millet (*tapé cantel*). Rice is washed, soaked, steamed, cooled to room temperature on a woven bamboo tray, sprinkled with powdered ragi, packed in small banana leaves, and fermented for 2 to 3 days at room temperature and a soft juicy mass of tapé is produced (Saono et al. 1977). Tapé ketala is deep-fried in coconut oil before consumption. It is sun-dried and used later in soups (Ardhana and Fleet 1989). Ethanol content ranged from 3% to 8.5% v/v (Cronk et

al. 1977). Rice lipids are hydrolyzed during tapé ketan fermentation (Cronk et al. 1979). Mixed cultures of *Streptococcus*, *Rhizopus*, and *Saccharomycopsis* produce aroma in tapé, whereas *Sm. fibuligera* produces α-amylase, and *Rhizopus* sp. produces glucoamylase (Suprianto et al. 1989).

### 4.10.6 Tapai

*Tapai* is the Malaysian fermented food/beverage commonly consumed as a dessert (Merican and Yeoh 1989). There are two main types of tapai, that is, *tapai pulut*, prepared from fermented glutinous rice, and *tapai ubi*, prepared from tapioca or cassava. Tapai tastes sweet, slightly alcoholic with a pleasant and fragrant aroma. Amylolytic starter used for production of tapai are *ragi tapai* or *jui-paing*, which originated from Indonesia and is mainly for dessert tapai, and *ragi samsu*, which originated from China and is mainly for the alcoholic drink tapai. Rice is washed, soaked, cooked, and cooled, powdered ragi tapai or jui-paing is mixed on a woven bamboo tray and is covered in banana leaves and allowed to ferment at room temperature for 1 to 3 days. The fermenting mass is stirred at least once a day to keep the surface moist. The resulting liquid becomes clear yellow and very sweet. *Candida* spp., *Sm. fibuligera*, *Am. rouxii*, *M. circinelloides*, *M. javanicus*, *Hansenula* spp., *Rhizopus arrhizus*, *R. oryzae*, and *R. chinensis* are found in tapai ubi and tapai pulput (Wang and Hesseltine 1970; Ko 1972; Merican and Yeoh 1982). *Lb. casei* is present in tapai (Mohd Adnan and Tan 2007). Protein content of rice doubles to approximately 16% after fermentation because of losses of total solids and synthesis of proteins by the microorganisms (Cronk et al. 1977). Microbial consortia to produce a good tapai pulut consists of a mixture of *A. rouxii*, *Sm. fibuligera*, and *H. anomala*, and for the production of good quality tapai ubi, the consortia include *A. rouxii*, and *Sm. fibuligera* (Merican and Norrijah 1983, 1985).

Tapai is also used as an alcoholic drink in Malaysia. After 1 week of fermentation, if continued, wine or brandy is added to the mash as a preservative and it is allowed to ferment for another 25 days. The alcoholic drink tapai, which is red to pink, is collected by immersing a strainer-like collection vessel into the mash (Wong and Jackson 1977).

### 4.10.7 Tapuy

*Tapuy* is an ethnic mild alcoholic beverage of the Philippines prepared from rice with sweet and sour taste. The rice is washed, cooked, placed in a clay pot, and mixed with pulverized bubod. The pot is covered with cheesecloth and incubated in a cool place for 2 weeks (Tanimura et al. 1977). *Sm. fibuligera*, *Rhodotorula glutinis*, *D. hansenii*, *C. parapsilosis*, *Trichosporon fennicum*, and *Leuconostoc* constitute the microbial consortia in *tapuy* (Uyenco and Gacutan 1977) mainly supplemented by bubod. Alcohol content of *tapuy* is 13.5% to 19.1% (Tanimura et al. 1977).

### 4.10.8 Basi

*Basi* is an ethnic, nondistilled alcoholic drink from the Philippines made by fermenting boiled, freshly extracted sugarcane juice (Tanimura et al. 1978). Sugarcane is extracted into juice and is boiled with tree barks to provide color and flavor. After 2 to 3 hours of boiling, the concentrated juice is filtered and poured into earthenware jars and allowed to cool, and inoculated within 24 hours with a binubudan starter, covered with a lid, and fermented for a week before bubod is added to speed up the fermentation. After 1 month of fermentation, the earthenware jar is covered with a clean cloth or absorbent paper and is sealed. The product, basi, is then allowed to age for 1 year before consumption. In another method of preparation, the sugarcane juice is inoculated with organisms present on 1-year-old dried fruit, leaves, and leaves or bark of *samac* (*Macharanga tanarius*, *M. gradifolia*; Tanimura et al. 1978). In this process, fresh cane juice is boiled for 2 hours to approximately three-quarters volume, at which point the concentrate is transferred to an earthenware jug and cooled overnight. Milled rice, dried samac leaves, bark, and dried fruit are added and mixed thoroughly. The mouth of the jug is covered with banana leaves and fermentation continues for 3 months, and is aged for 1 year. The dominant yeasts in basi are *S. cerevisiae*

as well as *Saccharomycopsis* spp. (Kozaki 1976; Sakai and Caldo 1985). An improved method for the preparation of basi has been developed which is more acceptable to consumers (Sanchez and Kozaki 1984).

### 4.10.9 Yakju and Takju

*Yakju* and *takju* are the ethnic Korean alcoholic beverages made from rice by using nuruk (Park et al. 1977). The lower or diluted concentration of yakju is known as *takju*. During yakju preparation, steamed rice is cooled and then mixed with nuruk and fermented, the liquid pressed from the fermenting mass is filtered under pressure, and is aged and bottled. Yeasts, *Bacillus* spp., *Lactobacillus* sp., and *Leuconostoc* spp., are present in these Korean beverages (Shin and Cho 1970; Kim 1970; Lee and Rhee 1970). *S. cerevisiae* is the most important organism in alcohol production, whereas *Hansenula* spp. plays an important role in flavor development (Kim and Lee 1970; Kim and Kim 1993). An increase in thiamine during the fermentation of yakju and takju has been observed (Kim and Choi 1970). High-value yakju possessing the pharmaceutical functionality of *Ganoderma lucidum* was developed with antihypertensive properties (Kim et al. 2004).

### 4.10.10 Brem

*Brem* is a nondistilled ethnic alcoholic drink from Indonesia which is prepared from rice. It is a dried, starchy, sweet-sour rice extract, and is eaten as a snack. Brem is of three types: *brem madiun*, which is yellowish-white, sweet-sour, and is prepared in blocks of 0.5 × 5 to 7 cm; *brem wonogiri*, which is sweet, very soluble, white, and thin circular blocks of 5 cm diameter; and *brem bali*, which is a famous alcoholic liquor produced in Bali, Indonesia (Basuki 1977). All three types of brem are made from the liquid portions of tapé ketan. During brem production, the filtrate of tapé ketan is boiled down, poured onto a table, covered with banana leaves, and left to cool at ambient temperature over 8 to 12 hours (brem madiun) or sun-dried for 1 day to produce brem wonogiri (Campbell-Platt 1987). The liquid portion of tapé ketan is aged for 7 months, during which solids precipitate, leaving a clarified brem, known as brem bali, and is decanted and bottled (Basuki 1977). Alcohol content of brem is 6.1% (Winarno 1986). Brem with improved ragi is produced which has more desirable flavor than conventionally made brem (Saono et al. 1984).

### 4.10.11 Krachae

*Krachae* or *nam-khaao* or *sato* is a nondistilled ethnic alcoholic drink from Thailand prepared from Thai rice using loogpang as starter (Vachanavinich et al. 1994). During krachae production, a local rice variety of Thailand is washed, soaked, cooked, and cooled and then sprinkled with loogpang powder and mixed well. The mixture is placed in an earthenware jar, and fermented at 30°C to 35°C for 2 days, and water is added. The jar is again incubated for 3 to 4 days. The fermented mass is filtered and only clarified supernatant is collected, which is a yellowish white color and effervescent and is now called *krachae*. Microorganisms in krachae are supplemented from the ethnic starter *loogpang*. Molds play an important role at the initial stage of fermentation for the cleavage of sugar polymers present in rice to substantial sugars which can be used for substrates for simultaneous fermentation by yeast and LAB (Lotong 1985). Molds produce sugars from starch, and subsequently, yeast converts sugars to alcohol (Ko 1982), and LAB helps in the formation of flavor and taste in krachae (Lim 1991).

### 4.10.12 Raksi

*Raksi* is an ethnic alcoholic drink from the Himalayas with a characteristic aroma, and is distilled from traditional fermented cereal beverages (Kozaki et al. 2000). Raksi is a common term in Nepali meaning alcoholic drink. Bhaati jaanr, poko, makai ko jaanr, kodo ko jaanr, gahoon ko jaanr, fermented masses of buckwheat, potato, canna, and cassava roots are distilled in a large cylindrical metallic vessel measuring

40 cm × 30 cm × 25 cm for 2 to 3 hours continuously over firewood in an earthen oven (Tamang 2005). A perforated container called *phunga* is placed above the main cylindrical vessel, inside of which is a small metallic collector called *poini*, that is kept on an iron tripod called *odhan* to collect the distillate called *raksi*. Another metallic vessel with cold water is placed above the phunga as condenser. The bottom of the condenser vessel is plastered with mud along with the tip of the phunga to prevent excess ventilation during distillation. Water is replaced three to five times after it is heated. Condensed raksi is collected in a small collecting metallic vessel called *poini*. Raksi obtained after replacing the condensing water thrice is known as *theen pani raksi*; this contains a high amount of alcohol and is traditionally prepared for religious purposes. Raksi prepared after replacing the condensing water five times is known as *panch pani raksi*, which is a common alcoholic drink. The traditional distillation apparatus can distil 2 to 4 kg of jaanr to obtain 1 to 2 liters of raksi after replacing the condensing water thrice. Raksi is usually stored in bottles capped with a piece of dry corncob. Sometimes, petals of *Rhododendron* spp. are mixed in during distillation to provide a distinct aroma to raksi. This type of raksi is commonly prepared in *Rhododendron*-growing regions of the Himalayas (Tamang et al. 1996). The alcohol content of raksi is 22% to 27% v/v (Tamang 2005). Raksi is drunk directly without the addition of water along with fried meat or any other curry. Raksi is commonly available in local liquor shops, restaurants, and hotels.

### 4.10.13 Toddy or Tari

*Toddy* or *tari* is an ethnic alcoholic drink from India prepared from palm juice. There are three types of toddy (Batra and Millner 1974): (1) *sendi*, from the palm; (2) *tari*, from the *palmyra* and date palms; and (3) *nareli*, from the coconut palm. *Geotrichum*, *Saccharomyces*, and *Schizosacchoramyces* spp. of yeast are responsible for fermentation (Batra and Millner 1974). Microorganisms that are responsible in fermenting toddy are *S. cerevisiae*, *Sch. pombe*, *A. aceti*, *A. rancens*, *A. suboxydans*, *Leuconostoc dextranicum*, *Micrococcus* sp., *Pediococcus* sp., *Bacillus* sp., and *Sarcina* sp. (Shamala and Sreekantiah 1988).

### 4.10.14 Kanji

*Kanji* is an ethnic Indian strong-flavored, mild alcoholic beverage prepared from beetroot and carrot by natural fermentation (Batra and Millner 1974). It is drunk as a mild alcoholic refreshing drink in India. The alcohol content of kanji is 2.5% and pH is 4.0; hence, the product's mild-alcoholic and acidic taste (Sura et al. 2001). During its preparation, carrots or beets are washed, shredded and mixed with salt and mustard seeds, and placed in earthen pots and allowed to ferment naturally at 26°C to 34°C for 4 to 7 days. Sometimes, the mixture is inoculated with a portion of a previous batch of kanji. After fermentation, pink alcoholic liquor is drained off and bottled or drunk directly. In northern India, it is prepared with purple or occasionally orange cultivars of carrots plus beets and spices, whereas in southern India, *torami*, a yeast-containing fermented rice gruel is used as a starter for kanji production. *Hansenlu anomala*, *Candida guilliermondii*, *C. tropicalis*, and *G. candidum* are involved in kanji fermentation (Batra and Millner 1974). *Leuc. mesenteroides*, *Pediococcus* spp., and *Lactobacillus dextranicum* have been isolated from kanji fermentation (Sura et al. 2001). Recently, Kingston et al. (2010) reported *Lb. paraplantarum* and *Lb. pentosus* from kanji based on rep-PCR identification method.

## 4.11 Conclusions

The diversity of Asian fermented foods is related to the diversity of ethnicity and unparalleled food culture of each community. The diversity of microorganisms ranges from mycelia fungi to enzyme-producing and alcohol-producing yeasts, to Gram-positive and a few Gram-negative bacteria with several functional properties. There is a relationship between human life and microorganisms. Asian ethnic fermented foods and beverages have biological functions enhancing several health-promoting benefits to the consumers because of the functional microorganisms associated with them, such as the biopreservation of perishable foods, bioenrichment of nutritional value, protective properties, bioavailability of

minerals, production of antioxidants and omega-3-polyunsaturated fatty acids, therapeutic values, and immunological effects. Some Asian ethnic fermented foods, such as tempe, natta, natto, shoyu, kimchi, etc., have been commercialized and marketed globally as health foods or functional foods.

It has been noticed that the consumption of several uncommon ethnic foods is declining in many Asian countries because of lifestyle changes; shifting from cultural food habits to commercial foods and fast foods, drastically affecting traditional culinary practices, and also because of climate change in some places. The effect of climate change is mostly on the production of indigenous crops, vegetables, legumes, seeds, etc. Many minor, but culturally important, ethnic foods are not seen in local markets of many Asian countries, and most of the young generation do not know ethnic foods, their culinary practices, and processing methods. Native microorganisms with vast biological importance and potential genetic resources, which are associated with ethnic fermented foods, have disappeared. Surveys on the consumption and production of ethnic fermented foods and beverages in every country, and the calculation of per capita consumption, needs to be urgently addressed by the food policy-makers of respective ministries or governments. Introduction of global ethnic fermented foods in the syllabus at the master's level in microbiology and food sciences courses of all universities may be initiated. The native skill of making ethnic fermented foods has been passed from mothers to daughters, fathers to sons, for generation to generation. Such family tradition of culinary skills using important indigenous knowledge of food fermentation is, nowadays, unnoticed because of the increased incidence of nuclear families, separation from elder people, a fast and busy lifestyle, the popularity of fast commercial foods, and a lack of interest among the educated urban mass to interact with elderly people from the villages to explore their vast indigenous knowledge. Everyday throughout the world, the indigenous knowledge of many elderly people has disappeared with their death. As a result, many important ancient and ethnic foods have become extinct worldwide. This is a serious phenomenon of the 21st century related to cultural foods.

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