Fermented Vegetable Protein and Related Foods of Southeast Asia with Special Reference to Indonesia

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ABSTRACT

As rising populations cause more demand for food, Southeast Asian residents will depend increasingly on plant sources, rather than animal sources, for their dietary protein and calorie needs. Tempeh and other fermented vegetable protein products already are familiar parts of the diet throughout Southeast Asia. The low cost production process also provides protection against aflatoxin contamination, an important consideration. All these factors indicate that fermented foods will play a larger role in the future diet for millions of people in Southeast Asia.

INTRODUCTION

Southeast Asia consists of nine countries having a total population of 332 million, whose average per capita income is 260 US dollars. Indonesia's population of 136.9 million is 40% of the Southeast Asia population (Table I). There is reason to believe that human nutrition in that area is unsatisfactory (1).

Due to the limited data available from other Southeast Asia countries, this presentation will be based mainly on data from Indonesia with the belief that it could represent other Asian countries. In addition, Indonesia is considered to have a wide variety of fermented vegetable protein foods.

Nutritional surveys and food pattern studies conducted in Indonesia in the last 20 years have shown that the main problems directly related to poor nutrition are protein calorie malnutrition (PCM), vitamin A deficiency, nutritional anemia, and endemic goiter (2).

Generally, the mortality rate of preschool children below the age of four is high, and PCM is common in villages and semiurban communities. A high mortality rate among infants and young children is often an indication of a country's poor nutritional status. It has been stated (3) that out of 1,000 live births in Indonesia annually, about 150 babies die before the age of one year. In a country with good nutritional status, the rate is 20 deaths per 1,000 live births.

FERMENTED FOODS AND FOOD NEEDS

As populations continue to grow, the world is going to have to review its present usage of all raw material potentially suitable for food and convert more of its present animal feed to human use. As the prospect of food shortages becomes more acute, people in Southeast Asia must depend increasingly on plant rather than animals for their calorie and protein needs in the diets (4).

Asia is a vast storehouse of ancient culture, art and knowledge, including food fermentation technology (5). Fermented foods are important components of diets in many parts of the world, especially Southeast Asia. In many cases such products make an important contribution to the diet of the people as sources of protein, calories and some vitamins.

The nutritional composition of some fermented foods in Indonesia are shown in Table II. Tempeh has the highest protein content and bongkrek has the lowest.

There are several kinds of fermented vegetable protein foods in Southeast Asia as shown in Table III. For the purpose of this presentation, only four kinds of promising or interesting fermented foods will be discussed: tempeh, oncom, bongkrek, and tauco.

TEMPEH AND ONCOM

Tempeh

Indonesians, centuries ago without modern chemistry and microbiology, developed a fermentation product called tempeh, in which soybeans are soaked, dehulled, partially cooked, and inoculated with molds belonging to genus *Rhizopus* (8).

Protein content is over 40% on a dry basis. Due to its high nutritive value, tempeh makes a good substitute for meat in the diet. After being fermented, soybeans require only 3-4 min deep fat frying (190 C) or 10 min boiling. Raw soybeans generally require about six hr boiling to pre-

TABLE I

Population, Population Growth and Gross National Income Per Capita in Several Countries in Southeast Asia

Country	Population (millions)	Population growth (%)	Average national income per capita (US $)
Burma	31.8	2.4	110
Republic Khmer (Cambodia)	8.0	2.8	70
Indonesia	136.9	2.4	180
Laos	3.5	2.2	70
Malaysia	12.6	2.8	720
Phillipina	44.3	2.7	370
Singapore	2.3	1.3	2,510
Muangthai (Thailand)	44.4	2.4	350
Vietnam	47.3	2.1	160
Southeast Asia	332.0	---	260

TABLE II

Nutrition Composition of Tempeh, Oncom, Bongkrek and Tauco per 100 gram (6)

Composition	Tempeh	Oncom	Bongkrek	Tauco
Calorie	149.0	187.0	119.0	---
Protein (g)	18.3	13.0	4.4	10.0
Fat (g)	4.0	6.0	3.5	5.0
Carbohydrate (g)	12.7	22.6	18.3	24.0
Vitamin A (IU)	50.0	---	---	0.0
Vitamin B (mg)	0.17	0.09	0.09	---
Vitamin B-12 (ng/g)	29 ± 5.00	31.00 ± 7.00	---	---

TABLE III

Fermented Vegetable Protein Foods in Southeast Asia (7)

Name	Organism used	Substrate	Nature of product	Area where article of commerce
Tempeh	*Rhizopus oligosporus*	Soybeans	Solid	Indonesia and vicinity
Bongkrek	*Rhizopus oligosporus*	Coconut presscake	Solid	Central Java (indonesia)
Oncom	*Rhizopus oligosporus* *Neurospora sitophila*	Peanut presscake	Solid	West Java (Indonesia)
Tauco	*Rhizopus oligosporus* *Aspergillus oryzae*	Soybeans and cereals	Liquid	West Java (Indonesia)
Kecap (Shoyu)	*Aspergillus oryzae* *Lactobacillus, Hansenula* and *Saccharomyces*	Soybeans, Wheat	Liquid	Indonesia and vicinity
Ang-kak	*Monascus purpureus*	Rice	Deep red pigmented solid	Phillipines and Indonesia
Sofu (Sufu, fermented Toifu)	*Actinomucor elegans* and *Mucor* sp.	Soybeans	Solid	China, Formosa

pare them for consumption (9). Tempeh is actually the first "quick cooking" food developed in the world (5).

In Indonesia, particularly for people who live on Java, tempeh is a key protein source for millions of people who daily eat 30-120 g, generally served as a meat substitute in their grain-centered diet. The estimated annual nationwide tempeh production is ca. 75,600 tons. Approximately 14% of the total annual Indonesian soybean production is made into tempeh. Tempeh also is becoming an important food in Malaysia.

One of four major nutrition problems in Indonesia is nutritional anemia. There are several kinds of nutritional anemia, including some due to iron and vitamin B-12 deficiency.

Consumers eating meat regularly have no problem getting enough vitamin B-12 in their diets. However, people subsisting principally or totally on rice, or other cereal grains, may receive insufficient vitamin B-12 which leads to pernicious anemia (10).

One interesting discovery is that tempeh made with the pure mold *Rhizopus oligosporus* contains very little vitamin B-12 compared with tempeh made by traditional processing. The mystery was solved when it was found that a specific bacterium present in commercial samples of tempeh produces vitamin B-12 during the fermentation. This finding shows that the presence of a certain bacterial species can be very beneficial from a nutritional point of view (11).

Indonesian tempeh may contain 30 μg/g of vitamin B-12. If the average daily consumption is 60 g per person, this would provide 60% of the daily requirement of vitamin B-12. Recommended dietary allowance of 3 μg (microgram) of vitamin B-12 per day for adults has been set by the Committee on Dietary Allowances (11).

It has been reported (12) that tempeh had a beneficial effect on patients with dysentery in the prison camps of World War II. The antibacterial activity or growth inhibitors produced by *Rhizopus oligosporus* during tempeh fermentation has been reported (13).

It was also reported that even though antibacterial tests indicated that the compound produced by *Rhizopus oligosporus* does not exhibit a broad spectrum activity, it is very active toward some gram positive bacteria.

The Southeast Asian people are constantly exposed to overwhelming sources of infection, and their diets are frequently inadequate, yet they possess a wonderful resistance to disease (22).

Oncom

Press cakes have been used for a long time principally for animal feed. Their fiber content and relative high content of undigestable components made them undesirable for human food. Centuries ago the Indonesians demonstrated a way to convert essentially animal feeds to human quality food, through a traditional fermentation process (5).

Oncom, prepared by allowing the mold to grow on peanut presscake for ca. 48 hr, makes a food used in the daily diet of some 25 million people (14).

The active microorganism used for oncom production is *Rhizopus oligosporus,* which produced oncom with a black color, or *Neurospora sitophila,* which produces red or orange oncom. Enzymes produced by the mold deeply penetrate into the substrate, making the protein, lipids, and other components more digestible and at the same time move flavorful.

Like tempeh, oncom can also produce vitamin B-12 in substantial amounts. The source of vitamin B-12 in this product is not known and needs further investigation (11). Oncom prepared from peanut presscake had 31 ± 7 μg/g of vitamin B-12; oncom prepared from soybean milk residue had 23 ± 2 μg/g.

BONGKREK AND TAUCO

Tempeh bongkrek

Tempeh bongkrek is a special type of tempeh which can be prepared from shredded coconut residue with

Rhizopus oligosporus (15).

A well made product is a compact cake which is completely covered and penetrated by the white mold mycellium. Occasionally the mold mycellium does not develop, and toxin-producing bacteria *Pseudomonas cocovenenans* overgrow the mold. Then the mass remains grandular and loose; it becomes slimy and developes a putrefactive ordor by extended incubation. Such poorly fermented products could be poisonous.

Outbreaks of food poisoning by tempeh bongkrek still occur periodically (6). During the latest large outbreak, early in 1977, more than 400 persons were involved and more than 70 victims died (6).

Tauco

Related to shoyu (soy sauce) fermentation, the Japanese also developed miso, and the Indonesians developed tauco, a meat-flavored soybean paste or liquid. Typically, tauco is used with various other foods including fish, or in vegetable soup, to enhance flavor (17). Since tauco is somewhat similar to miso, it has the potential to be developed into a mass consumption product, as many Japanese consume miso soup every morning at breakfast. The average consumption of tauco per capita per day in Indonesia is still very low. However, miso has long been a key source of protein in the Japanese diet. It presently accounts for up to 25% of the protein consumed in some Japanese rural inland areas and more than 8% for the population as a whole. The average Japanese consumes about 16 pounds of miso each year, or about 19 g per day (18).

WHOLESOMENESS OF FERMENTED FOODS

Production of fermented foods usually is not done under pure culture conditions and is done without sufficient aseptic precautions. Therefore, contamination with toxic-producing natural organism is always possible.

It has been reported that in comparison to other substrates or commodities, soybean was a poor substrate for aflatoxin-producing mold. The molds required for the fermentation of tempeh and oncom may be considered to protect these foods against aflatoxin (19). The ability of *Aspergillus flavus* to produce aflatoxin B_1 was considerably suppressed when grown together with *Neurospora* species on peanut substrate. Similar results were obtained when *Aspergillus flavus* was grown with *Rhizopus oligosporus* on soybean.

One researcher has reported that during fermentation of soybeans with *Rhizopus oligosporus* into tempeh, no aflatoxin was produced even though a considerable amount of *Aspergillus flavus* spores was purposely added before fermentation (19).

Due to production costs and familiarity to millions of people, tempeh and other fermented vegetable proteins look more feasible as a main source of protein for millions of people with very limited incomes.

When peanut presscake is used as substrate, particularly for oncom production, then the possible danger of aflatoxin exists. This was found to be the case in Indonesia. Raw peanut presscake containing from 230 to 5,000 parts per billion (ppb) of aflatoxin was received, and only aflatoxin B_1 was present (9). Using *Neurospora sitophila* as the fermenting organism, ca. 50% of the aflatoxin was destroyed during fermentation (20). *Rhizopus oligosporus,* used as the aflatoxin-fermenting organism, destroyed ca. 60% of the aflatoxin in the presscake. Five samples of commercial Indonesian oncom which had been analyzed contained 90 to 800 ppb aflatoxin. Thus, fermenting peanut presscake to produce oncom may make the substrate less dangerous from the aflatoxin standpoint (12).

Relying on fermenting organisms to control aflatoxin will provide real advantage only if the aflatoxin content of the raw material is low, otherwise the 30 to 50% aflatoxin which is left behind will still exceed the permitted levels (30 ppb).

TABLE IV

Composition and Nutritional Value of TFR (22)

Ingredient	Composition TFR-I	TFR-II
Tempeh (%)	30	30
Fish (%)	9	10
Rice (%)	30	30
Sugar (%)	27	25
Peanut oil (%)	4	5
	Nutritive value	
Protein (%)	23.7	23.7
Fat (%)	9.4	7.8
Carbohydrate	59.6	61.2
Ash (%)	2.3	2.4
Moisture (%)	5.0	4.9
NPU STO	64	62
NPU Op	46	51

The bongkrek toxin consists of two substances; toxoflavin and bongkrek acid (B.A.) (6). Bongkrek acid, particularly, has been responsible for deadly food poisoning which until recently claimed victims in Indonesia. Bongkrek acid is an active antibiotic against the mold *Rhizopus,* used to produce white bongkrek.

To reduce the possibility of bongkrek poisoning, people in the region when it is made add pounded dried "calingcing" leaves (*Oxalis sepuin*). Adding the leaves probably reduces the pH, inhibiting the growth of *Pseudomonas cocovenenans.*

It has been reported that addition of 1.5 to 2.0% NaCl to the raw material could suppress the accumulation of bongkrek acid in tempeh bongkrek. NaCl also neutralized the inhibiting effect of *Pseudomonas cocovenenans* on the growth of *Rhizopus oligosporus* (15). This discovery offers a promising method to reduce the number of bongkrek poisoning victims in Indonesia.

The available literature indicates we should not worry too much about aflatoxin content of fermented food, because of the internal protection of fermented foods against aflatoxin (15).

DEVELOPMENT OF FOOD SUPPLEMENT USING FERMENTED FOOD AS A BASIC INGREDIENT

In an evaluation study by the Applied Nutrition Program conducted in 1972-1973 (21), nutrition problems in eight of 26 provinces were studied from the standpoint of socioeconomics and family food habits. The study recommended that nutrition improvement programs should give priority to pregnant and nursing mothers, and to children under two years of age. These groups are called the vulnerable groups because they tend to be affected easily by malnutrition.

The vulnerable groups have a relatively high nutritive requirement which is difficult to fulfill because the amount of traditional food needed for good nutrition exceeds the capacity of mouth and stomach. Therefore, they need highly nutritious foods of small volume. When the diet cannot fulfill the daily requirement of nutrients, supplementary foods are needed.

Nutrition Research Institute at Bogor, Indonesia, has developed an indigenous mixture, using fermented food as a basic ingredient, which is called "Tempeh-Fish-Rice" (TFR). It is composed of tempeh, fish, rice, sugar and peanut oil, as shown in Table IV. There are two formulas; the second was made to improve the palatability and nutritional value. The mixture has been tested and given to children suffering from PCM. It was found that TFR can increase body weight and improve the general condition of the child (22).

The study for the development of "New Tauco Product" is now being enlarged to popularize consumption of tauco, by using different soup type recipes and other Indonesian dishes.

Due to its low cost and familiarity, fermented foods have great potential as key protein sources and as basic ingredients for food supplement. The fermented foods will certainly play a more important role in Southeast Asia in the future than they do today.

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