Nutritive Value and Wholesomeness of Fermented Foods

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It would appear that fermentation does not improve the nutritive value of the protein. During fermentation some vitamins increase; others may decrease. Digestibility for humans of certain fermented foods such as tempeh, ontjom, and bongkrek is improved over the ingredients. The keeping quality of fermented foods is generally increased. Cooking times are often decreased. The organoleptic characteristics of fermented foods are generally improved over the raw ingredients. It would appear that the wholesomeness of fermented foods is as good as and, in some cases, better than that of the ingredients from which they are produced. Certain fermented foods, such as ontjom and bongkrek, may be hazardous to health if they are produced from raw materials which contain aflatoxin or are improperly fermented.

Fermented foods are important components of diets in many parts of the world, especially Southeast Asia, the Near East, and parts of Africa. In many cases the final products make important contributions to the diet as sources of protein, calories, and some vitamins. In other cases they are used more as condiments, such as soy and fish sauces. Fish pastes generally contain too much salt to be consumed in large quantities.

In general, fermented foods are more attractive to the consumer than the raw ingredients. This certainly holds true for fermented soybean products such as tempeh, miso, and natto, fermented coconut press cake (Indonesian bongkrek), and fermented peanut cake (ontjom). Usually the fermented products have some characteristic properties—flavor, aroma, appearance, or consistency—which make them attractive to the consumer. Not to be overlooked is the fact that some of these products such as tempeh and Ecuadorian "yellow" rice (arroz requemado) require much shorter cooking times or lower cooking temperatures because of the fermentation.

It has been a question for sometime whether or not fermentation improves nutritive value. Also, it is a logical question in view of recent interest in mycotoxins whether the mold fermented products are wholesome and free of toxic products.

We have generally confined our investigations to Indonesian tempeh and ontjom, Indian idli, Southeast Asian fish paste, Ecuadorian "yellow" rice, and Middle-East fermented milk-wheat mixtures.

MATERIALS AND METHODS

This is a review paper of the research done on certain traditional foods in our laboratories. Details of methods of preparing, chemical analyses, and determination of nutritive value have been published along with pertinent related references in the publications referred to under each specific food.

Tempeh. Indonesian tempeh is made by fermenting dehulled, partially cooked soybean cotyledons with molds generally of the genus *Rhizopus* (Djien and Hesseltine, 1961; Steinkraus *et al.*, 1960; van Veen and Schaefer, 1950). Tempeh is a very important source of protein in the Javanese diet. Soybeans overgrown by mold become a cake which is either sliced thin, dipped in salt brine and deep fat fried, or cut into pieces and used in soups. Cooking time for the soybeans is reduced by fermentation from about 6 hr or more to a 10-min boil. In addition, the typical soybean flavor disappears.

Ontjom. Ontjom is fermented peanut press cake and is very popular in Western Java (van Veen *et al.*, 1968b). Sometimes technical press cake with a low oil content is used. The village product usually contains considerable amounts of oil. Two different fungi are used. The tempeh mold, *Rhizopus oligosporus*, is used to make a white ontjom and *Neurospora sitophila* is used to make a red ontjom. Ontjom, being based upon cheaper raw materials than tempeh, costs less on the market.

Bongkrek. Bongkrek is similar to ontjom, except that the raw material is coconut press cake (van Veen, 1967). In both ontjom and bongkrek, raw materials which would be relatively inedible and unpalatable to humans because of their content of fiber and insoluble materials are converted to foods which supply essential nutrients to millions of people.

Idli. Indian idli, made by fermenting mixtures of dehulled black gram (*Phaseolus mungo*), a legume, and rice in various proportions, is popular particularly in southern India (Mukherjee *et al.*, 1965; Rajalakshmi and Vanaja, 1967; Steinkraus *et al.*, 1967; van Veen *et al.*, 1967). During the idli fermentation, the major ingredients are transformed into a thin dough which, when steamed, resembles a sourdough type bread. The acid and gas required for leavening are produced by *Leuconostoc mesenteroides* which is generally present on Indian black gram.

Fish Sauces. Fish sauces and pastes are a standard article of diet in Southeast Asia (van Veen, 1965). They are highly accepted and do not have the inherent problems of fish flour, for which ways have to be devised to incorporate it into the diet. Fish paste protein has an excellent nutritional value. Generally the salt content of fish pastes is 15 to 20%, or higher. Thus, they cannot be consumed in large quantities. Fish pastes containing 10 to 12% salt and having good keeping quality and a true fish paste flavor can be produced (Tan *et al.*, 1967). These low salt fish pastes can be consumed in larger quantities than the traditional fish pastes.

Fermented Rice. Fermented or Sierra rice (arroz requemado) is a food consumed in the Ecuadorian Andes (van Veen *et al.*, 1968a). The unhusked rice is fermented by organisms present on the surface. During fermentation the rice kernel becomes yellowish or brownish. The milled rice retains the color. The fermented rice has a faint, definitive flavor. The Sierra rice is used exclusively for preparation of "dry rice," in which the rice is cooked until the grains separate evenly. "Dry rice" is considered indispensable with all

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Table I. PER,[a] Digestibility Coefficient, and Riboflavin Content before and after Fermentation

Food	PER Before	PER After	DC[c] Before %	DC[c] After %	Riboflavin Micrograms/gram Before	Riboflavin Micrograms/gram After
Tempeh (10%)[b]	2.63	2.56 (24 hr)	86.9	86.2	3	7
Ontjom (15%)[b]	2.17	2.17	82.5	83.0	No change	
Ecuadorian rice (6%)[b]	1.90	1.63	82.6	78.9	0.15	0.32
					0.28	1.04
Fish paste (8%)[b]	3.12	2.96	89.8	88.5	1.65	2.10
Idli (10%)[b]	1.99	1.84	...	...	1.37	0.77
Flour-Kishk	...	...	...	...	No change	

[a] Protein efficiency ratio. [b] Level of protein fed in diet. [c] Digestibility coefficient.

meals in some mountainous areas. Inasmuch as the fermentation subjects the rice to 50° to 80° C, Sierra rice requires less cooking, which is very important in the Andean altitudes where water boils below 100° C.

Yoghurt-Wheat Foods. Foods (Syrian *kishk*, Turkey *tarhana*, and Iranian *kushuk*) prepared from high extraction wheat flour or parboiled wheat (bulgur) and yoghurt are extremely popular in the Near East (van Veen *et al.*, 1969). They are used for feeding older infants and young children in Egypt, Syria, and Jordan. Exact details of manufacture vary from place to place. Generally, yoghurt is placed in a closed bag for a few days to drain off liquid. The residue is then mixed with some salt and incubated with soaked wheat flour or bulgur for a few days in a jar. Then the mixture is dried in hot shade or sun. Instead of wheat flour or bulgur, a sour dough can be used. Buttermilk sometimes is used in place of yoghurt. Tomato, tomato paste, red peppers, or chopped onions may be added before incubation and drying, especially in Turkey. The final product is not hygroscopic and can be stored in open jars for 2 to 3 years without obvious deterioration. The relatively low pH (after reconstitution with water) makes the food unattractive to pathogens and food spoilage organisms.

NUTRITIVE VALUE

In no case have we observed an improvement in the protein efficiency ratio (PER) of fermented over properly-heat-treated raw ingredients (Table I) (Hackler *et al.*, 1964; Tan *et al.*, 1967; van Veen *et al.*, 1967, 1968a,b). Rajalakshmi and Vanaja (1967) reported an increase PER for idli during fermentation; however, they did not state whether or not they had heat treated the unfermented ingredients. Without heat treatment, the raw ingredients would not be expected to show as high PER values as the fermented steamed idli.

DIGESTIBILITY

Digestibility, on the basis of feeding studies with weanling rats, is generally not improved (Table I) (Hackler *et al.*, 1964; Tan *et al.*, 1967; van Veen *et al.*, 1968a,b). However, it should be mentioned that most rat feeding studies are carried out with dry powdered feedstuffs. Chewing and mastication do not enter the picture as much as they do with human eating, for example soybeans or tempeh. van Veen and Schaefer (1950) observed that tempeh was very well tolerated even by persons suffering from gastrointestinal upsets in prisoner-of-war camps during World War II, while cooked soybeans were virtually undigestible. Wang *et al.* (1969) reported antibiotic production by the tempeh mold, and suggested that the antibiotic content of tempeh may be related to disease resistance among its consumers.

VITAMINS

We have found (Table I) that the riboflavin contents of various fermented foods have generally been reported to remain the same or be significantly increased over the unfermented ingredients [Murata *et al.* (1967); Roelofsen and Talens (1964); Steinkraus *et al.* (1961); Tan *et al.* (1967); van Veen *et al.* (1967, 1968a,b, 1969)]. van Veen *et al.* (1967) reported a decrease in riboflavin content of idli during fermentation. Rajalakshmi and Vanaja (1967) reported an increase in riboflavin during the idli fermentation. Unfortunately, thiamine content appears to decrease in the tempeh fermentation. Rajalakshmi and Vanaja (1967) reported an increase in thiamine during the idli fermentation. Niacin and vitamin B-12 are increased during the tempeh fermentation (Table II). Increases in thiamine and riboflavin content are very important when the fermented foods are part of a predominately rice diet. Increases of other vitamins are also very important where specific deficiencies occur in the diets.

ACCEPTABILITY

Organoleptic acceptability of the fermented foods is generally higher than it would be for the cooked raw materials. Tempeh, for example, has very little of the typical soybean flavor. Ontjom from peanut press-cake and bongkrek from coconut press-cake would be virtually inedible for humans without a fermentation to break down some of the insoluble materials. Indian idli changes black gram and rice into a sour-dough, steamed, bread-like product. Fried like a pancake, the same dough becomes Indian dosai.

Fish pastes and sauces not only provide excellent nutrients and keep very well, but they are highly prized for their flavor and as condiments.

WHOLESOMENESS OF FERMENTED FOODS

Neither the tempeh mold, *Rhizopus oligosporus*, or the ontjom mold, *Neurospora sitophila*, produced mycotoxins of the aflatoxin type (van Veen *et al.*, 1968b). However, the

Table II. A Comparison of Certain Vitamins in Soybeans and in Tempeh

Vitamin	Concentration In Soybeans per gram μg	Concentration In Tempeh per gram μg
Riboflavin	3	7
Pantothenate	4.6	3.3
Thiamine	10	4
Niacin	9	60
B-12	0.15 Mμg	5 Mμg

basic danger is that the peanut press cake used as a substrate may be contaminated with aflatoxin. This was indeed found to be the case in Indonesian peanut press cake which contained from 0.23 to 5 ppm of aflatoxin as received. Only aflatoxin B_1 was present. Using *Neurospora sitophila* as the fermenting organism, approximately 50% of the aflatoxin was destroyed during fermentation. *Rhizopus oligosporus*, as the fermenting organism, destroyed approximately 60% of the aflatoxin present in the peanut press cake. Five samples of commercial ontjom from Indonesia contained from 0.09 to 0.8 ppm of aflatoxin. Thus, fermenting peanut press cake to produce ontjom may make the substrate less dangerous from the aflatoxin standpoint. However, unfortunately, we do not know how dangerous aflatoxin is for humans and, even if the aflatoxin is degraded, we do not know what effect the metabolic or toxic products produced from the aflatoxin may have.

Bongkrek or fermented coconut press cake is susceptible to development of two very potent poisons when the fermentation occurs under conditions unfavorable to the mold (van Veen, 1967). Bongkrek poisoning, which has been responsible for many deaths in Indonesia, is produced by a specific bacterium *Pseudomonas cocovenenans*. The bacterium grows readily on moist coconut press cake, which appears to be a specific substrate for production of the toxin. The bongkrek toxins consists of two substances—toxoflavin and bongkrek acid. Bongkrek acid is an active antibiotic against the mold *Rhizopus*, used in production of white bongkrek. Thus, if conditions are favorable for development of the *Pseudomonas*, the mold is further inhibited from growing.

Two strains of *Aspergillus flavus* were isolated from Ecuadorian rice (van Veen *et al.*, 1968a). Neither produced aflatoxin on a whole wheat medium generally used for toxin formation. No aflatoxin was found in the Ecuadorian rice samples tested.

Consumption of fish sauces and fish pastes has a reputation in the Philippines for causing, on occasion, nightmares and sometimes death. It is said that these generally follow overconsumption of fish pastes. Since the fermentations are generally anaerobic with a wide variety of microorganisms present, it is possible that, under certain circumstances, microbial toxins or toxic amines may be produced.

Generally, Indian idli and the fermented milk-wheat foods such as bulgur kishk are resistant toward development of food spoilage or pathogenic microorganisms because of their relatively low pH.

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