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# A Low Cost Nutritious Food "Tempeh"- A Review

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**Abstract:** A variety of indigenous fermented foods exist today; however, tempeh has been one of the most widely accepted mold-modified fermented products. Tempeh is a popular fermented food in Indonesia which is rich in nutrients and active substances. Recently, the consumption of Tempeh has been increasing rapidly, not only in Indonesia but also in the United States and Europe. Although Tempeh is not likely to be exported, the product is consumed and produced in many countries. This paper reviews the significance of soybean fermentation in tempeh on the vitamins, amino acids, Nutritional quality, functional and physico-chemical properties.

**Key words:** Soy protein · Meat replacer · Fermentation · Functional Properties

## INTRODUCTION

Tempeh is a fermented product made from soybeans that have been soaked and cooked to soften them [1]. Like sour dough bread, tempeh requires a starter substance, which is added to the cooked beans. This mixture is left for 24 hours and the result is a firm textured product with a somewhat nutty flavor and a texture similar to a chewy mushroom. Because Tempeh is firm and it can be formed into a patty, it is used as a substitute for animal products in what in the West is typically called as "mock" burgers or sandwiches [2]. This soya product is especially popular in Indonesia and is considered a national specialty. It has the necessary characteristics of a dietary staple in that is high in protein and fiber and is rich in other nutrients. It also has the advantage of containing Vitamin B-12, which is a by-product of the fermentation process [3]. In this paper the research work carried out on tempeh fermentation and tempeh based products is reviewed.

**Role of Microorganisms in Tempeh Production:** The type of microorganisms involved in tempeh production has been reported by many workers [4, 5]. Tempeh is the result of mixed culture fermentation by a diverse group of microorganisms including moulds, yeasts, lactic acid bacteria and different gram-negative bacteria [6].

*Rhizopus oligosporus* is the dominant tempeh fungus [7] although some other moulds, such as *R. oryzae* and *Mucor* spp, may also contribute to the flavour, texture or nutritive value [8]. Heseltine *et al*. [9] isolated many fungi from different lots of tempeh made in Indonesia and found that only *Rhizophus* could make tempeh in pure culture fermentation. They also found that the 40 strains of *Rhizophus* studied, 25 of them are *R.oligosporus* others are *R.stolonifier, R.arrhizus.R.oryzae, R.formosaensis and.*This finding was also confirmed by Saono *et al* [10], who isolated 118 cultures from 81 tempeh samples collected from markets in various parts of Indonesia.

Mulyowidarso *et al* [11] also reported variable growth of bacteria during fermentation of soybeans into tempeh with *R.oligosporus*. Liem *et al*. [12] first reported that *Klebsiella pneumonia* was responsible for the production of vitamin B12 in commercial tempeh.Yeasts are frequently detected in tempeh, but their role is still unknown [13]. *Rhizopus* moulds produce natural, heat-stable antibiotic agents against some disease-causing organisms. Indonesians who eat tempeh as a regular part of their diet recognize it as a medicine for dysentery and rarely fall victim to the intestinal diseases to which they are constantly exposed [14]. All these workers agree on the fact that Soybean fermentation in tempeh is mainly *Rhizophus oligosporus* dependent.

**Process of Tempeh:** The process involved in Tempeh production differs from each and everyone reported their process based on various factors. The overall production method is followed by flowchart representation [15, 5].

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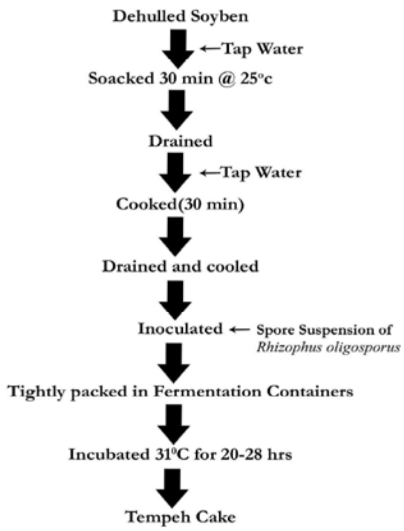


**Production Processes of Soybean Tempeh**

**Principles of Tempeh Production:** Although the principle step in making tempeh is the fermentation of soybeans by Rhizopus mould, many factors affect the success in production and the quality of the product. In the method employed by Steinkraus *et al* [16] raw, dried soybeans are hydrated by soaking in cold water overnight or for a shorter period of time if warm water is used. Lactic acid or acetic acid is added to the water to lower the pH of the solution and soybeans to 5 or below. This step is performed to discourage growth of undesired microorganisms.

The *Rhizopus* mould is largely unaffected by the acidic environment. It was found that mould growth rate remained stable as long as the pH is at or above 3.5 and was slightly slower when the beans were more acidic. After hydration, the skins on each bean are removed to encourage better growth of the mould. This step can be done by rubbing the beans together with hands or by other mechanical means. The skinned beans are then partially cooked by boiling them in the acidic soaking water at 100 °C for 90 minutes.

When the beans have cooled to 37-38 °C, the ideal temperature to begin the inoculation and the beans have been dried, the *Rhizopus* starter culture is mixed to the beans. Sufficient amounts of the culture, or inoculums, needs to be present. In the 1960 study by Steinkraus *et al*, the inoculums were added at 1 gram per kg of cooked soybeans. The inoculated beans are then placed on covered trays, in a layer no thicker than 2 inches, so that sufficient oxygen is available on the bean surfaces for mould growth. Small holes in the trays are also beneficial in ensuring sufficient oxygen supply.

In addition to oxygen, the mould grows better in high humidity levels (75-78%). However, no liquid water should be in contact with the beans [17]. The ideal temperature for *Rhizopus* growth is 37°C, so the trays of beans are best kept at this temperature. During the phase of active mould growth, however, the temperature of the beans will naturally rise above the ambient temperature. Temperatures of up to 49°C were measured, where further mould growth was inhibited by this high temperature. It was found that keeping the temperature below 415°C and above 25 °C was sufficient for satisfactory mould growth, although at 25 degrees Celsius, fermentation takes 5 days, which is 5 times as long as the time it takes to ferment at 37°C [5].

**Stages of Fermentation:** Steinkraus *et al* [6] reported that the initial few hours after inoculation, germination of spores takes place. Slow mould growth takes place for several hours after the germination phase. Later, rapid mould growth and temperature increase continues for 4 to 5 hours. As mould growth declines, the beans should be bound into a solid mass by the mycelium. After mould growth declines, sporulation and ammonia production due to protein breakdown appears.

Beuchat [18] reported that the pH level on the beans also changes as mould growth occurs. From an initial pH of 5.0, the pH level reaches 6.0 to 6.7 during the peak of mould growth and continues to increase to 7.6 as time passes. It was found that the tempeh is most palatable when the pH is between 6.3 and 6.5. This is the same time that the mould overgrows the soybean cotyledons. In short, two characteristic events from mould growth need to take place for the fermented soybeans to become tempeh. Firstly, the individual beans will be bound into a solid cake by the mould mycelium. Secondly, the soybeans become partially digested by the mould enzymes.

**Anti-microbial Effects of *R. Oligosporus*:** *R. oligosporus* can inhibit the growth and aflatoxin B1 accumulation of *Aspergillus flavus* and *A. parasiticus* [19]. *R. oligosporus* has been reported to produce 4 to 5 anti-bacterial compounds during soybean tempeh fermentation [20-22]. The fungus also produces phenolic compounds that inhibit the growth of pathogenic bacteria such as *Helicobacter pylori* [23-27].

An antibacterial protein has been purified from *R. oligosporus*, with activities against *Bacillus spp*. (especially against *Bacillus subtilis*), *Staphylococcus* *aureus* and *Streptococcus cremoris* [28]. *R. oligosporus* can also produce certain compounds that interfere with the adhesion of *E. coli* to small intestinal brush-border membranes [29].

**Preservation of Tempeh:** Freshly made, raw Tempeh remains edible for a few days at room temperature. The tempeh is neither acidic nor does it contain large amounts of alcohol. Tempeh does, however, possess stronger resistance to lipid oxidation than unfermented soybeans, due to its antioxidant contents [17]. Traditionally, fresh tempeh is preserved by sun-drying, but modern methods are faster and reduce the risk of contamination. In the study by Steinkraus *et al* [16] the tempeh were preserved by quick freezing (-15 °C) and lyophilisation, or by drying in a circulating hot air oven at 69°C. Deep fat frying is another possible preservation method for tempeh.

Biotechnology improved the inoculum, which makes a *Tempe* variant possible that may be protected by an international patent [30].Modern processing methods mainly entail improving equipment needed, maintaining a sanitary and hygienic environment, creating an inoculum by selected microorganisms and modernizing the methods of packaging [31].

**Nutritional Information:** The nutritional and functional characteristics of fermented soybean have been examined and reported.

**Tempeh is:**

- An excellent source of protein, contains all the essential amino acids; same quality protein as meat or poultry.
- Excellent source of calcium.
- Low in saturated fat
- High in essential fatty acids & B vitamins
- Cholesterol free.
- High in soluble dietary fiber.
- Fermentation neutralizes the phytate acid present in the soybeans; therefore tempeh does not restrict the body's absorption of minerals.
- Easy to digest because the fermentation process breaks down the complex proteins found in soybeans, making tempeh more easily digested than non-fermented soy foods or whole soybeans.
- High in isoflavones.
- A good source of folic acid.
- Low in sodium.

**Health Benefits of Tempeh:** Soy's key health benefits are related to its excellent protein content, its high levels of essential fatty acids, numerous vitamins and minerals, its isoflavones and its fibre. Recent reports suggest that tempeh contains a wealth of nutrients that are tied to an impressive array of health benefits, including decreased risk of heart disease and strokes, osteoporosis, cancer and digestive disorders, losing excess weight in addition to easing some of the symptoms of menopause.

**Soy Protein and Cardiovascular Disease:** Krumhar and Kim Carleton [32] reported that Considerable evidence supports a role for soy protein in reducing the risk of cardiovascular disease, the number one killer of adults. Soy products are free of the saturated fat implicated in many health problems and particularly heart related problems. Soy products appear to lower total blood cholesterol and LDL levels at about the same rate as decreasing fat in the diet. The U.S.A. Food and Drug Administration states that: "25 grams of soy protein a day as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease".

**Soy Protein and Bone Health:** Messina and Messina [33] reported isoflavones in soybean increase the bone mineral content of postmenopausal women, decreasing the possibility of osteoporosis. Good bone health throughout life helps prevent osteoporosis, a major cause of disability in later years. Research suggests that consuming soy protein may help protect bones from becoming weak and brittle, especially for post-menopausal women whose risk of osteoporosis is increased.

**Nutritional Facts**

*Serving Size:1 cup(166g)*

*Amount serving*

| | | |
|---|---|---|
| Calories 320 | Calories from fat 150 | |
| | | % Daily Value |
| Total fat | 17.93 | 28% |
| Saturated Fat | 3.69 | 18% |
| Sodium | 14.94mg | 1% |
| Potassium | 683.92mg | 20% |
| Carbohydrate | 15.59mg | 5% |
| Calcium | 184.26mg | 18% |
| Iron | 4.48mg | 25% |

*Source: USDA Nutrient Database for Standard refernce*

Table 1:

| Raw materials | Organisms | References |
|---|---|---|
| Legumes | | |
| Soybeans (Glycine max) | *R.oligosporus* | Nout *et al* [40], Varzakas [41] |
| Black gram (*Phaseolus mungo*) | *R.oligosporus* | Jha and Verma [42] |
| Cereals | | |
| Barley (*Hordeum vulgare*) | *R.oligosporus* | Nout and Rombouts[2],Hachmeister and Fung[15],Berg *et al*., [43] |
| Wheat (*Triticum vulgare*) | *R.oligosporus* | Hesseltine and Wang [44] Nout and Rombouts[2], Hachmeister and Fung[15] |
| Sprouted Broken rice | *R.oligosporus* | Dinesh [45] |
| Mixture of legumes with nonlegumes | | |
| Sesame and soybean | *R.oligosporus* | Shurtleff and Aoyagi [14] |
| Maize and soybean | *R.oligosporus* | Nout and Kiers [5] |
| Press cake (by-products) | | |
| Soybean residue from soy milk preparation or okara | *R.oligosporus* | Ko Swan and Hesseltine[46], Matsuo [47] |
| Groundnut presscake (*Arachis hypogaea*) | *R.oligosporus* | Gandjar [48] |

**Soy Protein and Cancer:** Badger *et al* [34] reported that soy protein may have a role in reducing the risk of certain cancers, particularly breast, colon and prostate cancer.

**Weight Loss:** Yee Kaye [35] reports that fat levels are known to lead to increased risk of several diseases, including heart disease, stroke, bone fractures, breast cancer and other cancers. Research studies have documented two key properties of soy protein that help with weight loss independent of its low-calorie and low-carbohydrate content. The studies show that consumption of soy protein contributes to weight loss by decreasing the amount of fat your body stores while increasing lean muscle mass.

**A Healthy Transition Through Menopause:** D Lee Alekel *et al* [36] reported that soy products appear to decrease the symptoms of menopause, especially hot flashes.

**A Health-Promoting Meat Replacer:** Adisak Akesowan [37] reported that the soy products are excellent vegetable sources of protein. Many current health recommendations suggest limiting animal protein, so substituting tempeh for chicken, beef, or pork makes sense. Most of the non-vegetarians started to consume soy protein Tempeh instead of meat.

**Mild for Kidney:** Pedraza Chaverrí [38] reported that the people with reduced kidney function--such as those with diabetes who have nephropathy--can benefit by replacing animal protein with soy.

**Tempeh Based Products:** Traditionally, tempeh was made from soybean. Yellow-seeded soybeans are usually preferred as raw material [7], but many different substrates can be used to produce tempeh (Table 1). Some substrates can only be processed to obtain high quality tempeh by combining them with soybeans [21, 39, 14].

## CONCLUSION

Tempeh provides the staple food for a large population in Indonesia and Malaysia. Soybeans are the primary ingredient in many processed foods, including dairy product substitutes. It is commonly consumed by poor masses of many countries and it forms a major source of proteins and calories. Now it is also made in modern, sanitary plants, using stainless steel equipment and sometimes, pure cultures of mould. Fermentation of soybean improves digestibility by reduction of anti-nutritional factors: tannin and phytase in addition to production of acids which inhibit the production of pathogenic bacteria and this is particularly important in the manufacture of food designated for special targeted groups such as infants and old aged ones. Tempeh is a low cost nutritious food and can consume by all socio-economic groups.

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