Soy Sauce

Introduction

The term soy sauce commonly refers to a light- to dark-colored liquid made from soybeans. Soy sauce is a condiment and seasoning which has a savory taste and specific aroma, and it contributes to palatable cuisines in many Asian countries. There are three different categories of soy sauce on the market, according to the production process, i.e., fermented soy sauce, chemical soy sauce, and a combination of fermented and chemical soy sauce (Fukushima, 1981; Hesseltine & Wang, 1980). However, the original soy sauces are usually the fermented ones (Fukushima, 1981).
They started to use chemical soy sauce decades ago; it was made by a rapid acid hydrolysis of soybean proteins. Fermented soy sauce has been produced since ancient times by using microbes to ferment soybeans for months. Traditionally, the fermentation process involves molds at the first stage and then bacteria and yeasts at the next stage under high salt condition.

History

Soy sauce has been traditionally produced since 2,000 years ago in China, where it was formerly called chiang and shih and then chiang-yu in the sixteenth century. This tamari-type soy sauce was introduced into Japan before 700 AD, and in the sixteenth century, the name of shoyu was recognized. Chiang-yu in China and shoyu in Japan have the same Chinese characters (Yokotsuka, 1986).
The tamari-type soy sauce was also widely produced in Southeast Asian countries, including Indonesia, Singapore, Malaysia, Thailand, and the Philippines, previously following the Chinese or Cantonese traditional techniques spread from generation to generation, but since several decades ago applying Japanese modern production techniques. In Indonesia, soy sauce is called kecap. But, this term is also familiar to people in some Southeast Asian countries such as Malaysia and Singapore.

Types of Soy Sauce

Soy sauce can be grouped into two types: Japanese and Chinese. Japanese soy sauce uses soybeans and wheat in equal amounts; this type is differentiated further into koikuchi, usukuchi, and saishikomi shoyu in Japan regarding their different production process and product characteristics in color, aroma, and viscosity. Another type of shoyu, shiro shoyu (shiro means white in Japanese), actually has a very light and transparent yellow color because of the large amount of wheat with very few soybeans. Chinese soy sauce uses no or a small amount of wheat as an addition to the soybeans; this type is called tamari shoyu in Japan and has a very dark color.
The type of soybeans used for Japanese soy sauce production is commonly yellow soybeans, while the Chinese type found in Indonesia uses black soybeans. Yellow and black soybeans are of the same species Glycine max, but they are different in their outer color.

Traditional Production

In general, there are two steps to the fermentation process in soy sauce production either in traditional or modern industrial production. The first step is solid-state fermentation (typically called koji in Japan or bungkil in Indonesia) which involves some molds. The second step is brine fermentation (called moromi in Japan or baceman in Indonesia) at high sodium salt concentrations, ranged 17.5-20 %w/v, by involving some halophilic bacteria and osmophilic yeasts. Molds in the first step are mainly Aspergillus oryzae, Aspergillus sojae, and Aspergillus tamarii as found in soy sauce production in Japan, China, and Southeast Asia. Bacteria and yeasts in the second step of fermentation are salt-tolerant lactobacilli, Saccharomyces rouxii and Candida versatilis found in Japanese soy sauce (Yokotsuka, 1986) and Pediococcus halophilus, coryneform bacteria, Zygosaccharomyces rouxii, and Candida parapsilosis found in traditional Indonesian soy sauce production (Röling, Apriyantono, & van Verseveld, 1996; Röling, Schuurmans, Timotius, Stouthamer, & van Verseveld, 1994; Röling, Timotius, Prasetyo, Stouthamer, & van Verseveld, 1994). In Indonesia, traditional production applied the spontaneous solid-state and brine fermentation.

A study on traditional soy sauce production in Southeast Asia was conducted with Indonesian soy sauce, kecap. The boiled whole soybeans are subjected to spontaneous solid-state fermentation for 1-2 days, and then the resulted bungkil is sun dried and mixed with brine solution (three to four times of volume); afterwards the baceman fermentation stage started for 4 months or less spontaneously. Since ancient times, people used sun drying for the bungkil and the baceman. The sun-dried bungkil gave a faster growth of lactobacilli in the next step of fermentation. The baceman process under the sun could avoid the growth of spoilage microbes at the surface. Otherwise, the salt hygroscopic property might lower the salt concentration at the surface, and therefore lesser salt-tolerant microbes such as film/pellicle-forming yeasts could grow and spoil the baceman (Röling, Timotius, Stouthamer, & van Verseveld, 1994). The salt concentration range could be maintained if the baceman was simply left to be opened under the sun with a periodic mixing.

At the final process of traditional production, the moromi or baceman yielded is then filtered manually or mechanically to obtain a raw liquor. This liquor is then pasteurized and bottled for shoyu before being marketed, or else it is boiled, and then a high amount of brown sugar is added during boiling to produce a thick and sweet soy sauce, called kecap manis. Or a very small amount of brown sugar is added to produce a thin and salty soy sauce, called kecap asin.

Modern Industrial Production

Modern industrial production has been widely applied for Japanese-type soy sauce production, either in Japan or in Indonesia, which applied the modern soy sauce process technology and used defatted yellow soybean flakes and wheat for raw materials. The modern technology allows a more controlled koji and brine fermentation with the use of pure microbial cultures, temperature controls, and mechanical mixing. The full equipment process for automatic koji preparation replaced the traditional process. The equipment consists of a continuous soybean cooker as well as continuous wheat roaster, automatic inoculators with an automatic mixer, large perforated shallow vats equipped with forced air devices, temperature control device, and mechanical turning device during incubation (Fukushima, 1985). The length of koji preparation, nevertheless, is almost the same as in the traditional process, 48 h.

By the use of modern technology, the length of brine fermentation could be reduced from 1 to 3 years in the traditional shoyu production to less than 1 year (4-8 months) in modern industrial production in Japan (Yokotsuka, 1986). The length and condition of brine fermentation either in traditional or modern production in Indonesia are the same, 4 months and at the same spontaneous condition subject to tropical weather. This is because the soy sauce aroma found in shoyu is less important for Indonesian soy sauce (Röling et al., 1996).

In the final process, moromi filtration using modern equipment with high pressures is applied. Currently, the membrane technology using nanofiltration has been developed to provide the standard color for soy sauce products in modern industries (Miyagi, Suzuki, Nabetani, & Nakajima, 2013).

Chemistry and Biochemistry

Yong and Wood (1977) studied the release of extracellular protease and carbohydrase complex enzymes during koji fermentation. Protease complexes in koji hydrolyze soy proteins into peptides and amino acids, while carbohydrase complexes hydrolyze wheat carbohydrates into sugars. The ratio of peptides to amino acids in koji is nearly 1:1. The main free amino acids found in koji are glutamine and glutamic acid (Flegel, 1988). Glutamic acid is related to an umami taste (Lioe, Apriyantono, Takara, Wada, & Yasuda, 2005).

In the brine fermentation, lactic acid is produced at the earlier stage by the action of lactobacilli; therefore, the pH of moromi decreases rapidly, and then some phenolic and aroma compounds are formed due to the alcoholic fermentation by osmophilic yeasts at the next stage of moromi production. However, the alcoholic fermentation was not found in Chinese- or tamari-type soy sauce because of the lack of carbohydrate during the fermentation process as a result of the use of different composition of raw materials (Apriyantono, Husain, Lie, Jodoamidjojo, & Puspitasari-Nienaber, 1999). The presence of lactic acid as a dominant organic acid in soy sauce could be used to identify the fermented soy sauce from chemical soy sauce which is dominated by formic acid.

Glutamic acid is the main amino acid in soy sauces and contributes to their intense umami taste. In fact, the use of black soybeans could lower the glutamic acid present in soy sauce, compared to the use of yellow soybeans (Apriyantono,

Setyaningsih, Hariyadi, & Nuraida, 2004).
Nitrogenous compounds such as small peptides and free amino acids, as well as sugars, are still present in the final product and contribute to the quality and taste of soy sauce. However, the peptides make a relatively low contribution to the intense umami taste of soy sauce (Lioe, Takara, & Yasuda, 2006). Some dipeptides - Ile-Gln, Pro-Lys, Ile-Glu, Thr-Phe, and Leu-Gln - are clearly found to correlate to soy sauce sweetness (Yamamoto et al., 2014). Japanese-type soy sauce has more esters and phenols as aroma compounds. Volatile organic acids are dominant in Chinese- or tamari-type soy sauce.

Potential Benefits and Risks

The use of soy sauce as an antioxidant in a food system such as raw beef patties has been investigated (Kim et al., 2013). A kokumi peptide is also found in soy sauce, i.e., γ-Glu-Val-Gly (Kuroda et al., 2013) at concentrations 1.5-6.1 ppm. The kokumi characteristic could contribute to the savory taste of the food.
The use of molds during koji fermentation has become a concern about the mycotoxin in soy sauce. As much as 97.5 % of soy sauces marketed in China were contaminated with deoxynivalenol or DON at concentrations of 4.5-1,245.6 ppb (Zhao, Wang, Zou, & Zhao, 2013). Kojic acid, another mycotoxin, is also produced by Aspergillus oryzae, Aspergillus sojae, and Aspergillus tamarii (Flegel, 1988). Therefore, harmless strains of the molds should be used for soy sauce production.
A high-temperature-derived contaminant, 3-monochloropropane-1,2-diol (3-MCPD), could be found in the half-fermented soy sauce and chemical soy sauce products. This contaminant is formed during the acid hydrolysis of soy proteins by hydrochloric acid (HCl) under a certain condition due to the reaction between HCl and the soybean fat under heat (Nagodawithana, 1995; Nyman, Diachenko, & Perfetti, 2003). 3-MCPD is carcinogenic in human with a tolerable daily intake (TDI) of 7 μg/kg body weight/day (Rietjens, Scholz, Berg, Schilter, & Slob, 2012). However, 3-MCPD is found even though at a relatively low level in some traditional fermented soy sauces.

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