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MiniReview
Popular fermented foods and beverages in Southeast Asia

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Abstract: Fermented foods are prevalent in Southeast Asia to balance the fluctuation in food availability in the area during the stage of monsoonal circulation. Techniques of preserving cereal and seafood products are well-developed in Southeast Asia. The review concerning the indigenous carbohydrate-based fermented foods the region, including rice wine, fermented palm sap and *tapai*. The paper focuses on the popular indigenous fermented foods and beverages produced in the region including the consumption and processing methods. Microbiological and chemical properties of these indigenous fermented foods were also discussed. Another issue is in the alcohol-related health risk due to the consumption of the foods and beverages with high alcohol content. Hence, ethanol and other alcohol-related compounds present in the selected alcoholic fermented foods will be highlight.

Keywords: Traditional fermented food, *tapai/tape*, toddy, rice wine, Southeast Asia

Introduction

Foods are the basic survival needs for human being. Since ancient time, various methods have been used to process and to preserve foods. Fermentation is one of the oldest and widely used food preservation methods in households, small-scale food industries as well as in large enterprise. Fermented foods generally preserved pleasant flavor, aroma, texture, enhanced nutritive values and good keeping quality under ambient conditions. Holzapfel (2000) described fermented foods as palatable and wholesome foods prepared from raw or heated raw materials. Several classifications had been used to categorize the wide spectrum of fermented foods including the diversification of microorganisms, different food groups and types of fermentation involved (Steinkraus, 1996; Yokotsuka, 1982; Campbell-Platt, 1987; Dirar, 1993). Alcoholic fermentation involving the production of ethanol is generally yeast fermentation. Fermented foods are generally produced from plant or animal-based raw materials in combination with fungi or bacteria, which are either present in the natural environment, or added intentionally by human to obtain the desirable end products.

According to Nout and Mortarjemi (1997), fermented foods are typically unique and vary according to regions due to the variation in climate, social patterns, consumption practices and most importantly the availability of raw materials. Availability of raw materials brings about the conversion of the raw materials to different form of fermented food products in order to increase the food varieties as well as to maintain food security. Techniques and practices of preserving plants such as rice and seafood products are well-developed in Southeast Asia region as to balance the fluctuation in food availability in the area during the stage of monsoonal circulation. Southeast Asia produces 150 million tones of paddy per year (25% of world production), of which 95% is consumed within the region (Mutert and Fairhurst, 2004). Fermentation of cereal grains to produce a wide variety of foods had been a practice for long time. Rice wine is one of the popular alcoholic beverages in Asian country. Cassava supports nearly half a billion people as a source of dietary calories and as a source of income. Asia region produced 32% of the world cassava, only behind the African region with 48% of total production (Onwueme, 2002). Cassava tubers normally consumed as staple food, used for starch processing or as carbohydrate-rich animal feed in Southeast Asia region. In countries such as Malaysia and Indonesia, cassava tubers is fermented to produced the popular sweet and sour snack namely *tapai/tape*. Stanton and Owens (2004) reviewed the history of fermentation in the Southeast Asia region and concluded that the foods and beverages consumption practices in the region greatly influenced by the migrating cultures. Consumption of wines from the inflorescences of palm such as coconut and *talipot* palm, is derived from the landscape of Indo-China and Sri Lanka.

This review aims to summarize the consumption

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and production process of the local alcoholic fermented foods including the *tapai*, which are common in Southeast Asia region. This review also aims to highlight some of the microbiological and chemical properties of these foods. All information and knowledge about the traditional fermented beverages and foods were complied by computer-assisted literature search using the online scientific database including Science Direct, Scopus (Elsevier, Amsterdam, Netherlands), PubMed (United State. National Library of Medicine, Bethesda, MD), EBSCOHost (Nucleus Medical Media Inc.) and Springerlink (Springer Science Publishers). The following terms were searched: "alcoholic fermented beverages", "traditional beverages in Southeast Asia", "rice wine", "toddy/fermented palm sap", "starter culture/ microorganism fermentation", "higher alcohol in homemade/surrogate alcohol". Relevant references imported into RefWork (ProQuest LLC, Bethesda, MD) and downloaded for information.

Consumption of the alcoholic-containing fermented products in the region

Palm based fermented products

Fresh nipah palm (*Nypa fruticans*) sap and neera (sap obtained from by tapping the unopened spadix of the coconut palm are popular beverages in the region. For Muslim consumers, palm juice (fresh saps) are consumed within 2 days after tapping as it is highly susceptible to spontaneous fermentation to produce alcohols and acetic acids. Fermented palm saps can also be used to produce alcohol, vinegar or alcoholic beverage such as palm wine. The fermented beverage is called "*panam culloo*" in Sri Lanka, "tuba", "*soom*" in the Philippines, "*nuoudua*" in Vietnam, "*arak*" in Indonesia, and "*tuak*" (tuack) or toddy in Malaysia, India and Bangladesh. (Lee and Fujio, 1999). Palm wine is obtained by the natural fermentation of palm sap and collected through the tapping of unopened inflorescence. Palm wine has mild alcoholic flavor, sweet in taste, vigorous effervescence and milky white in color as it contained suspension of numerous bacteria and yeast. Palm wine from coconut flower juice is most popular among Southeast Asia regions. A community survey on the non-Muslim Balinese village in Indonesia showed approximately 40% excessive consumption of locally produced palm wine in 1990 (WHO, 2004).

Rice based fermented products

Rice wine is a popular alcoholic beverage in the Asian country. According to Lachenmeier *et al*. (2009), the most common unrecorded alcohol beverage in the Philippines is rice wine. In rural area of Vietnam, the production of fermentation of grain such as rice to produce rice wine is one of the income sources for farmer families (Dung *et al*., 2007). *Tapuy* and *ruou nep* are the popular rice wine in Philippines (Kozaki and Uchimura, 1990). *Tapuy* is a sweet and acidic alcoholic rice wine whereas *ruou nep* is a turbid suspension of pink red color with some residual sugar and contained 8–14% (w/v) alcohol (Aidoo *et al*., 2006). Rice wine is normally used for celebration or ceremony. Traditional alcoholic beverages made from rice starch are very popular in Thailand and produced locally in large amounts (Techakriengkrai and Surakarnkul, 2007). Thai rice wines are normally cloudy and yellow in color. *Sato* and *krachae* are examples of popular rice wine in Thailand made from cooked/raw glutinous rice (Aidoo *et al*., 2006). Rice wine such as *Tapai* and *Tuak* are popular at East Malaysia. *Tapai* (not the fermented snack) is made by Kadazan-Dusun-Murut (KDM) ethnics from Sabah. This drink is prepared by the Kadazan for gathering and festival celebration (Chiang *et al*., 2006).

Tapai as fermented product

Tapai is a very popular fermented snack in Asian countries. It can be prepared using either glutinous rice (*Oryza sativa glutinosa*) or cassava tuber (*Manihot utilisima*). After fermentation, the glutinous rice or cassava is soft and juicy. *Tapai* is a popular dessert/snack with a sweet and acidic taste with mild alcoholic flavor. *Tapai* is a perishable product and has to be consumed immediately (within 3 to 4 days) after the optimum stage of fermentation. It is produced in the region on a cottage industry scale by traditional manufacturers or at home for family consumption. In Indonesia and Malaysia, *tapai* is served during traditional ceremonies such as celebrating birth of babies, marriage, and religious activities. *Tapai/tape* is also consumed as snack and commonly sold in departmental stores (Gandjar, 2003). In some eastern state of Peninsular Malaysia, *tapai* from cassava is very popular and used to prepare sweet delicacies. They can be consumed as such or used as an ingredient in homecooking and baking. There are many recipes with *tapai* as main substrate. The cassava *tapai* is sometimes baked as a cake (cheese *tapai* cake) or cooked in coconut milk with palm sugar as a delicious snack.

Production method

Palm based fermented products

There are a number of genera of palm that are prevailing in the region, including coconut palm

(*Cocos nucifera*), nipa palm (*Nypa fruticans*), palmyra palm (*Borassus flabellifer*) and kithul palm (*Caryota urens*) (Owen and Stanton, 2003). Coconut palm is native to the coastal regions of tropical Southeast Asia. The coconut provides a nutritious source of meat, juice, milk, and oil that has fed and nourished populations for generations. *Nypa fruticans* is also an outstanding provider of various products which are essential to everyday living and therefore is said to be the mangrove's counterpart of coconut (Quimbo, 1991). Kithul palm naturally grow in the wild, in forest covers, in fields and in rain-forest clearings. It is a species of indigenous flowering plant in the palm family from Sri Lanka, Myanmar and India. Palmyra palm is widely grown in the districts nearby the sea-shore also available all over the region. Most tapped palm trees give a sap very rich in sugar (10 to 20%), can either consumed as fresh juice, syrup, sugar. or fermented to alcoholic drinks (toddy). Palm juice is a transparent fresh sap with pH 7.0-7.4. It is sweet and non-alcoholic before it is fermented. Palm wine or toddy, is an alcoholic beverages produced from fermented sap of various species of palm trees.

Tapping is the method of obtaining palm sap from unopened inflorescence of the palm (Grimwood and Ashman, 1975). Highly sophisticated techniques of tapping were developed through the centuries in Asia, Africa and America. The spathe of unopened inflorescence is bounded tightly for about three weeks before tapping to prevent it from opening. During tapping, around 5cm of the spathe are cut from the end to obtain the sap. In traditional method, local manufacturers used bamboo tubes that adhered by many lactic acid bacteria and yeasts to collect the oozed sap from the palm (Aidoo *et al*., 2006). Tapped palm saps left spontaneously fermented in the earthern pitcher (Sri Lanka) or in the bamboo tube (Thailand), which promotes the proliferation of yeast and bacteria present. The tapper usually changes the pot twice daily (Grimwood and Ashman, 1975). Tapping of another popular palm sap, Nipah palm (*Nypa fruticans*) is slightly different from the coconut sap. Sap is collected from its mature fruit stalk after cutting away the almost full grown fruit head. During tapping, a bamboo container or plastic bag is fastened at the sliced end for sap collection. The stalks are grown from the ground, so climbing is not needed for tapping neera sap as for coconut sap. Palmyra palm, is common in tropical countries such as Sri Lanka, India, Malaysia, Indonesia and Philippines. Collection of sap from palmyra palm was done by cutting the panicles grown at the head of the tree a very sharp sickle or knife. The inflorescence axis of these palms when tapped can secrete about 4 liters of sap per day, with maximum production in April and May when the plants are in full bloom (Steinkraus, 1985). As in most palms, the kithul palm sap is extracted from the young inflorescence. The main inflorescence axis yields the greatest amount of sap. The terminal end of the main axis is gradually sliced off with a very sharp knife. The exuding sap is collected in a vessel. The vessel full of sap is removed twice a day, usually at 6 am and 4 pm. A thin slice is cut off the end of the inflorescence axis each time a collection is made and replaced with a fresh pot. This process being carried out for a period of about two months (Zoysa, 1992).

As soon as the sap trickles down from the spather, spontaneous fermentation by microorganism from the inflorescence, collection tube and the environment. Fermentation is very vigorous after 24-48 hours. Microorganisms convert sugars in sap to alcohol and further to acetic acids. Due to the highly fermentable nature of the sap, the final product of the prolonged fermentation will produced unacceptable flavor and aroma. Quality of the fermented toddy was improved by using pure cultures inoculation method (Sanchez, 1979). During the fermentation process, yeast sediment at the bottom of the container after few hours and produced typical yeasty odor. The composition and quality of palm sap greatly affected by the location, weather, time and duration of tapping (Borse *et al*., 2007).

Microbiological and biochemical changes during fermentation

The palm sap fermentation involved alcoholic–lactic–acetic acid fermentation, by the presence of mainly yeasts and lactic acid bacteria. Aidoo *et al*. (2006) concluded that *Saccharomyces* spp. present in the natural fermented palm sap and are important for the formation of characteristic aroma of the palm wine. *S. cerevisiae* and *S. pombe* have been reported to be the dominant yeast species (Odunfa and Oyewole, 1998). Other yeast species such as other *Candida* spp and *Pichia* spp. are also present (Atacador-Ramos, 1996). Lactic acid bacteria and other bacteria such as *Lactobacillus plantarum*, *L. mesenteroides*, *Acetobacter* spp. and *Zymomonas mobilis* are also present. The microorganisms are reported to originate from the palm tree, the gourd used for sap collection and fermentation, or the tapping equipment. Study done by Atputharajah *et al*. (1986) reported the presence of seventeen (17) species of yeasts and seven (7) genera of bacteria in the natural fermented coconut palm sap. Yeast species found include the *Candida paropsilosis*, *C. tropicalis*, *C. valida*, *K. javanica*, *Pichia etchellsii*, *P. farinose*, *P. guilliermondi*, *P. membranaefciens*, *P. ohmeri*, *Rhodotorula glutinis*, *Saccharomyces chevalieri*, *S. ludwigii*, *S. bailii*, *Schizosaccharomyces pombe*, *Sporobolomyces salmonicolor* and *Torulopsis* spp. *Bacillus* is the predominant bacteria genus while others included *Enterobacter*, *Leuconostoc*, *Micrococcus* and *Lactobacillus*.

Fresh coconut sap contained 12-15% of sucrose (by weight) and trace amount of reducing sugar including glucose, fructose, maltose and raffinose. The sap contains approximately 0.23% protein, 0.02% fat. Half of the total sugars are fermented during first 24 hours and ethanol content of the fermented palm sap reaches maximum of 5.0 – 5.28% (v/v) after 48 hours (Sekar and Mariappan, 2005). Atputharajah *et al*. (1986) studied the chemical changes of coconut palm sap during fermentation. Coconut sap contains 15% sucrose and is converted to ethanol during fermentation. A constant pH drop observed at the initial fermentation stage, and sugar conversion begins and produces ethanol production at constant pH. Ethanol production reaches maximum after five days fermentation. Shamala and Sreekantiah (1988) reported that the fermentation produces mainly ethanol, acetic acid and lactic acid. pH of the sap rapidly dropped from around 7.2 to 5.5 due to formation of acetic acid and ethanol content drastically increased to 5% (v/v) within 8 hours. Palm wine was found rich in mineral as it contains 0.019 – 0.028% (w/v) of vitamin B-12 and 0.008% of ascorbic acid (Van Pee and Swings, 1971). Steinkraus (1994) reviewed the nutritional value of the fermented palm sap and stated that palm toddies are one of the cheapest sources of vitamins B among the poorer communities in the region. Amount of thiamine, riboflavin and pyridoxine increases during the fermentation. Fermented palm sap also contained significant amount of vitamin B12 (0.02%) and vitamin C (Van Pee and Swings, 1971).

Rice based fermented products

Rice is the dominant and preferred cereal crop in Southeast Asia. Almost all cultivated varieties of rice belong to a single species, *Oryza sativa* with about 120,000 varieties. Glutinous rice (or sweet rice), grown mostly in Southeast Asia and are typically used in ceremonial dishes and in paste. Most rice-based alcohol is brewed form the sticky rice. Rice wines produced in Indonesia, Myanmar, Thailand, Malaysia and Vietnam are typical alcohol brews from the waxy or glutinous rice. The round and short grains of glutinous rice is ideal for rice wine making. Preparation of rice wine varies according to locations and traditional practices. Generally, rice wine fermentation can be categorised into submerged and solid state process. Submerged process involving saccharification of rice to liberate sugar and converted to ethanol by submerged fermentation of yeast in liquid medium occur with plenty availability of free water (Ray and Ward, 2006).

General procedure to produce rice wine includes wash the rice, immerse the washing rice in water for certain period, and steam it. Steamed rice will be spread out on cloth for cooling to room temperature (Sanchez *et al*., 1988). Starter culture is then added at ratio of at 1g per 100g of raw rice and mixed well. Starter culture normally contains *Rhizopus* which have the ability to decompose amylase and *Sacharomycopsis* which have the ability to promote alcohol fermentation. The inoculated glutinous rice are incubated in trays and covered with a piece of paper (Chiang *et al*., 2006). After two days at room temperatures (25–30 ºC), the products were transferred to a fermentation jar with a water seal to allow rice to ferment for two weeks. The fermented mass is squeezed using cheesecloth to collect alcoholic juice and residues were discarded. The freshly harvested wine was pasteurized at 65-70 ºC for 30 minutes. Pasteurized wine was allowed to stand for one to three months in dark, cool place to prevent discolouration. After the maturation, wine can be bottled and pasteurized at 65-70ºC for 20 minutes. Approximately 1 liter of rice wine can be harvested from 1kg of the rice. *Pangasi* in northwestern Mindanao, *ba-si-de* and *tapuy* in Vietnam, *tapay/ tapai* in Eastern Malaysia and brem in Indonesia were produced using similar method (Sanchez *et al*., 1988).

Solid state fermentation is another way of rice wine production. *Ruou nep* and *ruou nep than* in Vietnam, Ou in Thailand and rice wine from Cambodia and Laos are produced using the method. Solid state fermentation is, process where microbial growth and product formation occurs on the surface of solid materials (Aidoo *et al*., 2006). Glutinous rice is first soaked in water overnight and cooked by steaming. The steamed rice is cooled, mixed with dry starter culture and incubate in solid state at room temperature for 1 to 2 days. The inoculated rice paste is then transferred into an earthenware jar, covered and tightly sealed The jar is left at room temperature to ferment for more than a week. The fermented content was eluted with water upon drinking (Chuenchomrat, *et al*., 1998; Aidoo *et al*., 2006).

Microbiological and biochemical changes during fermentation

There are two primitive methods used in cereal saccharification and fermentation. Malting process used in beer production is common in Europe. Another method which through the degradation of carbohydrate into simple sugar followed by alcoholic fermentation via yeast is more commonly practiced in rice wine production in the Southeast Asia region (Lee and Lee, 2002). Rice wine preparation involved alcoholic fermentation using mainly yeast from *Saccharomycopsis* spp.. *S. fibuligera* with high ethanol producing capacity and amylolytic activity, is the common yeasts present in rice wine starter in Southeast Asia region (Limtong *et al*., 2002). At the initial solid-state fermentation, mould produced enzymes such as *alpha-amylase* and *amyloglucosidase* for rice starch degradation to form simple sugar, mainly glucose (Crabb, 1999).

Rice wine and tapai produced using the same amylolytic starter culture as both fermented from carbohydrate-rich raw materials. Some molds and yeast can produce enzyme to hydrolyze unpalatable carbohydrate and protein into simpler sugar and amino acids. However, the combination of the microorganism is also found. Hesseltine *et al*. (1988) stated that amylolytic starter in Oriental (East and South Asia) typically combined the fungus, yeast and bacteria. Mixed cultures were used instead of sequential fermentation in the amylolytic starter, which moulds are able to degrade starch and yeasts are for fermentation (Aidoo *et al*., 2006). Mixed cultures are commonly used for fermentation of carbohydrate-rich substrate such as starchy crops and cereals, for example in converting rice, sorghum, wheat, barley, and cassava into alcoholic beverages and snacks.

Amylolytic starters commonly known as “chinese yeast cake” in the Western world and are used in the form of starchy tablets. It is believed that the usage of the dry form starters originated from China (Limtong *et al*., 2002). These starters or inoculum are commercially produced and given different names in the different Southeast Asian region. Studies on the microflora of the starter cultures have been widely reported (Ko, 1972; Batra and Millner ,1974; Cronk *et al*., 1977; Ardhana and Fleet, 1989; Lee, 1990; Limtong *et al*., 2002; Chiang *et al*., 2006; Thanh *et al*., 2008). Table 1 summarized the different starter culture and their respective substrate. Generally, there are three major microorganism groups namely yeasts, molds and bacteria present in the traditional amylolytic starter (Hesseltine *et al*.,1988; Steinkraus, 1996) where moulds produce amylase to degrade starch into fermentable sugar. Yeast followed up with converting the sugar into ethanol. Lee and Lee (2002) stated that the presence of lactic acid bacteria (LAB) in the starter culture, most likely as opportunistic contaminants. However, the interaction functionality of the different microorganism groups is still yet to be discovered.

Sanchez *et al*. (1988) determined the chemical composition of Vietnam rice wine *tapuy* using different rice varieties. *Tapuy* contained 10.6-12.9% (v/v) of ethanol, pH 4.65-5.0, total soluble solid 3.0-3.9 º Brix, and total titratable acidity 10.2-20.2. Chemical composition of some Thailand rice wines were analyzed (Chuenchomrat, 2007).

Table 1. Amylolytic starter cultures and their predominant microorganism of carbohydrate-based fermented products in Southeast Asia

Country	Starter	Substrates	Microorgansim	References
Indonesia Malaysia	*Ragi*	Rice, Cassava	*Amylomyces rouxii,* *Endomycopsis, Burtonii,* *Amylomyces rouxii* *Candida utilis,* *Candida pelliculosa* *Sacharomyces Cerevisiae*	Ko (1972); Cronk *et al*. (1977); Ardhana and Fleet
Philippines	*Bubod*	Rice, glutinous rice	*Saccharomyces , Amylomyces*	Lee (1990)
Philippines	*Banh men*	Rice, glutinous rice	*Rhizopus oryzae*, *R. microsporus* *Absidia corymbifera*, and *Amylomyces* spp.	Thanh *et al*. (2008)
Thailand	*Loog-pang*	Rice,glutinous rice	*Saccharomyces fibuligera,* *Torulaspora globosa,* *Pichia anomala*	Limtong *et al.* (2002)
Malaysia	*sasad*	Rice, cassava,	*Saccharomyces cerevisiae,*	Chiang *et al.* (2006)
(Sabah)		pineapple,maize	*Candida krusei, C. pelliculosa,* *C.sphaerica, C.magnoliae* and other yeast	
Thailand, Malaysia, Indonesia, Philippines	Naturally occuring	Sap of coconut, date or palmyra palm	*LAB,AAB, S. cerevisiae* *Schizosaccharomyces pombe* , *Kodamaea ohmeri* and other yeasts	Batra and Millner (1974)

The ethanol concentration of the solid state fermented rice wines was in the range of 0.001- 0.01 % (w/v). Other parameters tested including pH (4.5–5.5), protein (0.45–0.99 % w/w), ash (0.10–0.30% w/w), total solid (1.72–14.34% w/w), glucose (0.41 -0.79% w/v) contents. Study done by Woraratphoka *et al*. (2007) evaluated the antioxidant properties of the rice wine produced in the northeast Thailand. Health promoting t-resveratro and phenolic acids such as gallic acid were found present in rice wine. Rice wine contained D-glucose, ethyl α-D-glucoside, glycerol, organic acids and amino acids and suggested to be a potential effective agent for the prevention and treatment of UV-induced skin aging (Seo *et al*., 2009).

Tapai as fermented product

In the Southeast Asia countries, glutinous rice has been used for the preparation of paste-type food products. *Tape ketan* (Indonesia) and *Khaomak* (Thailand) are prepared from glutinous rice which has been steamed, inoculated and allowed to ferment at ambient temperature. On the other hand, cassava tubers are also widely used materials for the *tapai* production. Humans have been fermenting foods from root crops for over 1000 years. Fermentation helps to improve the palatability, nutritive values and texture quality of the cassava roots. *Tapai* had different local names with different substrates including cooked white rice, cooked black/white glutinous rice, or cassava tubers. The following are the local names of this low-alcohol snack food in Southeast Asia. *Tape ketan* from glutinous rice (Indonesia), *tapai nasi* from cooked rice (Indonesia, Malaysia, and Singapore), *tapai ketela / peuyeum* from cassava roots (Indonesia, Malaysia). *Tapai pulut* from glutinous rice (Malaysia), *chao* made from rice (Cambodia), *khao-mak* from rice (Thailand), *basi binubran* from cooked rice (Philippines), (Saono *et al*., 1986, Hesseltine and Wang 1986; Aidoo *et al*.,2006; Steinkraus, 1996).

The general procedure for preparing *tapai* form glutinous rice starts with washing and soaking of the substrate one hour or longer (sometimes overnight). The substrates were steamed for approximately 30 min until soft and sticky. After cooled to room temperature (28-30ºC), it is added with starter culture. The inoculated substrate can either placed in wide mouth glass jars which are then covered tightly with a piece of cheese cloth or divided into small portion and placed in plastic bag or in banana leaves (to obtain pleasant aroma). Fermentation continued for 24- 48 hours at ambient temperatures (25-30°C). The fermented product is a partially liquefied, having a sweet-sour and mildly alcoholic taste. The product is ready to be consumed. It can also be kept in the refrigerator until needed. To prepare *tapai* from cassava, roots are peeled, cut into pieces, washed, steamed until cooked and cooled. Traditionally, the cooked cassava roots are placed in layers on bamboo baskets which are covered with banana leaves. *Ragi tapai* is then sprinkle on each layer. Incubation is carried out at 30ºC for 48-72 hours. During fermentation, the cassava roots soften and develop a sweet/sour slightly alcoholic flavor. The product which is somewhat juicy can be consumed right away. The preparation method of *tapai* has been revised intensively by other researchers (Steinkraus, 1996; Gandjar, 2003; Stanton and Owens, 2003; Aidoo *et al*., 2006).

Microbiological and biochemical changes during fermentation

Ragi is a traditional starter inoculum that is available commercially for *tapai* production. The methods to prepare *ragi tapai* is discussed intensively by Gandjar (2003). Traditionally, *ragi tapai* is prepared by mixing rice flour with various spices including garlic, plant roots, peppers, red chillies, cinnamon, fruit, coconut water, ginger and water (or sugar cane juice). The mixtures is molded into small circular flat cake and let sundried. Diverse range of fungal and yeast species has been found in *ragi* (as shown in Table 1.) Moulds in the inoculums *ragi* degrade the carbohydrate compounds in rice or cassava, followed by the function of yeast to convert simple sugar alcohol. The process produced some acids and softens the raw material during the fermentation. Reaction between the acids and alcohols resulting in a pleasant aroma of the fermented food. During fermentation, moulds like *Chlamydomocular oryzae* converts starches to sugars, and yeast, *Endomyces fibuligera* converts sugars to alcohol and flavour components (Beuchat, 1987). Study done by Ardhana and Fleet (1989) reported the microbiological changes occurred during the fermentation of the *tape ketan*. *Amylomyces rouxii* and *Candida pelliculosa* are the dominant microorganisms, followed by *Saccharomyces cerevisiae*, *Hansenula anomala* and bacteria such as *Bacillus* and *Acetobacter*. Study found that pure culture in the inoculum failed to produce typical structure and taste of *tape ketan*.

Cronk *et al*. (1977) investigated the biochemical changes of *tape ketan* in Indonesia using various combination of microorganism as starter culture. Ethanol content of *tape ketan* at first 24 hours fermentation was 2.3% (v/v) and reached the maximum of 8.0% (v/v) after 144 hours. *Tape ketan* contained 30.7 -39.3 % of total soluble solid, pH ranges from 4.2 to 4.5, soluble crude protein 13.8-18.4 % (w/w), titratable acidity 5.74-8.11. Study found that soluble crude protein in rice increased significantly from 8.4% (unfermented) to 13.8-18.4% after fermented for 194 hours. The doubling increase in the protein content of rice in *tapai/tape* providing the community a good and cheap source of protein. *Tapai* with cassava contained at least 3% of protein (wet basis) as compared to 1% (wet basis) of raw cassava (Steinkraus, 1996). Steinkraus (1996) reviewed the bio-enrichment of the rice/cassava in *tape ketan* after fermentation. *Tapai* contained essential amino acid, lysine and thiamine. Thiamine content in tapai is comparable to the unpolished rice. Consumption of the snack helps to prevent *beri-beri* among the people that consumed polished rice in the Southeast Asia region.

Health risk

Alcohol-related health risks

Alcohols have been identified as a major risk factor for global burden of diseases (Rehm *et al*., 2003). Consumption of the indigenous or homemade alcoholic foods and beverages are normally unrecorded. It is important to obtain a scientific database on the alcohol content of the homemade/traditional fermented beverages and foods in order to study and control the health-risk caused by alcohol consumption in the specific region. Higher alcohols (alcohol with more than 2 carbon atoms) occur naturally in alcoholic beverages as metabolites from bacterial activities. Higher alcohols are important flavor compounds and have been treated as generally recognized as safe (GRAS). However, issues have been raised recently about the percentage of higher alcohols in homemade alcohol products as few studies indicated that the presence of higher alcohol might lead to higher incidents of liver diseases (Narawane *et al*., 1998; Lal *et al*., 2001).

Traditional brew is commonly made from fruits, vegetables, grains or palm sap by the local people in home and villages. As compared with the Middle East and Europe which uses mostly fruits as the raw material to produce indigenous alcoholic beverages, Southeast Asia region tend to produce alcoholic beverages from cereals especially rice and also from the palm sap (Lee and Lee, 2002). Although distilled alcohols, wine and beer are readily available in the market, traditional alcohol continued to be widely used due to the availability of the raw materials, ease of fermentation process and affordability of the community (Nordlund and Osterberg, 2000). It is believed that traditional brews are commonly consumed by the people in the region but remain unrecorded (WHO, 2004). There is variation in drinking pattern in developing countries such as in South-East Asia. Distilled alcohols and wine generally consumed in urban area and by more affluent group. On the other hand, traditional brews (such as fermented grain or palm sap) are normally consumed by poorer population and distributed in more urban area (Patel, 2007). Local brews commonly consumed by the local community in some Southeast Asia region are listed in Table 2.

Table 2. List of local brews in Southeast Asia Countries

Country	Local brews
Bangladesh	*Bangla Mad*[a], *Cholai Tari*[a]
Bhutan	*Ara*[a]
India	*Arrack*[a], *Desi*[a] *Sharab*[a], *Tari*[a], *Tharra*[a], *Toddy*[a], *Fenny*[a]
Indonesia	*Palm Wine*[a]
Nepal	*Raksi*[a], *Tadi*[a], *Chayang Tomb*[a]
Sri Lanka	*Toddy*[a], *Arrack*[a]
Thailand	*Oou*[a], *Namtanmao*[a], *Sartha Waark*[a] *Sato* [d], *Krachae* [d]
Malaysia	*Tuak*[b], *Tapai* Sabah[b] , *Arrack*[a], *Samsu*[a]
Philippines	*Tapuy*[c] , *Ruou nep than*[d]

a: WHO, 2004, b: Chiang *et al*., 2006, c: Blandino *et al*.,2003, d: Aidoo *et al*., (2006)

Palm based fermented products

The fermented palm sap is commonly known as toddy. Verma and Joshi (2000) defined toddy as the product formed from fermentation of palm sap, which contained about 7% (v/v) of ethanol. Ethanol content of a naturally fermented coconut palm sap reached maximum (approximately 9% v/v) after 5 days fermentation (Atputharajah *et al*. 1986). Joshi *et al*. (1989) also stated that 9% (v/v) ethanol produced from natural fermentation of a fresh cut sap with 10–18% (w/w) sugar. Freshly prepared toddy has an average alcohol content of 7.9%. For commercial toddy or palm wine, alcohol content ranged from 3 to 7% (v/v) for fermented palm sap and 20-40% (v/v) for the distilled (Bennett *et al*., 1998). Complete higher alcohol profiling of local surrogate such as rice wine and toddy in Southeast Asia region is still yet to be developed.

Rice based fermented products

Coronel *et al*. (1981) analyzed *tapuy* made from fourteen Philippine rice varieties. Result indicated the ethanol content of tapuy ranges from 12.0 to 13.3% (v/v). Tanimura *et al*. (1978) reported that ethanol content of tapuy ranges from 13.50 -19.10 % (v/v). Dung *et al*. (2007) stated that the alcohol content of Vietnamese rice wines varies with some even reached almost 15 % (v/v); and those by distillation, contained approximately 50% (v/v) ethanol. Lachenmeier *et al*. (2009) collected and analyzed the homemade/unrecorded fermented alcohol product such as rice alcohol and found the majority had alcohol contents between 30 and 40% (v/v). *Tapai* (a Sabah's fermented rice beverage) contained approximately 12.3% (v/v) after 3 weeks fermentation (Chiang *et al*., 2006). Lachenmeier *et al*. (2009) investigated both homemade and commercial alcohol products in Vietnam and reported the presence of higher alcohols such as 1-propanol, 1-butanol and isobutanols.

Tapai as fermented product

Ethanol concentrations of approximate 5% in the *tapai/tape* have been reported (Beuchat, 1983). Cronk *et al*. (1979) reported the alcohol content of *tape ketan* inoculated with different starter culture ranged from 2.6 – 3.7% (v/v) after fermention for 48 hours and 4.2-7.4% (v/v) after 96 hours. Muchtaridi *et al*. (2005) analyzed black *tape ketan* at different fermentation time from 3 to 31 days. Study reported alcohol content of 3.99% (v/v) in *tape ketan* after 3 days fermentation and the alcohol content reached 5.30% (v/v) at day 31. Typical fermentation time of inoculated *tapai/tape* is 2-3 days at ambient temperature. Hence, *tapai/tape* ready for consumption is expected to contain approximately 2-3% of alcohol. Cronk *et al*. (1979) reported the presence of higher alcohols such as isobutanol (0.016% v/w), isoamyl (0.012% v/w) and active amyl alcohol (0.001% v/w) in *tape ketan* after 96 hours fermentation.

Conclusion

Fermented food is important to human's diet and posses a natural and healthy image. However, ethanol as a major product of alcoholic fermentation is well known for causing intoxication in human. The consumption of these alcoholic brews in Southeast Asia region is commonly unrecorded. Traditional forms of alcoholic food products have been produced communally and having difficulties in controlling the product quality and production hygiene. Besides, knowledge about the significance of the presence of the metabolite and their chemical interaction is still insufficient. Furthermore, little scientific literature is found to date related to health relevant constituents and contaminants in these alcoholic beverages and foods.

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