Fermented Rice - Tapai

Hajah Junaidah Haji Abu Bakar
Department of Biology

Introduction

Fermentation is a method of preserving food in various forms known worldwide from ancient time. Generally fermentation is of carbohydrates, some however primarily involve proteins.

Fermentation can be defined as the metabolic process in which substrate such as carbohydrates and related compounds are oxidised with the release of energy in the absence of any external electron acceptors or simply as a process in which chemical changes are brought about in an organic substrate through the action of enzymes elaborated by microorganisms. This resulted in the alteration of the chemical composition and other characteristics of the final products. Tanner (1944) was sceptical about whether the flavour of a fermented food is improved with the change produced. However, it is worth mentioning that the likes, and dislikes and prejudices about foods are very much a matter of opinion and what one is used to (Platt, 1955a).

In theory, fermented foods can never be considered completely safe when they are not prepared under carefully controlled conditions. Nevertheless, more or less natural processes have evolved with relatively few documented cases of food induced disease (Stanton, 1985). This view is supported by Stilliker et al. (1980), who compared them to frozen and prepared packed foods which have been known to cause serious outbreaks of food poisoning.

Whitaker (1978) cited “The Occidental culture has a deep seated prejudice against mouldy products”. Indeed many people in the West associate spoilage, poisoning and the associated unpleasant consequences with the combination of ‘food’ and ‘mould’. However, it is somewhat confusing to discover that the Western phobia of moulds in food runs hand in hand with the great appetite for mouldy cheese, such as Roquefort and Camembert which are generally consumed without any additional preparation, completely fresh and with growing and living fungus. This apparent contradictory behaviour is partly explained by Wood (1977): “...in the Western world, uses of fungi as a food are bounded by a mixture of legend and taboos which often impinge only peripherally upon reality. It is automatically assumed that filamentous micro-fungi are necessarily harmful...”

A factor which cannot be overestimated is the monotonous diet of much of the world where protein in the form of meat and dairy products are easily available. In South East Asia, where the rice is the staple diet but lacking in flavour, fermentation of food is very much involved in improving and adding some variety in the diet of the population.

The diversity of food products produced by fermentation involving microorganisms is considerable. One of the popular traditionally fermented food in South East Asia is saccharified rice or popularly known as Tapai in Brunei darussalam, which is consumed without further processing as a dessert or snack. This fermented product is a partially liquified yet cohesive mass, having a sweet acid and mildly alcoholic taste. It is known by various names. (Table 1)

A mixed culture of microorganisms is used as a starter culture known as laru, to initiate the fermentation. The starter is prepared under relatively poor microbiological conditions by persons untrained in microbiology. The starter preparation and also the products go under a variety of names according to the countries from which they are made as shown in Table i.
The method of preparation and use of these starter cultures go back many centuries. By selection of mutant strains, particular organisms that are rare or do not exist anywhere else have been produced.

**Tapai**

Tapai is a fermented rice product and has been described as a mildly alcoholic, partially liquefied (juicy) rice paste having a sweet-acid taste (Djion, 1972; Cronk et al., 1977; Ardahana et al., 1989; Merican and Yeoh, 1989).

The word tapai in Malaysian and Bruneian, has the same meaning as tape in Indonesian. Hesseltine (1983) reported that lao chao, a similar product to tapai has a sweet, slightly fruity taste (like juicy fruit chewing gum) flavoured with alcohol.

In Asia, similar products to tapai are found in many countries and are known under different names. Starters are used in the manufacture of these products and these starters are also known by different names although the product is basically the same (see Table 1).

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>Tapai</td>
<td>Fermented non-glutinous rice</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Tape ketan</td>
<td>Fermented glutinous rice</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Tape ketella</td>
<td>Fermented cassava</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Tapai pulut</td>
<td>Fermented glutinous rice</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Tapai ubi</td>
<td>Fermented cassava</td>
</tr>
<tr>
<td>Philippine</td>
<td>Bimubudan</td>
<td>Fermented rice</td>
</tr>
<tr>
<td>Thailand</td>
<td>Khaomak</td>
<td>Fermented glutinous rice</td>
</tr>
<tr>
<td>China</td>
<td>Lao chao</td>
<td>Fermented glutinous rice</td>
</tr>
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</table>

**Table 2 Alcoholic beverages using similar starter**

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>Tuak</td>
<td>Rice wine</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Brem wine</td>
<td>Rice wine</td>
</tr>
<tr>
<td>Malaysia (East)</td>
<td>Tapai</td>
<td>Alcoholic liquid from fermented rice</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Samsu</td>
<td>Distilled product</td>
</tr>
<tr>
<td>Phillipines</td>
<td>Tapuy</td>
<td>Rice wine</td>
</tr>
<tr>
<td>Japan</td>
<td>Sake</td>
<td>Rice wine</td>
</tr>
</tbody>
</table>
Table 3 Starter

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>Laru</td>
<td>Starter for tapai</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Ragi Tape</td>
<td>Starter for tape ketan/ketella</td>
</tr>
<tr>
<td>Malaysia (West)</td>
<td>Ragi Tapai</td>
<td>Starter for tapai</td>
</tr>
<tr>
<td>Malaysia (East)</td>
<td>Laru</td>
<td>Starter for tapai</td>
</tr>
<tr>
<td>Malaysian Chinese</td>
<td>Chiu-piah</td>
<td>Starter for tapai</td>
</tr>
<tr>
<td>Philippine</td>
<td>Bubod/labadora/binok boh</td>
<td>Starter for tapai-like product</td>
</tr>
<tr>
<td>Thailand</td>
<td>Lookpaeng</td>
<td>Starter for khaomak</td>
</tr>
<tr>
<td>China</td>
<td>Chiu-yueh</td>
<td>Starter for lao-chao</td>
</tr>
</tbody>
</table>

Table 1 - Names of tapai and tapai-like products from Brunei Darussalam, China, East Malaysia, Indonesia, Japan, Malaysia and Philippines.
Source: compiled from Wang and Hesselline (1970); Ko (1970); Abu Bakar (1986); Merican and Yeoh (1989).

Tapai is a perishable product because even after the optimal stage of fermentation is achieved, the fermentation continues. Therefore, the product has to be consumed immediately since over-fermentation will result in a sour alcoholic product which is not acceptable organoleptically (Merican and Yeoh, 1989).

Tapai is considered a delicacy and is normally consumed without further processing (Djien, 1972). It is also served at festivals and weddings in the Malay communities (Merican and Yeoh, 1989).

In China, lao chao is part of the diet of new mothers as it is believed that it helps them to regain their strength (Wang and Hesselline, 1970). It can also be cooked with eggs or used in other dishes such as seafoods (Frazier, 1967).

The liquid form tapai is used as a leavening agent in making traditional Malaysian cake called 'apan' (Merican and Yeoh, 1989), and in Indonesia it is made into 'brom', a confectionery product (Djien, 1982).

The production of tapai is mainly on a cottage industry scale or at home for family consumption (Abu Bakar, 1986, unpublished; Merican and Yeoh, 1989).

Substrates for Tapai Production

Tapai can be made from the fermentation of glutinous rice (Oryza sativa glutinosa), cassava (Manihot utilisima) (Djien, 1972) or wheat or corn (Van Veen, 1972; Sakai and Caldo, 1984a). In the Malaysian Peninsula, depending on the locality, rice or cassava tapai may be popular and sometimes black glutinous rice is used (Merican and Yeoh, 1989). In Brunei Darussalam, ordinary white polished rice is more popular for tapai production (Abu Bakar, 1986, unpublished).
Tapai Preparation

The preparation of tapai and similar products such as lao-chao and khaomak, using laru and laru-like starters are more or less the same. Traditionally, steamed non-waxy rice is allowed to cool before pureed ginger with added sugar is mixed into the rice alternatively with pulverised laru. Small portions of the mixture are wrapped in banana leaves and placed in a container, before incubation at ambient room temperature (25°C - 30°C) for 24 hrs (Abu Bakar, 1986, unpublished).

In some cases glutinous rice is used and the tapai is allowed to ferment for 24 - 72 hrs at the same temperature before consumption (Djian, 1972; Hesseltine, 1965; Saono, et al., 1974; Went and Prinsen-Geerligs, 1895) (see Table ii).

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>TIME OF CONSUMPTION (h)</th>
<th>REDUCING SUGAR (%)</th>
<th>ALCOHOL CONTENT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapai (Brunei)</td>
<td>24 - 36</td>
<td>18.6</td>
<td>1.0 - 2.0</td>
</tr>
<tr>
<td>Tapai (Malaysia)</td>
<td>72</td>
<td>26</td>
<td>3.48 - 5.20</td>
</tr>
<tr>
<td>Tapai (MARDI)*</td>
<td>72</td>
<td>32</td>
<td>1.58</td>
</tr>
<tr>
<td>Tape ketan (Indonesia)</td>
<td>36 - 48</td>
<td>20</td>
<td>up to 8.50</td>
</tr>
<tr>
<td>Khaomak (Thailand)</td>
<td>72</td>
<td>12.7 - 18.0</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Table ii - Time of consumption, amount of reducing sugars and alcohol content from the different places and countries. Note:* MARDI - Malaysian Agricultural Research and Development Institute. Source: Compiled from Cronk et al (1977); Abu Bakar (1986 - unpublished); Merican and Yeoh (1989); Steinkraus (1989).

The steps involved in the preparation of tapai have also been described by Campbell-Platt (1987); Merican and Yeoh (1989); Abu Bakar (1986 - unpublished); Djien (1972); Hesseltine (1965); Saono et al., (1974); Went and Prinsen-Geerligs (1895).

The fermentation of tapai is not a totally anaerobic process and this accounts for the low alcohol content. Tapai is normally consumed when the reducing sugar produced is optimal (48 - 72 hrs) and before all the sugars are fermented to alcohol (Merican and Yeoh, 1989).

The shelf life of tapai is 2 - 3 days at room temperature, up to 2 weeks under refrigeration (chilling slows down fermentation) and several months if frozen (Merican and Yeoh, 1989).

Merican and Yeoh (1989) reported that the best conditions for tapai fermentation are a microaerophilic atmosphere and a closed plastic container providing a good closed fermentation system.
Tapai Fermentation

The microorganisms essential for the fermentation of tapai i.e. moulds, bacteria and yeasts were studied by several authors including Went and Prinsen-Geerligs (1895); Boedijn (1958); Dwijoseputro and Wolf (1970) and Saono et al., (1974). The presence of amylolytic and alcohol producing yeasts appeared to be necessary for producing good tapai.

The process is carried out by a mixture of yeasts, moulds and probably also bacteria. Evidence has shown that tapai fermentation could be brought about by a mould e.g. Amylomyces rouxii, or Rhizopus species, or a mixture of one of these moulds with certain yeast species e.g. Hansenula species. However it appears that the fermentation could not be carried out solely by yeasts (Dgien, 1972; Tanuvidjaja, 1972; Cronk, et al., 1977).

Yeast involved in the fermentation process produce alcohol which improves the aroma of the product. In addition, alcohol at certain concentration makes the substrate unsuitable for microorganisms which might in turn create undesirable properties in the product. The inhibitory effect of alcohol on undesirable microorganisms is increased with the presence of organic acids that are produced by lactic acid bacteria (Dgien, 1982). Lactic acid bacteria also produce antimicrobial compounds such as diacetyl, lactate, acetoin and bacteriocins hence contributing to the inhibitory and preservative effect in the product.

Cronk et al., (1977), reported the presence of higher alcohols such as butanol in tapai, produced by Amylomyces rouxii in combination with species of the yeast Endomyopsis (Saccharomyces), Candida and Hansenula.

Acids develop in tapai during fermentation and this imparts the slightly acid taste of the product. The main organic acids detected are acetic acid, lactic acid, citric acid and succinic acid (Merican and Yeoh, 1989).

The initial phase of the fermentation process involves starch hydrolysis which eventually results in the formation of various end products including reducing sugars and ethanol (Saono and Basuki, 1978).

Ragi

A mixed culture of microorganisms is used as the starter culture for tapai fermentation. Traditionally the starter called ragi, is prepared under relatively poor aseptic conditions by persons untrained in microbiology. The starter and products are known under a variety of names according to the countries in which they are made (Table 3).

This type of inoculum or starter is commercially produced, combining three groups of microorganisms viz: mucoraceous fungi, yeasts and bacteria. The starters are used to convert starchy materials to sugars and subsequently to alcohol and organic acids. In contrast to sequential fermentation, all the microorganisms are used together at the same time (Hesseltine, 1988).

Ragi is equivalent to the English word Yeast, but is wider in scope because it may include filamentous fungi and refer to the starter or inoculum used to initiate various kinds of fermentations (Dwijoseputro and Wolf, 1970).
Chu, a ragi-like starter from China has been described in the old Chinese classics as the most important ingredient in the manufacture of alcoholic beverages. Yamazaki (1932) studied its preparation and uses.

The ragi-type inocula are available in the markets of most ASEAN countries and are generally produced by household or village manufacturers using closely guarded secret recipes.

Ragi is always in the form of a dry product, either as a small flattened cake, (see Fig.1) a ball of a few centimeters in diameter, or as white dusty powder. Typically one or more plant materials e.g. fresh galangal, ginger and spices such as cloves and white pepper are added to the rice flour that makes up the greater part of the ragi (Hesseltine, 1988). The method of preparation and use of ragi and ragi-like starter cultures has been handed down from generation to generation. By selection of mutant strains, particular organisms that are rare or do not exist elsewhere have been produced. For example, it was cited by Hesseltine (1988) that Amylomyces and its single species Amylomyces rouxii which may have been selected as a mutant from the genus Rhizopus, occurs only in ragi.

Preparation of Ragi and Ragi-like Starter Cultures

Ragi contains microorganisms which produce enzymes necessary for the breakdown of carbohydrates and proteins in grains, legumes and roots used as fermentation substrates.

Ragi cakes are made of rice flour containing the required mould and yeast cells obtained by natural infection from the surroundings and equipment used by traditional manufacturers (Djien, 1972).

Fresh plant materials (fresh ginger, galangal, garlic) and spices (chilli, white pepper, cloves) are added during the preparation of starter. In many cases, the initial inoculum comes from floral nectar which contains yeasts and other microorganisms (Batra et al., 1973; Gillian et al., 1974; Lodder 1970). The spices added contribute other microorganisms and may inhibit development of undesirable microorganisms (Sie, 1962; Soedersono, 1972). According to Frazier (1967) the essential oils found in spices have some inhibitory properties. Although most spices are not very bacteriostatic, in combination with other materials in foods they may exhibit a specific effect. He also reported that spices such as garlic, galangal, ginger and cardamom, may inhibit growth of undesirable microorganisms and that garlic has a selective effect in that it does not inhibit the growth of amylolytic moulds but does inhibit Rhizopus oryzae, Aspergillus niger and Bacillus subtilis.

Voderman (1893); Went and Prinsen-Geerligs (1895); Macfadyen (1903); Donath (1935); Djien (1986), have described the traditional manufacturing methods for making ragi. The starters have been reported to be viable after 2 - 3 years (Macfadyen, 1903) and even after 5 years storage at room temperature (Hesseltine, 1988), although the exact temperature was not mentioned.
Figure 1  Two different sizes and form of ragi seen as dry small balls (Indonesian ragi) and flattened round cakes with obvious thumb print in the middle (maker's trade mark - Brunei Darussalam laru).

Figure 2  Tapai is a fermented rice product. The tapai in Brunei Darussalam is normally packed in young nipah leaves which have been cut to size and held together using the nipah leaves rachis.
In Brunei, ragi disintegrates if stored at room temperature (28°C - 30°C) due to the growth of rice weevils which feed on the ragi. The rice weevil eggs must have been present initially in the rice flour. Normally such ragi is discarded because tapai makers believe that it will produce unpalatable tapai (Abu Bakar, 1986 - unpublished).

Rice flour is normally the main substrate used in ragi making. In Brunei, ordinary white polished rice is washed and soaked overnight. It is then drained and spread onto a nyiru (bamboo tray) and allowed to dry for at least 1 hour at room temperature (25°C - 30°C). The rice is made into flour, traditionally using a 'lesong' (a granite pestle and mortar). Alternatively an electric grinder can be used. Spices such as cardamom, cinnamon, cloves and white pepper are finely ground and mixed into the rice flour. In addition, pureed fresh ginger, ground lalang roots (*Imperata cylindrica*) and powdered 'old ragi' are added to the rice flour mixture. The proportion of the ingredients varies according to the makers and this is part of their trademark. Water is added and the mixture is made into a paste, shaped into a cake 6 cm - 8 cm in diameter (see Fig. 1a & b) and sometimes the thumb is pressed onto the centre as a trademark or a hole is made (Abu Bakar, 1986, unpublished). Five to six pieces of ragi cakes are sold in a pack for BS 2.00 in Kianggeh Tamu of Brunei Darussalam.

The ragi are placed on a nyiru, covered with a muslin cloth and incubated for about 2 - 5 days at room temperature (25°C - 30°C). Desiccation occurs simultaneously with growth of the desired microorganisms, before the ragi are sun-dried for about 48 hours.

Rice flour and spice mixture act as a selective medium for the growth in the flour of the desirable fermentative microorganisms. A close control of the amount of inoculum, spices and flour should produce a better starter which in turn will result in a more uniform fermentation product (Hesseltine, 1983). The ragi once dried has a water activity (*a_w*) ranging from 0.55 - 0.79 (Adang, 1991) and has a moisture content of about 8% (Ishimaru and Nakano, 1960) thus making it more selective for only the desired organisms.

Variation in ingredients and steps in ragi preparation can be observed in different regions of South East Asia. The basic steps ragi preparation can be seen in Fig. 3.
Fig. 3  Flow diagram of the stages involved in the traditional ragi preparation in Brunei Darussalam, adapted from Abu Bakar (1986, unpublished).
Microflora of Ragi and Tapai

The microflora of ragi and Chinese yeast cake has been studied by Went and Prinsen-Geerligs (1895) and Wehmer (1900 a,b). Various microorganisms for example species of Candida, Saccharomyces, Mucor, Rhizopus and Pediococcus have been found in ragi and ragi-like starter.

Steinkraus (1983) cited in his report that other scientists who have described and discussed these starter cultures include Heyne (1950); Hesseltine (1965); Dien (1965, 1972) and Sie (1962). General review articles dealing in part with ragi and its microorganisms have been published by Van Veen (1972); Dien (1982, 1986) and Hesseltine (1965).

The microorganisms in ragi are the result of more or less incidental infections, either from the rice itself or from the environment. As happens in many such cases, if the product is always manufactured in the same place under rather standardised conditions, it is expected that the microflora becomes limited to a few dominating microorganisms (Van Veen, 1972). For example, Hesseltine (1988) reported the consistent occurrence of filamentous yeasts (Saccharomyces), mucaceous fungi (Rhizopus) and bacteria (lactic acid bacteria) in ragi.

Dien (1979) suggested that the presence of Amylomyces rouxii in ragi is essential to degrade starch to reducing sugars and ethanol. In combination with one or more yeast species from certain genera (eg. Candida, Saccharomyces and Saccharomyces) which are present in ragi, the combination enhances ethanol formation and the development of a rich aroma and flavour in tapai.

Suprianto et al., (1989) found that optimal production of volatiles occurs at 30°C after 3 days of fermentation of tapai with ragi, and results in a sweet tapai with a pleasant aroma. The aroma is formed by a mixed culture of Rhizopus and Saccharomyces species and the hydrolysis of starch by mainly α-amylase of Saccharomyces species which results in the production of glucose, maltose and maltotriose.

Dien (1977) prepared ragi using defined mixed cultures of Amylomyces rouxii and Endomycopsis chodati (Saccharomyces fibuligera) which produced acceptable tape ketan.

Wang and Hesseltine (1970) used Rhizopus chinensis NRRL-3671 and Saccharomyces species NRRL-7067 to produce lao chao which has a distinct sweet fruity aroma, and contains 1 - 2% ethanol and 20 - 30% reducing sugar.

Dien (1972) used defined mixed culture starter (Chlamydomonacor oryzae and Saccharomyces fibuligera) in tape ketan fermentation on an industrial scale. He concluded that good fermentation characteristics were produced. Merican and Yeoh (1989) found that Amylomyces rouxii, Saccharomyces fibuligera and Hansenula anomala were necessary to produce satisfactory tapai pulut and that A. rouxii and S. fibuligera were required for tapai ubi. Cronk et al., (1970) investigated the basic biochemical changes that occurred during a typical tape ketan fermentation under defined mixed culture conditions. Amylomyces rouxii in combination with 8 yeasts isolated from ragi were used. A. rouxii used about 30% of the total rice solids, resulting in a crude protein content of 12% in 96 hours.
Amylomyces rouxii and Endomycopsis burtonii (Syn: E. chodati) reduced the total solids by 50% in 192 hours, crude protein increase to 16.5%. Mould alone reduced total starch content of rice from 78% to 10% in 10 hours. The thiamin content of the rice is increased nearly three-fold as a result of fermentation by A. rouxii in combination with E. burtonii. The mould and at least one species of yeast were required to develop the rich aroma and flavour of typical tape ketan (Cronk et al., 1977).

Excellent reviews on the biochemical changes during tapai and tapai-like fermentation were reported by Steinkraus (1983). Studies on the changes in pH, amount of sugars, alcohol and acids present during the tapai fermentation were done by several authors, including Cronk et al., (1970); Djien (1977); Wang and Hesseltine (1970); Djien (1972); Merican and Yeoh (1989) and Tanuwidjaja, (1972). In lao chao (a similar product to tapai) fermentation the suggested process occurs initially by the conversion of the starch to glucose by amyloses and glucosidases. The glucose is further converted by yeasts to alcohol and lipases breakdown lipids of rice fatty acids, which react with alcohol resulting in a mixture of esters (Wang and Hesseltine, 1970).

References


