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Botanical biology

Exploring tua-sabu (brandy) in Timor-Leste: production, marketing, and consumption patterns - a review

Explorando tua-sabu (aguardente) no Timor-Leste: padrões de produção, comercialização e consumo - uma revisão

Lúcio Belo[I], Julio Cesar Colivet Briceno[I], Julião Pereira[I]

[I] Universidade Federal de Goiás, Goiânia, GO, Brazil

ABSTRACT

This work provides a theoretical approach to *tua-sabu*, a brandy of palm sap typical of Timor-Leste, presenting the aspects of production, commercialization, consumption, and quality control. Timor-Leste explores various types of plants with great economic potential, such as the production of rice, corn, coffee, cassava, vanilla, soybeans, and other crops. Some of the main palm trees, such as *akadiru*, *tua-metan*, *tua-tali,* and *nuu,* are also exploited to produce various products, such as *tua-mutin*, *tua-sabu,* sugar, vinegar, and others. *Tua-sabu* is one of the main products derived from these palm trees, whose production process consists of steps like sap extraction, natural fermentation, distillation, separation of fractions classified as *tua-ulun*, *tua-klaran,* and *tua-ikun,* and bottling of the products. Most of the products are packaged in reused plastic bottles, such as polyethylene terephthalate (PET) from mineral water beverage bottles and high-density polyethylene (HDPE) from cooking oil bottles, which are intended for direct consumption. Furthermore, the hygienic conditions of the bottles used are inadequate, as they are neither sterilized nor subjected to suitable treatments before being used for bottling. *Tua-sabu* is widely consumed by the Timorese, however, the country lacks quality control standards for commercialization and consumption purposes, in addition to not being registered by state institutions and inspection bodies. One of the factors that explains this is that Timor-Leste does not yet have adequate laboratory conditions or specific standards to control these products, negative factors that compromise the quality and reliability of production, putting consumer health at risk.

Keywords: Palm trees; Sap; Spontaneous fermentation; Distillate fractions; Quality control; Economic value

RESUMO

Este trabalho fornece uma abordagem teórica ao *tua-sabu*, uma aguardente de seiva de palmeira típica do Timor-Leste, apresentando aspetos de produção, comercialização, consumo e controlo de qualidade. Timor-Leste explora vários tipos de plantas com grande potencial econômico, como a produção de arroz, milho, café, mandioca, baunilha, soja e outras culturas. Algumas das principais palmeiras, como

akadiru, *tua-metan*, *tua-tali* e *nuu*, também são exploradas para a produção de diversos produtos, como *tua-mutin*, *tua-sabu*, açúcar, vinagre, entre outros. O *tua-sabu* é um dos principais produtos derivados destas palmeiras, cujo processo produtivo consiste em etapas que incluem extração de seiva, fermentação natural, destilação, separação das frações classificadas como *tua-ulun*, *tua-klaran* e *tua-ikun* e engarrafamento dos produtos. A maioria dos produtos é acondicionada em garrafas plásticas reaproveitadas, como o tereftalato de polietileno (PET), proveniente de garrafas de bebidas de água mineral, e o polietileno de alta densidade (PEAD), proveniente de garrafas de óleo de cozinha, destinadas ao consumo direto. Além disso, as condições higiênicas das garrafas utilizadas não são esterilizadas nem foram submetidas a tratamentos adequados antes de serem utilizadas para engarrafamento. O *tua-sabu* é muito consumido pelos timorenses, porém, o país ainda carece de padrões de controle de qualidade para fins de comercialização e consumo, além de não ser registrado pelas instituições estatais e órgãos fiscalizadores. Um dos fatores que explica este fato é que Timor-Leste ainda não dispõe de condições laboratoriais e normas específicas para controlar estes produtos, fatores negativos que comprometem a qualidade e confiabilidade da produção, colocando em risco a saúde do consumidor.

Palavras-chave: Palmeiras; Seiva; Fermentação espontânea; Frações destiladas; Controle de qualidade; Valor econômico

1 INTRODUCTION

Timor-Leste has a large agricultural area, where most of the land is used to grow various products such as rice, corn, coffee, cassava, vanilla, soybeans, and others. Most agricultural production systems are still non-mechanized or traditional, especially in mountainous areas with high slopes, which in turn can have an impact on low production yields. In this sense, the economic base of most rural Timorese is still dependent on the exploitation of forest resources, which are considered the main source of income for their subsistence (Henriques et al., 2014; Correia, 2015; Reis, 2021).

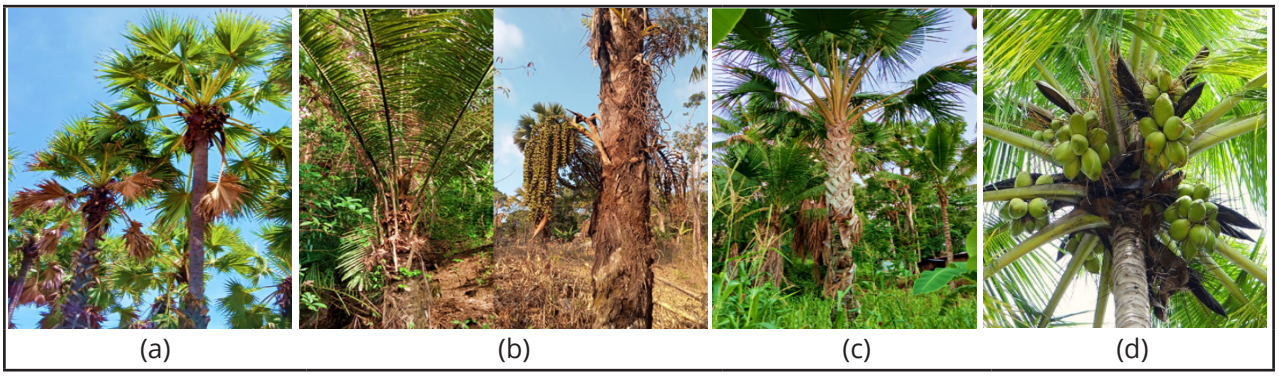
In addition to the food cultivation activities mentioned above, historically, the Timorese are also producers of distilled alcoholic beverages made from palm trees, commonly known as *tua-sabu*[1] in the local language Tetum[2], which is mainly a product of the distillation of the sap taken or extracted from palm trees, especially *Lontar palms (Borassus flabellifer* L.*)*, sugar palms (*Arenga pinnata* (Wurmb) Merr.), *Corypha utan palms (Corypha utan* Lam.*)*, *nuu (Cocos nucifera* L.) namely *Akadiru, Tua-metan, Tua-tali,*

1 It is a name given in Tetum to the brandy or distilled product obtained from the sap of palm trees in Timor-Leste

2 It is an official language of Timor-Leste

and *Nuu* in Tetum (Figure 1). This beverage has been produced since ancient times and is usually served in various sociocultural ceremonies (Belo et al., 2023).

Figure 1 – Types of sap-producing palm trees: (a) Akadiru (*Borassus flabellifer* L.), (b) Tua-metan (*Arenga pinnata* (Wurmb) Merr.), (c) Tua-tali (*Corypha utan* Lam.), and (d) Nuu (*Cocos nucifera* L.)



(a) (b) (c) (d)

Source: Authors (2025)

For the Timorese people, *tua-sabu* continues to be a product of great cultural significance, rooted in their heritage and identity. Furthermore, this beverage occupies a prominent place in the market, being one of the most economically valued alcoholic beverages, alongside industrial alcoholic beverages. These activities diversify the local economy, provide more subsistence options, and contribute to the country's sustainable development (MC William, 2022; Belo et al., 2023).

In this review, *tua-sabu* is theoretically approached, presenting aspects related to its production, quality control, and consumption. Given that scientific literature on the subject is scarce, the dissemination of this information is essential for the development and improvement of the quality of *tua-sabu*, as well as for its eventual introduction into the international market.

2 SAP-PRODUCING PALM TREES AND THEIR COMMON USES IN TIMOR-LESTE

In the territory of Timor-Leste, a variety of palm trees are found, each with distinct characteristics that make them suitable for different purposes. These

plants are used in a variety of ways, including extracting sap to produce brandy, sugar, and other products.

2.1 *Lontar* palm/Akadiru (*Borassus flabellifer* L.)

The *lontar/akadiru* palm (*Borassus flabellifer*) (Figure 1a) is a species of the palm family, Aceraceae (Sukamaluddin et al., 2016). Originating in Africa, this plant spread to India, Malaysia, Cambodia, Thailand, Indonesia, and other countries (Sancayaningsih, Santosa & Utami, 2016; Sarma et al., 2022), including Timor-Leste. Higher palm species measuring between 15 and 40 m in height (Nasri et al., 2017) are suitable for cultivation in tropical, temperate, and dry climates at an altitude of 0 to 800 m above sea level, surviving in soil containing areas with an ideal temperature of 30 ºC (Konay, Pakan & Kareri, 2019).

Akadiru has several Indonesian local names, such as *ental, siwalan*, *lonta,* or *lontara.* In other countries, it is known for names such as *brab tree* or *palmyra palm* (India), *dom thout* (Cambodia), *Cay thout lot* (Vietnam), *tanta note* (Thailand), *palmyra-palm* (England), *Palmeira* (Portugal), *toddy palm or palmyra-palm* (United States), and *jagerborn* in the Netherlands. In Africa, it is known *as African fan palm, Borassus aethiopium (African palmyra palm) and Borassus akeassii (Ake Assi's palmyra palm),* in Papua New Guinea as *Papua New Guinea Borassus heineanus* (*New Guinea palmyra palm*), in Madagascar as Madagascar *Borassus madagascariensis* (*Madagascar palmyra*), and in France it is known by several names, including *Borassus sambiranensis* (*Sambirano palmyra*), *deleb palm*, *ron palm*, *black palm*, and *ronier palm* (Nasri et al., 2017; Sukamaluddin et al., 2016).

Akadiru is a multipurpose plant, where all parts of the palm, such as stems, leaves, and others, are used by communities for construction (shelters, house walls, and more), domestic, artistic, or craft furniture (rugs, hats, mats), as well as culture and food (Baihaqi, Wisanti & Putri, 2022). Several benefits can be obtained from different parts of this plant, especially from the flowers that produce sap. The pulp of the youngest green fruit (between five and six months) is tasty, resembling the green coconut fruit with a soft texture (Sukamaluddin et al., 2016). The Timorese and

Indonesian populations widely consume it as food, while the ripe or dried fruit is used for pig feed (Saludung & Yahya, 2008; Kurniawan & Yuniati, 2015).

A study carried out in Indonesia by Baihaqi, Wisanti & Putri (2022) showed that the plant has important values in its leaves, flowers, and fruits, with the highest utility value being around 77% in the form of a beverage. The sap of *akadiru is* a sweet liquid that can be obtained by extracting the female or male flowers of the plant (Hawa, Lutfi & Makhfudhi, 2019). In Bengali, the sap known as "*Neera*" is used to produce brown sugar with a sweet taste, not to mention other products such as chocolate, cake, sweet soy sauce, food toppings, and typical Bengali ice creams (Hebbar et al., 2018).

In the Nusa Tenggara Timur (NTT) and Maluku provinces of Indonesia, the sap is used for various products, including liquid sugar, brown sugar, and ant sugar/or fresh sap for immediate consumption. Furthermore, the sap can be naturally fermented and converted into alcoholic beverages that can be consumed and/or used as raw material to produce brandy and vinegar (Solo et al., 2019; Ceunfin et al., 2021). Fermented beverages have been widely used by various societies and cultures around the world since ancient times, where fermentation was traditionally developed as a process of preserving raw foods, in addition to producing new foods with different sensory characteristics such as texture, flavor, and aroma, as well as to add nutritional value (Baschali, 2017).

2.2 Sugar palm/*tua-metan* (*Arenga pinnata* (Wurmb) Merr.)

The *tua-metan* palm tree (*Arenga pinnata*) (Figure 1b) is a plant native to tropical Asia, which has spread naturally from eastern India, Laos, Cambodia, Sri Lanka, Thailand, Vietnam, Malaysia, the Philippines, Indonesia, and Australia (Sahari et al., 2012; Ishak, 2013; Sarma et al., 2022). The plant generally survives and grows in various types of soil at altitudes between 0-1,500 m above sea level, with an average temperature of 25°C and 1,200 mm of precipitation per year (Ferita, Tawarati & Syarif, 2015). It also has high adaptability, developing in marginal lands and being very suitable for water and soil conservation purposes (Sari et al., 2019). This plant

can reach up to 25 m in height; the stems are resistant and have palm fiber; the inner part of the stem contains starch, being a plant matrix with high potential for use in starch and sugar production (Sahari et al., 2012; Ishak, 2013).

The parts of the plant are important and used for various purposes, including palm flour obtained from the inside of the plant, which is used as an ingredient for the formulation of food products such as cakes, breads, biscuits, and other foods (Wulantika, 2019). The leaves are often used to build roofs of houses and huts, while the roots have been used in the production of handicrafts such as flowerpots, baskets, and others. The fibers are also used to make brooms, brushes, mats, rugs, cushions for chairs or sofas, house roofs, ropes, water filters, and more (Ticoalu, Thiru & Cardona, 2014; Yunita et al., 2015; Wulantika, 2019).

Female flowers are good sources of sap production (Suka, Un & Rammang, 2020). Furthermore, male flowers are also the main sources of sap production through the extraction process (Ishak et al., 2013). The sap can be consumed fresh and used as raw material to produce many products like brandies, vinegar, cream, and sugar. (Solo et al., 2019; Suka, Un & Rammang, 2020; Sarma et al., 2022).

2.3 *Tua-tali* palm (*Corypha utan* Lam.)

The *tua-tali* palm *(Corypha utan)* (Figure 1c) is from the Palmae family, class monocotyledon, a subdivision of angiosperms. It is a large tree, grows between 10 and 30 m in height, preferably in hot climates, and survives in low and mountainous areas (Sancayaningsih, Maharani & Santoas, 2012; Amody & Anggreani, 2017). *Tua-tali* is cultivated in a wide region in Bengal-India, the Philippines, Maluku in Indonesia, the Malacca Peninsula, northern Australia, and regions of Timor-Leste, primarily in coastal areas (Sarma et al., 2022). It is a type of plant that is resistant to drought and adapts well in open areas as a constituent of the savanna ecosystem community (Witono, Kusuma & Naiola, 2018).

The use of *tua-tali* for various purposes has been known for a long time, both in Timor-Leste and in other hemispheres (Partomihardjo & Naiola, 2009). It is considered

a multipurpose plant and is known by Asian people who use it efficiently in their daily lives as a source of food, beverages, raw materials for construction (to make shelters or shade), fences, ropes, handicrafts (rugs, mats, drums, baskets), sap production, and others (Naiola, 2007). The inner rib fiber can be used as a raw material for polymer composites with economic value, being easily obtained in large quantities (Kurniawan & Yuniati, 2015; Amody & Anggreani, 2017). In the Philippines, cultivation of *tua-tali* has potential as an export product (Partomihardjo & Naiola, 2009), while in Timor-Leste, they are wild. However, various parts of the plant have been used for daily needs, such as for building houses, artisanal products, animal feed, and as raw material to produce alcoholic beverages, sugar, and food products (Witono et al., 2018).

Communities in the province of Nusa Tenggara Timur (NTT) and the Timorese consider the starch of *tua-tali* as an alternative food to replace rice, mainly. The starch is obtained from the inside of the trunk and cooked with coconut flakes or grated for consumption, known as "*akar-bilan"* in Tetum, or "*puta*" or "*laka*" (Witono et al., 2018).

Furthermore, the plant has great potential as a source of sap production. The sap extraction process is generally done by cutting the top of the tree before flowering, being the main raw material for the production of *tua-sabu* and other diverse products such as brown sugar and vinegar (Nahak et al., 2021). Despite being socially important due to its wide use, the continuous process of extraction of *tua-tali* has threatened the extinction of the species.

2.4 Coconut tree/*Nuu* (*Cocos nucifera* L.)

Nuu (*Cocos nucifera*) (Figure 1d) is a tropical species known as the "tree of life or tree of abundance", which has spread widely around the world, even on distant islands from Asia to America, by migration and trade between countries of the world (Nampoothiri et al., 2019). The species has great phenotypic variability, such as dwarf varities (var. nana), which are composed of three dwarf varieties distinguished by colors such as green, yellow, and giant varities (var. typical), which also present variations in

its characteristics and can be divided into populations identified by the name of the country where the variety grows (Daher et al., 2002).

The plant is widely cultivated throughout the world for its multiple uses, mainly nutritional, medicinal, and cosmetic (Daher et al., 2002; DebMandal & Mandal, 2011).

All parts of the plant are used in various ways in the daily lives of people in traditional cultivation areas. Trunks, stems, stalks, the outer layer of the trunk, peels, nuts, fruit fibers, and leaves are used in the wood, in addition to being used for constructions and for domestic and craft materials, such as brooms, carpets, flowerpots, brushes, ropes, and more (Wearn, Montagna & Passador, 2020).

Mainly in tropical countries, the water and the pulp of the coconut are consumed as beverages and foods, because they contain essential nutrients for human health, such as minerals (iron, zinc, manganese). Coconut water has numerous medicinal properties, such as antibacterial, antifungal, antiviral, antiparasitic, antidermatophyte, antioxidant, hypoglycemic, hepatoprotective, and immunostimulant, being widely used in multiple regions, especially in India (DebMandal & Mandal, 2011; Eyres et al., 2016). Green coconut water is consumed naturally in several countries around the world. Furthermore, coconut water is also used for the production of brown sugar (Yong et al., 2009; Santosa et al., 2020).

Copra or coconut milk, extracted from the pulp of old/dried coconuts, is normally used for cooking rice and sauces. In Asian countries such as Timor-Leste and Indonesia, it is also the main source to produce oil via refining, bleaching, and deodorization (RBD) specifically for cooking oil (Marina & Man, 2009). Unlike refined oil, virgin coconut oil (VCO), also known as unfermented oil (Eyres et al., 2016), is produced through a wet method or aqueous processing (Marina & Man, 2009; DebMandal & Mandal, 2011).

On the other hand, *nuu* is also one of the sap-producing plants, being composed of male and female flowers that can develop into fruits or be used to extract sap. The sap is a transparent, sweet, and translucent liquid, rich in nutrients (Nampoothiri et

al., 2019). The saps can be converted into alcoholic beverages through spontaneous fermentation and are generally consumed fresh and/or used as raw materials to produce brandy, and vinegar (*tua-siin* in Tetum), among others (DebMandal & Mandal, 2011; Hebbar, 2015; François et al., 2021).

The production of *nuu* sap in Timor-Leste is still minimal compared to other palm trees such as *akadiru*, *tua-metan,* and *tua-tali*. This is due to the limited number of experienced producers extracting the sap from this plant, in addition to other economic benefits that can be derived from it, such as the high yield and selling price of the young or unripe fruits on the market, and its use to produce cream, coconut milk, edible oils, and other products.

3 CHARACTERISTICS AND CHEMICAL COMPOSITION OF PALM SAP

Alcoholic fermentation is a well-known fundamental process from a strictly biochemical point of view; an organism converts carbohydrates such as starch or sugar into alcohol or acid (Maicas, 2020). The sap extracted from palm trees is an aqueous solution containing 10 to 20% of sugar, where the composition and quality of the sap vary depending mainly on the plant species, location, season, and time or duration of extraction (Francisco-Ortega & Zona, 2013). Sap flow occurs slowly throughout the extraction and is highly susceptible to fermentation (Hebbar et al., 2015); the sap has a pH close to neutral that can drop rapidly as the sap undergoes spontaneous fermentation during the collection period (Thabet et al., 2009; Francisco-Ortega & Zona, 2013).

A study by Karamoko et al. (2016) reported that wild or indigenous microorganisms present in the sap have been present since the extraction process began and are responsible for the spontaneous fermentation. In their studies, the microorganisms identified included aerobic mesophiles, lactic acid bacteria, yeasts, *Enterococci*, total and fecal coliforms, including sulfite-reducing bacteria (Karamoko et al., 2016).

Furthermore, some of the main players involved in the fermentation of palm sap are lactic acid bacteria (LAB) and yeasts (Shetty et al., 2017).

Palm tree saps, known as *tua-mutin*, are widely consumed in the intertropical regions of Asia, America, and Africa (Astudillo-Melgar et al., 2019). Most countries that have this resource (palm trees) are frequently exploited for the abundance and productivity of sap, used for several functions, and highlight the production of alcoholic beverages and sugar (Francisco-Ortega & Zona, 2013). Palm tree sap mainly consists of sugars such as sucrose, glucose, fructose, maltose, and raffinose, which are susceptible to fermentation by the microflora present in the sap (Sarma et al., 2022).

The sap is also rich in other compounds such as organic acids, minerals, vitamins (B, C), soluble proteins, amino acids, amides, phenolic compounds, and flavonoids, serving as a rich substrate for the growth of various types of microorganisms like bacteria and yeast (Santiago-Urbina et al., 2013; Zongo et al., 2020).

According to the study by Hebbar et al (2018), fresh sap contains the main compounds, total and reducing sugars, including free amino acids, proteins, phenolic compounds, essential elements (nitrogen, sodium, phosphorus, potassium, calcium, and magnesium), and micronutrients (zinc, iron, and copper). As illustrated in Table 1, previous studies present the levels of the main sugars found in the sap produced by different species of palm trees from various locations.

Reducing sugars act as a substrate for the *Maillard* reaction that occurs during the production of palm sap. The high presence of these sugars in the sap can also cause the juice to darken later, due to the same non-enzymatic browning reaction as the *Maillard* reaction (Naknean et al., 2019). There is a wide variation in the composition and quality of the sap depending on the location, time, and duration of extraction (Borse et al., 2007), although the sap is harvested from the same production area, the difference in quality is mainly due to the fermentation of the sugars by the activity of microorganisms during sap collection (Naknean et al., 2019).

Table 1 – The sugar content found in the sap of different palm tree species in previous studies

Plant species	Sugar content in the sap						Sources
	Total sugars (%)	Reducing sugars (%)	Sucrose (%)	Glucose (%)	Fructose (%)	Soluble solids (°Brix)	
Acronym aculeate "coyol"	na	na	0.22-11.36	0.05-2.15	0.27-3.54	na	Santiago- Urbina et al., 2013.
Arenga pinnata	na	na	50.37-61.20	3.83-6.53	3.27-6.77	na	Yonus et al., 2018.
Arenga pinnata	15.73	na	10.88	1.08	1.46	13.00	Asghar et al., 2019.
Borassus flabellifer Linn.	10.36-18.94	0.88-3.56	9.29-17.44	0.50-1.85	0.48-1.81	10.67-17.33	Naknean et al., 2019.
Borassus aethiopum Mart.	9.65-12.62	2.51-2.37	5.05-10.02	3.23-7.03	6.72-7.86	na	Zongo et al., 2020
Cocos nucifera	6.57-7.50	0.44-0.65	na	na	na	13.0-18.0	Hebar et al., 2015.
Cocos nucifera	9-11	na	na	na	na	14.0-15.6	Ramaswamy & Ramaswamy, 2017.
Cocos nucifera	18.77-20.00	na	9.47-13.71	2.76-4.96	3.53-4.37	16.15-16.55	Pathirana et al., 2023.
Cocos nucifera	na	na	1.76-5.76	2.25-4.46	3.23-5.76	na	Somawiharja et al., 2018.
Cocos nucifera	12.92	na	6.91	2.53	3.48	12.40	Asghar et al., 2019.
Cocos nucifera	15.56	4.76	10.80	2.65	2.11	na	Shetty et al., 2017
Nipa (Nypa fruticans)	15.9-18.9	na	9.3-11.1	5.1-6.5	1.4-1.6	na	Tamunaidu et al., 2013.
Phoenix dactylifera	na	na	95.27	2.5 1	1.61	na	Thabet et al., 2009.
Phoenix canariensis	66.0	na	37.8	9.50	4.80	na	Luis et al., 2012.
Phoenix dactylifera L.	70.40-85.58	na	19.96-63.38	16.88-48.56	1.14-3.55	10.0-16.7	Makhlouf- Gafsi et al.,2016.

*na: not analyzed
Source: Authors (2025)

4 PRODUCTION OF DISTILLED ALCOHOLIC BEVERAGES

In Brazil, alcoholic beverages of plant origin are popular, with sugarcane brandy being the primary product. This brandy is defined as a beverage with an alcohol content of 38 to 54% v/v at 20°C through a simple alcohol distillation process. Furthermore, cachaça is the most common brandy and is a typical Brazilian beverage produced exclusively in the country, it has an alcohol content of 38 to 48% v/v at 20 °C, obtained by the distillation of fermented sugar cane with special sensory sugars at a maximum sucrose concentration of 6 g L^{-1} (MAPA, 2005).

Alcoholic beverages derived from the thorn coconut (*Acrocomia aculeata*), known as the "*coyol*" palm, are produced in Central America, particularly in the southern region of Mexico. The sap is extracted from palm trees between 10 and 14 years old using the destructive method (Santiago-Urbina, Verdugo-Valdez & Ruiz-Terán, 2013). This process is detailed in the first and second items of Table S2.

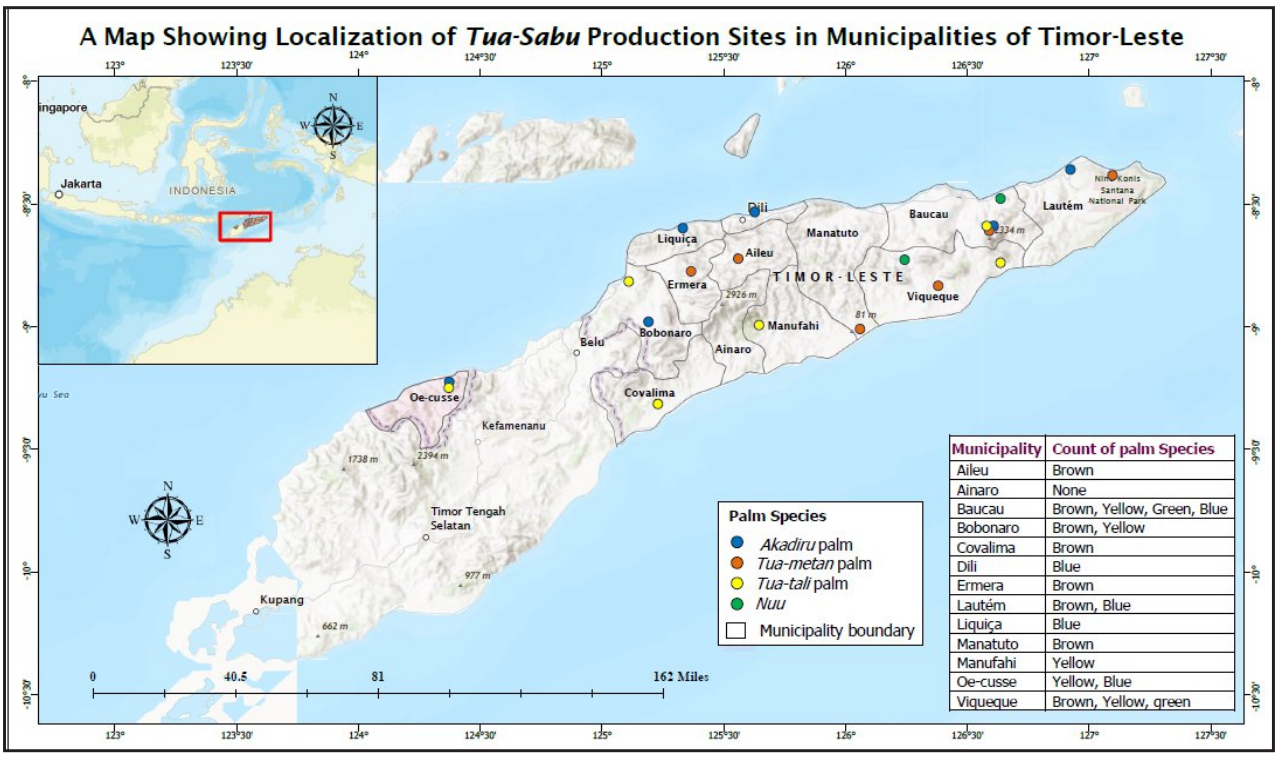
Alcoholic beverages are also produced from palm trees in African countries such as Nigeria, Ghana, Mozambique, South Africa, Burkina Faso, Tunisia, and Asian countries such as Myanmar, Malaysia, Sri Lanka, Thailand, Philippines, India, and Indonesia (Thebet, 2009; Ishak, 2013; Hebbar, 2015; Solo, Putra & Suparthana, 2019; Nahak, Aliah & Karim, 2021). A detailed description of each process for different palm species and regions can be found in Tables S1 and S2.

In Indonesia, one of the best-known alcoholic beverages, traditionally known as sopi or arak, is obtained from the sap of palm trees such as *tua-metan, tua-tali, akadiru*, and *nuu*, as well as from grapes and sugar cane (Sukadanal & Tenaya, 2016; Juniantara & Terjawati, 2021). While in India, wine is produced from palm trees such as the Palmyra palm (*Borassus flabellifer*), the Indian date palm (*Phoenix sylvestris*) and coconut palms (*Cocos nucifera L*) (Chandrasekhar, 2012).

5 THE PRODUCTION OF *TUA-SABU* IN TIMOR-LESTE

Tua-sabu is available throughout all regions of Timor-Leste, primarily in markets. However, regarding production, data collected from a 2021 field visit revealed that not all regions have production of all species. As shown in Figure 2, some municipalities have only one plant species for production, while others may have two or more. This variation depends on the availability of plant species and the experience of the producers, particularly in sap extraction.

Figure 2 – The production of tua-sabu in the regions of Timor-Leste represents the origin of the palm species



Municipality	Count of palm Species
Aileu	Brown
Ainaro	None
Baucau	Brown, Yellow, Green, Blue
Bobonaro	Brown, Yellow
Covalima	Brown
Dili	Blue
Ermera	Brown
Lautém	Brown, Blue
Liquiça	Blue
Manatuto	Brown
Manufahi	Yellow
Oe-cusse	Yellow, Blue
Viqueque	Brown, Yellow, green

Source: Authors (2025)

6 *TUA-SABU* PRODUCTION CHAIN IN THE CONTEXT OF TIMOR-LESTE

The process of producing *tua-sabu* from palm sap in the context of Timorese producers consists of main stages such as palm selection and sap extraction, fermentation, distillation, and bottling.

6.1 Extraction process

The palm sap extraction process in Timor-Leste consists of two traditional methods: extraction through palm inflorescences, known as a non-destructive method, and extraction performed by drilling the cavity of the soft meristem or soft apical stem, known as a destructive method.

6.1.1 Extraction of palm sap using the non-destructive method (inflorescences)

Sap extraction through inflorescence or by a non-destructive method is applied to palm trees such as *akadiru*, *tua-metan,* and *nuu*. The sap extraction process consists of four main steps: selection, preparation, extraction, and collection. Local producers reported that the palm tree selection process is done through direct observation of the plants, based mainly on their age, maturity, and size, as well as inter alia, the productivity in terms of quantity and quality of inflorescences. Therefore, these measurements are considered fundamental factors in determining the quantities of sap produced.

Figure 3 – The indigenous process of extracting palm sap from the (non-destructive) inflorescence of palm trees, (a) akadiru palm (*Borassus flabellifer* L.), (b) Tua-metan palm (*Arenga pinnata* (Wurmb) Merr.), and (c) nuu (*Cocos nucifera* L.)

(a) (b) (c)

Source: Authors (2025)

The preparation stage begins with climbing the palm tree trunk until reaching its dense crown, where it produces a series of fibrous inflorescences. For *akadiru* palms, non-fruiting male stems are preferred. The chosen flowers are subsequently cleaned

and sanitized, and the flower tips are tied and sealed (Figure 3a). The lower part of the stem of the tied flowers is beaten or pressed, and the ends of the stems are cut into thin slices twice a week for about a month.

The release of clear droplets or sweet liquid (sap) can be observed in the presence of bees, and at this point, the flower tips are continuously cut in the order of harvest days, and the resulting sap flow is collected in a plastic bottle or bamboo cylinder attached to the rod. The presence of bees not only indicates the release of sap but is also vital for flower pollination, potentially impacting the yield. The bees' activity can influence sugar concentration in the sap, eventually improving the quality of the sap harvested.

A common tapping process involves collecting sap every 12 to 24 hours, usually in the early morning or late afternoon. At each tapping, a thin slice of the stem is cut to encourage more flow, and this process continues for several months until the stem is reduced to a stump against the trunk and later abandoned. Then, a new inflorescence will be selected at another point on the trunk, and the process will be repeated. A similar form of extraction is also carried out in regions of Indonesia (Hawa et al., 2019).

On the other hand, the extraction of sap from *tua-metan* involves bruising and cutting the young inflorescences that produce the seed head from the flowering stems (inflorescence) that emerge from its trunk (Figure 3b). This extraction process requires experienced hands to produce great results. As it matures, the grower may strip and peel the tough coverings from the stems or the stalks, and using a wooden stick, begin a twice-weekly process of beating the stalk causing bruising along its entire length for approximately a month, then look for signs of sap flow at the yellow end of the seeds, the presence of bees, or assess the release of sap in the stem through a prick with thorns. At this stage, the fruiting head of the inflorescence is cut off, and the resulting sap flow is collected in a bamboo cylinder or plastic bottle attached or tied to the stem.

For the extraction of coconut/*nuu* sap, clusters of young flowers are preferred and must be cleaned and sanitized. After this, processes similar to those used with the *akadiru* palm may be employed, or the first cut can be made directly at the tip,

approximately 10 cm, to facilitate the release of the sap. This eliminates the need to hit or press the lower part of the flower stem (Figure 3c).

According to local producers, the estimated volume of sap extracted from the *akadiru* palm tree varies from 3 to 5 L per flower/day throughout 2 to 3 months. In the *tua-metan* palm, the estimated daily sap flow sustains an average of 10 L and can last approximately 2 to 3 months, where the amount of sap produced is twice that of *akadiru* production. Meanwhile, a cluster of coconut flowers/*nuu* is capable of producing an average amount of sap between 2 and 3 L per day. According to Mc William (2022), a well-managed palm tree can produce an amount of sap of approximately 10 L (for *akadiru*) and 20 to 24 L (for *tua-metan) every* day during the process until the flow is reduced. Variations in the amount of sap produced depend on several factors such as preparation stage, plant productivity, soil fertility, age, and size of the plant, climatic factors, and seasonal factors (Mc William, 2022).

In the south of Tunisia, mainly in the Tunisian Sahara, there is a traditional practice of producing date palm sap, which is used to make a popular juice known as "*Lagmi*". This beverage is highly appreciated by consumers due to its sweet and distinctive flavor. It is generally harvested in spring for approximately four months from March to June with a production quantity of 8 to 10 L per day per palm tree (Thebat, 2009). There are also several methods of extracting sap using non-destructive methods (through the inflorescence) that are applied for several palms in some countries around the world **(Table S1)**.

6.1.2 Extraction by a destructive method of the tua-tali palm (Corypha utan)

Obtaining the sap begins by selecting the plant before flowering, primarily due to its maturation. For extraction, the leaves, stems, and top cleaning are initially removed, followed by cutting or excavating the cavity in the soft apical meristem (Figure 4) twice a day for 1 to 2 weeks (Belo et al*.,* 2025). Once formation has begun and the liquid starts bubbling, collection can commence. The sap is directed into a container

using a rope or wood to position it. According to local producers (interviewed), the volume of sap extracted per tree/day can reach 30 to 40 L for a period of two to three months; however, the quantity produced depends on several factors such as the stages of preparation, production season, climatic factors, soil fertility, and productivity, including the age and size of the plant. This form of extraction is similar to the process carried out in African and Western countries, where extraction is done by felling or incising the apical meristem of the palm tree.

The collection of sap in this process involves drilling or excavating the cavity in the soft apical meristem of the tree trunk and inserting a tube or opening directed into traditional containers such as a calabash pot, a terracotta clay pot, or containers such as plastic bottles (Franciso-Ortega & Zona, 2013; Djeni et al., 2020).

Figure 4: Palm sap extraction process using the destructive method of the *tua-tali* palm tree (*Corypha utan* Lam.), (a) before extraction, (b) cleaning, excavation in the cavity or drilling of the apical meristem, (c) sap extraction and collection, and (d) tree trunk after extraction

(a) (b) (c) (d)

Source: Authors (2025)

Furthermore, there are several methods of extracting sap by destructive methods from different palm trees **(Table S2).**

6.2 Fermentation process

In tropical countries under environmental conditions that include the use of non-sterilized or unsanitized materials, fermentation occurs easily, as the sap is rich in nutrients, and contains carbohydrates and proteins that harbor a complex microbiota,

which includes native and invasive flora carried by insects, and materials and tappers used for sap collection (Karamoko et al., 2016). In this context, bacteria naturally present in the sap easily ferment sugar due to exposure to light and/or increased temperature (Hebbar et al., 2018). Therefore, in some cases, it is necessary to add natural antimicrobial ingredients or agents, such as lime, ground bark, or leaves from a specific tree, to avoid the rapid fermentation process. In addition to this fact, the containers are regularly sterilized and sanitized, sometimes using lime or smoke, as their hygiene is very important (Francisco-Ortega & Zona, 2013).

According to some producers interviewed by the author himself, mainly from the eastern region of Timor-Leste, producing brandies from palm trees such as *akadiru*, *tua-metan,* and *nuu* requires gathering a volume of sap of around 50 L (Belo et al., 2023). For palm sap, *tua-tali* requires approximately 200 L, depending on the capacity of the vats used, leaving it to ferment for a period of two to five days, and in some cases, fermented immediately after extraction. The fermentation process is mostly carried out in open spaces, where variations in environmental conditions and consequent changes in the process of converting sugar into alcohol can occur. The fermented broth is then qualitatively evaluated based on the manufacturer's experience, considering its appearance, such as the quantity of desired volume, the color appearance, and the number of days of rest before being subjected to the next stage. Also, according to producers in the region, some use the green peels of some plants, such as *Kusum* (*Ai-daak),* in the process, intending to fortify the flavor or alcohol concentration, including the color of the final product (Belo et al., 2023). It is worth mentioning that the presence of peels in the extract can contribute to the formation of undesired secondary compounds in the product and can also affect the yield of the final distillate, as the peel can act as a natural antimicrobial agent capable of inhibiting the fermentation process (Francisco-Ortega & Zone, 2013).

6.3 Distillation process

Distillation is a separation process based on the phenomenon of liquid-vapor equilibrium of a mixture. Thus, the alcoholic fraction can be separated through the condensation of alcohol vapor from the liquid when it is heated because the boiling point of alcohol is lower than that of water in the must (Belo et al., 2023).

In the distillation process, Timor-Leste features a wide variety of still systems or distillers, such as stills based on iron (iron barrel/*bidon*) (MC William, 2022; Belo et al., 2023) or aluminum (pot/*sanan*), with various types, shapes, and sizes varying depending on each region or producer. Furthermore, there are several forms of distiller assembly systems depending on the experiences of each producer and each producing region.

The distillers used by producers in the respective municipalities of Bobonaro, Covalima, and Liquiça are made of an iron called 'Bidon,' with a capacity of 220 L, and are placed in vertical positions. The same stills are also used by producers in the municipalities of Viqueque and Covalima; however, these distillers are positioned horizontally.

The swan neck tube, made of bamboo-based material, varies in height between 1.5 and 2.0 m. It is placed in a vertical position and connected directly to the mouth of the still. The type of condenser tube used also varies by region; bamboo tubes are the most used, although some producers in the municipality of Bobonaro opt for PVC (polyvinyl chloride) tubes. These tubes, measuring over 15 m in length, are mounted in various configurations, often shaped like the letters 'C,' 'V,' or 'U.' At the end of the process, the distillate is collected from these tubes.

Some producers of Baucau and Lautém municipalities also use the "*Bidon*" still, with a maximum capacity of 110 L or half of the remaining capacity. In this system, the still is placed in a vertical position, where two clay or aluminum-based pots are placed one on top of the other like a swan neck, functioning as an evaporator tube.

Once this is done, the bamboo condenser tube measuring between 6 and 15 m in length is connected directly to the pots, placed in a straight position, and inclined to

the ground, with the distillate being collected at the end of it. In some municipalities, including Baucau, Manatuto, and Liquiça, an aluminum-based distiller still is used, with a maximum capacity of 80 L.

The system has a pot-based connection in the form of a hood that is placed between the distiller pot and the swan neck tube, made of bamboo and typically between 1.5 and 2 m high in a vertical position. A condenser tube is connected directly to the hood and extends generally up to 6 to 15 m long, inclined towards the ground, where the distillate is collected at its end. However, some operational systems used by producers in the municipalities of Manatuto and Liquiça incorporate a condenser tube refrigeration system throughout the process.

In general, the process initially pours the fermented sap into a still, followed by heating using a wood stove for 60 to 90 minutes. The separation of distillate fractions varies among producers. Most producers separate the fractions into three categories: first, second, and third, like the head, heart, and tail. In some cases, only two fractions are separated: the first (*tua-ulun*) and the second fraction (*tua-ikun*). The final distillate volume collected corresponds to 10 to 15% of the total boiler volume.

The first distilled fraction, classified as *tua-ulun*, has a considerably high alcohol content compared to the subsequent fractions, whereas the second fraction, namely *tua-klaran,* contains a moderate alcohol content, and the third fraction, called "*tua-ikun*", has a significantly lower alcohol content compared to the *tua-ulun* and *tua-klaran* fractions, and is also referred to as weak water (Belo et al., 2023).

6.4 *Tua-sabu* bottling process

Packaging a product is a step that requires careful attention and thorough knowledge of container use and materials. In this context, packaging is crucial for preventing health issues and maintaining the product's identity and characteristics during storage. In Timor-Leste, products ready for sale are mostly packaged in plastic bottles, including PET (Polyethylene Terephthalate) and HDPE (High-Density

Polyethylene) (Belo et al., 2023). Additionally, these products are often lined with LDPE (low-density polyethylene) plastic materials, such as plastic bags, to prevent alcoholic liquids from leaking.

A concern regarding the use of petroleum-derived containers is the potential contamination through direct contact or the migration of plasticizers and other substances into beverages, which can impact consumer health (de Almeida et al., 2023).

Thereby, the use of glass bottles or containers would be more suitable for storing the product, as it reduces the risks of health problems.

6.5 Process related to the maturation or aging of the product

In Brazilian literature, it is commonly noted that in the production of distilled alcoholic beverages, the product is often subjected to the aging process immediately after distillation. This process is considered an important stage for the maturation of the product and contributes to improving the flavor and aroma, as well as changing the transparent color of the newly born products to a yellowish tone at a certain period, making the beverage soft and creamy and reducing the unpleasant sensation of dryness of alcohol in the beverage (Rodrigues et al., 2019; Carvalho et al., 2020).

Aging for a certain period before finally being bottled for distribution and commercialization is a very common process for the maturation of products in different types of wooden barrels in Brazil (Garbin, Junior & Montano, 2005; Borges & Takemoto, 2019). This process is regulated by current legislation in the country (MAPA, 2005).

In the context of *tua-sabu* production, Timorese producers do not apply any type of maturation or aging to their products, due to limitations of knowledge and resources. As a result, the products are directly distributed for sale and consumption. Therefore, it is worth highlighting that the maturation process could be an important step to contribute to the improvement of the quality of *tua-sabu* in Timor-Leste in the future.

7 THE POSSIBILITY OF PRODUCING *TUA-SABU* ON AN INDUSTRIAL SCALE IN TIMOR-LESTE

The production of *tua-sabu* in the country is growing rapidly, in line with an increase in the number of enthusiasts and consumers. Currently, *tua-sabu* is widely circulated and sold in the country, from production sites to roadsides, houses, kiosks, and fairs in the domestic market. Due to the increasing demand, there is an opportunity to expand production on a medium scale.

Local producers report that a *tua-tali* palm tree can produce an average of 30 to 40 L of sap per day over a two to three-month extraction period. For *tua-metan*, a flower can produce an average of up to 10 L per day; therefore, if ten flowers are extracted on the same day, an average of up to 100 L of sap is obtained. "In contrast, the *akadiru* palm and coconut/*nuu* palm produce an average sap volume of around 2 to 3 L per flower per day, which is less than the *tua-metan* palm. However, if three flowers are picked from a tree on the same day, an average of 6 to 9 L can be obtained. If this is multiplied by ten trees, the total sap obtained per day would be 60 to 90 L.

The palm sap extraction flow period can last up to three months. Considering the availability of these plants and their potential as a reliable source of sap production, there is an opportunity to expand the production process on an industrial scale for the middle class.

8 COMMERCIALIZATION AND CONSUMPTION OF *TUA-SABU* IN TIMOR-LESTE AND PROBLEMS RELATED TO PUBLIC HEALTH

Tua-sabu production capacity in Timor-Leste is intended only for local sale and consumption. The product is still far from its export expectations due to low productivity, lack of standardization and quality control, and being considered an anonymous product within the country. However, it is currently being sold alongside other imported industrialized alcoholic beverages. The current prices of *tua-sabu* on the market vary from US$ 3 for 5 per L for the first fraction (*tua-ulun*), between

US$ 2 for 3 per L for the second fraction (*tua-klaran*) or around US$ 1.5 for 3 per L for the mixed fraction between the first (about 5 to 10%) and the second fraction of the final distillate (MC William, 2022; Belo et al., 2023). These variations depend largely on demand, originality, geographic location, and product quality.

The sales price information is based on data collected from the places of production and sale, as well as direct market research conducted in the municipalities of Lautém, Baucau, Viqueque, Manatuto, Díli, Liquiça, Bobonaro, and Covalima.

However, in terms of control, the hygienic and safety aspects of *tua-sabu* are still quite questionable due to the conditions of vulnerable stages of the production chain, and the use of unsuitable product packaging materials, such as the use of reused plastic-based products (Belo et al., 2023).

Given this, it is necessary to understand that there must be a national quality standard established by the government institution itself, such as the Agência de Investigação e Fiscalização das Atividades Econômicas, Saneamento e Alimentação, Instituto Público (AIFAESA.IP) (Jornal da República, 2016) and a national regulatory agency of metrology standardization and qualification, such as Instituto para a Qualidade de Timor-Leste, Instituto Público (IQTL.IP) (Jornal da República, 2018), to make it possible to control and regulate all productions that are permitted by current regulations before being distributed to the market, thinking about a safe product for the consumer, from a hygienic-sanitary point of view.

On the other hand, in Timor-Leste, alcohol consumption begins in adolescence. The most consumed alcoholic beverages are industrial and imported beverages, such as red wine, whiskey, and beer, among others, including beverages produced locally, such as *tua-mutin* and *tua-sabu,* on various occasions throughout the country. According to the World Health Organization in 2018, the results of the investigation showed that Timor-Leste was one of the countries with the highest youth alcohol consumption, at 15.7%, involving adolescents aged between 13 and 17 years. This shows a greater social concern for the country.

Worldwide, harmful alcohol use causes 3% of all deaths, representing 1.8 million people each year (WHO, 2018). It is estimated that alcohol use has caused about 20-30% of diseases worldwide, such as esophageal cancer, liver disease, homicide and other intentional injuries, epilepsy, and traffic accidents. Excessive alcohol consumption also puts a person at greater risk of cardiovascular disease, and although alcohol-related deaths are often the highest between the ages of 45 and 54 in most countries, the association between early age of alcohol use and patterns of use and abuse in adults makes the status of alcohol consumption among adolescents important (WHO, 2018).

In a study carried out by Jani et al (2021) in the United Kingdom on the risks of consuming various alcoholic beverages, the results showed that the consumption of brandies was associated with a 25% higher risk of mortality, 31% of MACE (Mortality, Major Adverse Cardiovascular Event), a side effect of heart disease, 48% higher risk of liver cirrhosis and 10% higher risk of accidents/self-harm compared to red wine.

Similarly, beer/cider consumption was associated with approximately 18% increased risk of mortality, 16% with MACE, 36% with increased risk of liver cirrhosis, and 11% with increased risk of accidents/self-harm.

Carvalho et al (2021) carried out a study analyzing the relationship between alcohol consumption and the prevalence of hypertension in patients admitted to the Gleno Inpatient Health Center, in the municipality of Ermera. The results showed that patients who consumed alcohol were more likely to eventually suffer from hypertension with increased blood pressure, compared to patients without alcohol consumption.

Furthermore, patients admitted to the Hospital Nacional de Guido Valadares (HNGV) were also positively affected by hypertension caused by alcohol consumption (Pinto et al., 2022a), and the study reported that the alcohol consumption of the population of Baucau contributed to the incidence of hypertension as well (Pinto et al., 2022b).

Problems with alcohol can also interfere with human psychological development and negatively affect social aspects such as the work environment, school, social activities, and leisure. Its consumption can harm the paths of young

Timorese people from a young age, such as leading them to drop out of school and live other ways of life. In Timor-Leste, incidents associated with alcohol consumption are frequent, such as arguments, fights, homicides, and traffic accidents, in addition to the direct risk to health, resulting in various diseases (WHO, 2018). The core of the problems with alcohol consumption in the country is the lack of social control and implementation of prohibition rules to control the trade and free consumption of alcoholic beverages throughout the territory.

Given this, the government of Timor-Leste relaunched the consumer protection policy and created a decree law to control trade and free consumption of alcoholic beverages to protect and guarantee the health of consumers. Through Decree-Law no. 26/2016, the government established an entity to execute the powers to inspect, supervise, and control the exercise of economic activities, sanitary conditions, and quality control in the food sector under the law in force aims to eliminate, reduce, or prevent risks to the health of consumers (Jornal da República, 2016).

In Article 20 of Decree-Law nº. 8/2016 on "Consumer Protection", deviant commercial practices are not permitted, and it is prohibited to place any capital or services on the market without complying with applicable rules, laws, and regulations.

Each product must provide, at a minimum, accurate, correct, clear, and objective information about the characteristics, quality, quantity, composition, price, guarantee, expiration date, and origin, among others, as well as the risks associated with consumer health and safety, which is provided in article 21 of the legislation Law nº. 8/2016 (Jornal da República, 2016).

9 FINAL CONSIDERATIONS

The best performance in the production of the *tua-sabu* beverage in terms of quality, efficiency, and productivity in the context of Timor-Leste can be achieved through control of the stages, from preparation, extraction, and fermentation, encompassing time and environmental control, in addition to distillation. It is extremely important

to maintain the cleanliness of the sap-collecting materials and the fermentation tank, set the right time, and control the conditions of the fermentation environment, which takes place in open systems or free areas, thus avoiding different types of contamination, and contributing to a good performance in the process of converting sugar into alcohol. It is necessary to control all occurrences of the refining process until the final collection of the distillate, using appropriate materials and equipment and adequate cleaning conditions, ensuring maximum control over the time and pressure applied and the separation of the distillate fractions. Furthermore, distilled products must be stored in appropriate containers, such as glass and new bottles, rather than reused plastic bottles. The development of this local beverage can guarantee a better quality of life for many communities living in rural and forestry regions that work with the sap extraction process and the production of *tua-sabu*, generating jobs and income for local families. On the other hand, one must consider that means of large-scale production should be considered and linked to rigorous quality control, making it more interesting in the eyes of other nations and consumer markets, as it is a unique and typical beverage that represents a bit of the culture of Timor-Leste. The availability of forest resources, especially palm trees as a source of raw material, brings great benefits to the production of beverages on an industrial scale, so that it can meet the needs of domestic consumption and its insertion in international markets.

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SUPPLEMENTARY TABLE

Table S1 – Sap extraction with the non-destructive method (Inflorescence threading) of different types of palms

No	Scientific name	Type of extraction	Sources
1	*Elaeis guineensis L.* (Oil palm)	Inflorescence extraction	Francisco-Ortega and Zona, 2013.
2	*Phoenix sylvestris (L.) Roxb.* (Wild date palm)	Inflorescence extraction	Francisco-Ortega and Zona, 2013.
3	*Arenga pinnata (Wurmb) Merr* (Sugar palm)	Inflorescence extraction	Kurniawan, Kustiningsih & Firdaus, 2020.
4	*Borassus akeassii*	Inflorescence extraction	Zongo, O., et al., 2017
5	*Phoenix dactylifera L.* (Datepalm)	Inflorescence extraction	Nguyen, Harifara e Shiro, 2016.
6	Coconut (*Cocos nucifera* L.)	Inflorescence extraction	Nguyen, Harifara e Shiro, 2016.

Source: Authors (2025)

Table S2 – Extraction of sap by destructive method (Cavity cutting and extraction) from different types of palm trees

No	Scientific name	Type of extraction	Sources
1	*Acrocomia aculeata Mart.* (Macawpalm, Coyolpalm)	Tipping (Cutting and excavating the cavity in the soft apical meristem).	Francisco-Ortega and Zona, 2013.
2	*Jubaea chilensis (Molina) Baill.* (Chilean palm)	Tipping (Cutting and excavating the cavity in the soft apical meristem).	Francisco-Ortega and Zona, 2013.
3	*Pseudophoenix Ekmanii Burret.* (Dominican cherry Palm)	Perforation or excavation of the cavity in the soft apical meristem.	Francisco-Ortega and Zona, 2013.
4	*Phoenix canariensis Neubert.* (Canary Island date)	Tipping (Cutting and excavating the cavity in the soft apical meristem).	Francisco-Ortega and Zona, 2013.
5	*Borassus aethiopum Mart.* (African fan palm)	Perforation or excavation of the cavity in the soft apical meristem.	Djeni et al., 2020
6	*Raphia hookeri* (Raffia palm, Wine palm)	Perforation or excavation of the cavity in the soft apical meristem.	Djeni et al., 2020
7	*Hyphaene coriacea Drude.* (Lalapalm)	Tipping (Cutting and excavating the cavity in the soft apical meristem).	Martins & Shackleton, 2017.
8	*Hyphaene petersiana Mart.* (Realfanpalm, Ivorypalm)	Tipping (Cutting and excavating the cavity in the soft apical meristem).	Babitseng & Teketay, 2013.

Source: Authors (2025)

Authorship contributions

1 – Lúcio Belo

PhD in Food Science and Technology from the Universidade Federal de Goiás (UFG).
https://orcid.org/0000-0001-6885-959X • luciobelo88@gmail.com
Contribution: Conceptualization, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft and Writing – review & editing

2 – Julio Cesar Colivet Briceno

Post-doctoral studies at the Universidade Federal de Goiás (UFG), as part of the Food Science and Technology program.
https://orcid.org/0000-0001-5389-9548 • juliocolivet@gmail.com
Contribution: Supervision, Validation, Visualization, and Writing – review & editing

3 – Julião Pereira

PhD in Chemistry from the Universidade Federal de Goiás (UFG).
https://orcid.org/0000-0002-9757-5083 • racalele@ufg.br
Contribution: Project administration, Resources, Supervision, Validation, Visualization, and Writing – review & editing

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