

Plant Species for the Manufacture of Malagasy Traditional Alcoholic Beverages

Tabita N. Randrianarivony^{1*}, Fortunat Rakotoarivony¹, Armand Randrianasolo², Robbie Hart²

¹Missouri Botanical Garden (MBG), Research and Conservation Program Madagascar, Antananarivo, Madagascar. ²William L. Brown Center, Missouri Botanical Garden (MBG), St. Louis, USA.

*tabita.randrianarivony@mobot.mg

Abstract Alcoholic beverages are an important component of many traditional events of Madagascar, including life-course events like male circumcision, burial and exhumation. As with many other parts of Malagasy customary practice, these beverages incorporate the unique and richly diverse flora of Madagascar. We conducted structured interviews with producers and consumers of Malagasy Traditional Alcoholic Beverages (MTABs) in 10 regions of Madagascar, spanning the island from east to west and north to south. We documented 75 plant species used to make three types of Malagasy Traditional Alcoholic Beverages: distilled *toaka gasy*, fermented cane wine *betsa*, and fermented palm wine *trembo*. Of the 75 species, 14 were main materials/main ingredients, 55 were additives during fermentation, and six were used as tools for distillation. The species were diverse, occurring in 35 plant families. Particularly species-rich families were Arecaceae (palm family) as main materials and Rutaceae (citrus family) as additives.

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Introduction

Madagascar is known for its unique and diverse landscapes, biodiversity and cultures. Many of its plant species are endemic to the island, occurring natively nowhere else in the world (Ralimanana et al. 2022). The Madagascar flora also constitute essential natural resources for the people in Madagascar who rely on plants in their daily life. In Madagascar, plants provide medicine, materials for housing and transportation, animal fodder, fuel, cultural heritage, and food, including alcoholic beverages (Randrianarivony et al. 2021).

Throughout the world, alcoholic beverages are embedded in many aspects of social life, including traditional customs (Egea et al. 2016; Keskin and Günes 2021; Tamang 2010). Alcoholic beverages can be a situation definer, status indicator, statement of affiliation, and gender differentiator (SIRC 1998). Homemade and traditional alcoholic beverages also span the world—Tamang (2010) cites more than 50

including Mangizi, Kaffir, and Mbege (Africa), Sake, Toddy (Asia) Raksi (India) and Bagni (Russia), among many others. In Madagascar, alcoholic beverages are both consumed as part of regular and commercial life and—in the form of Malagasy Traditional Alcoholic Beverages (MTABs)—are important to customary practice. For example, at funerals a few drops of alcohol are poured on the ground as a sign of respect for deceased person. Alcoholic beverages are also consumed before opening the family tomb and before the solicitation of ancestral spirits to welcome the deceased into the afterlife. In the West and South-west of the country, MTABs are also used during the *fanompoambe* and *fitampoha* ceremonies (bathing of royal relics) (Chazan-Gillig and Haidaraly 2006). Three general types of MTABs are produced in Madagascar: the distilled rum *toaka gasy*, the fermented cane wine *betsa* or *betsabetsa*, and the fermented palm wine *trembo*.



Figure 1 Production process of *toaka gasy* a) Collection and preparation of sugar cane b) Fermentation process with additives, c) Cooking and distillation with traditional alembic, d) Recuperation of *toaka gasy* (photos by authors).

Toaka gasy, which literally means “Malagasy rum,” is the name commonly given to alcoholic beverages. It is also called *galeoka* or *ambodivoara* by people from the highlands and *gantriaka* or *lemadio* by people in the north of Madagascar. The plant substrate and distillation process for making *toaka gasy* are the same in both regions, but plant additives are different according to ethnic group. *Toaka gasy* is usually made through fermentation and distillation of sugar cane (*Saccharum officinarum*), using traditional utensils and tools. Sugar cane is mixed with plant additives commonly called *laro*, cut into tiny pieces then mashed with mortar. These plant additives used to improve aroma and taste and to enhance fermentation. *Laro* includes species like *Cedrelopsis grevei*, *Syzygium jambos*, *Melicope madagascariensis* and *Cajanus cajan* previously studied for their role as enhancers in the production of *toaka gasy* (WWF

2011; Randriamisetra 2016). The mixture is fermented for about three to seven days in metal barrels sealed with cow dung and clay. After the fermentation process, barrels half-full of fermented sugarcane are put on an open fire. The evaporating alcohol is collected in a metal pipe, where the surrounding water cools down the vapor and the alcohol condenses (Figure 1). At the end of the pipe, two products are obtained from a single distillation—the first of around 70° for the first 75% of the liquid (*lohatoaka*) and the second of about 40° for the remaining 25% (WWF 2011). *Toaka gasy* is among the most popular alcoholic beverages in Madagascar and is cheaply available in the market. Because of the uncertainty of ethanol content, the trade of this product for consumption is currently prohibited by the Malagasy government (Gouvernement Malagasy 2013). *Toaka gasy* is considered a sacred beverage that is used to



evoke ancestral spirits during healing ceremonies such as *tromba* and *bilo* (Beaujard 2014). It is also poured in the northeast corner of the house (*zoro firarazana*), which is considered as a dwelling place for the ancestors, to ask for benediction and to show respect. It also plays an important role in a variety of other traditions like male circumcision, traditional weddings, and exhumations (Mauro 2001).

Betsa, a fermented cane wine, is also called *betsabetsa* or *badezy*. *Betsa* is mostly known from the eastern part of Madagascar. The process of preparation consists of extracting sugar cane juice by pressing it with a traditional wooden press. After pressing, sugar cane juice is collected in a large vessel. Plant additives like *Cedrelopsis grevei* are added to the sugar cane juice, which is then covered and fermented for four to five days (Jaonina 1986). The whitish or yellowish liquid obtained from the fermentation process is the *betsa* and has a sweet or sour taste with around 4°–5° of alcohol.

Trembo, also called *sora*, is obtained from a direct fermentation of sap of young palms such as *Hyphaene coriacea*. This kind of traditional alcoholic beverage is mostly found in coastal villages in northern and western Madagascar. The terminal bud of palm near inflorescence is cut, the palm sap that flows is collected in a plant container (a bamboo, *Bambusa maxima*) then left to be fermented in the sun for a week (Beaujard 2011). The product obtained (*Trembo*) is a white milky liquid with about 3° of alcohol.

In Madagascar and countries in mainland Africa, literature on Traditional Alcoholic Beverages (TABs) manufacture, the impact of alcohol consumption, and the impact of MTABs production on forests and biodiversity are used as support documents for decision makers (Irwin and Ravelomanantsoa 2004; WWF 2011). Among the over 14,000 estimated plant species inventoried in Madagascar, many have been identified as sources of food and there is some information on species used in the manufacture of MTABs (Rakotoarimanana 1996). However, accurate and comprehensive information on plant species used to make MTABs is scarce. The present study's goal is to fill this informational gap by documenting plant species used in the manufacture of TABs in Madagascar.

Methods

Structured interviews (Cunningham 2001) were

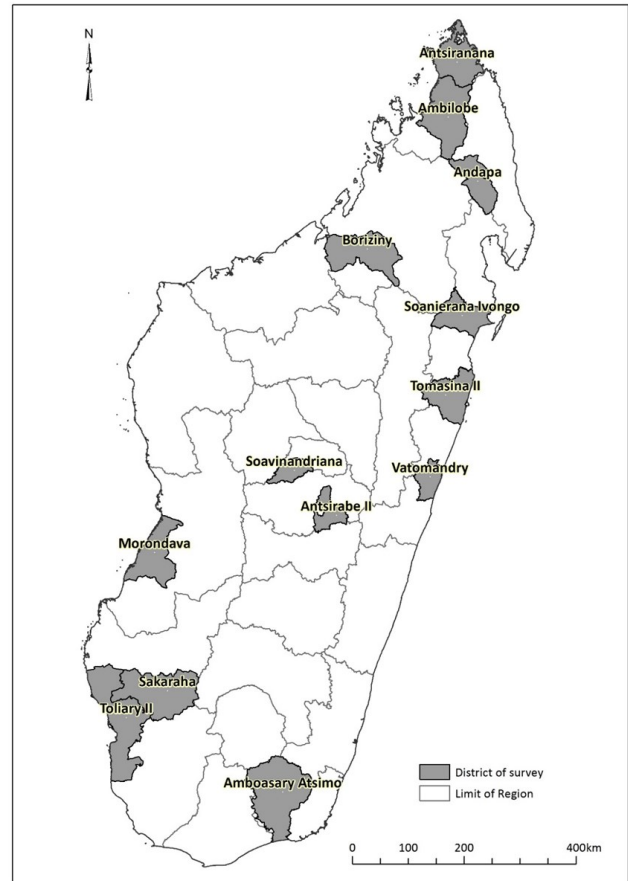


Figure 2 The fourteen districts within ten regions (Analanjirifo, Anosy, Atsimo-Andrefana, Atsinanana, Boeny, Diana, Itasy, Menabe, Sava, and Vakinakaratra) in rural areas of Madagascar in which interviews on plants used in Malagasy Traditional Alcoholic Brinks were conducted.

conducted from July to October 2016. Surveys were done in ten regions of Madagascar (Analanjirifo, Anosy, Atsimo-Andrefana, Atsinanana, Boeny, Diana, Itasy, Menabe, Sava, and Vakinakaratra) (Figure 2). We focused the surveys in rural areas of those ten regions as people from urban areas rarely consume alcoholic beverages made in traditional ways (Razanamihaja and Befinoana 2013). In each village, the target informants were both consumers and manufacturers of MTABs above 18 years old. All interviews were conducted after obtaining oral and written prior informed consent (Supplementary Document 1). In some regions, local people who were locally recognized as knowledgeable about traditional customs were hired and trained in conducting ethnobotanical surveys to conduct the survey. The

Table 1 Profile of informants interviewed about plants used in Malagasy Traditional Alcoholic Beverages.

Stratum	Category	Percentage (%)
Gender	Men	90
	Women	10
Age	18–30	19
	30–45	42
	45–60	33
	60–75	6
Occupation	Producers	45
	Consumers (including farmers and sellers)	55

questionnaire (Supplementary Document 2) focused on the types of MTABs that participants drink or prepare, the method and materials of preparation, plant species used, plant location and abundance, and the reason of the selection of additives as well as for preparation of MTABs.

Data treatment

The frequency of plant species used to produce MTABs was calculated to identify the most commonly used species, and then the species used for the preparation of MTABs were compared all over Madagascar. Frequency index (FI) which is the expression of the percentage of citation frequency of a species by informant, was calculated as:

$$FI = (FC/N) * 100$$

With

FI: frequency index (%)

FC: number of informants who mentioned the use of the species

N: total number of informants.

Differences between plants cited by consumers and manufacturers of TABs were tested using non-parametric Mann Whitney test.

Results

Informant Knowledge

In total, we interviewed 128 informants including 115 men and 13 women. This gendered difference is because few women reported producing MTABs (Table 1). Informants were between the ages of 18 to 70 years. We interviewed 57 people for their knowledge as producers of MTABs and 71 people for their perspectives as consumers of MTABs.

Consumers and producers both cited on average three plant species used during the preparation of MTABs (3.2 ± 1.8 for manufacturers and 2.6 ± 1.4 for consumers).

Useful Plants for the Production of MTABs

Thirteen plant species were cited as the main materials used for the preparation of MTABs, 55 species cited as additives, and 9 as utensils and tools used like stills and containers (Table 2, Supplementary Document 3).

Useful Plants: Main Materials

Plant species used as main materials for preparation of **trembo** were Arecaceae including *Cocos nucifera* (**Voanio**), *Hyphaene coriacea* (**Satrana**, **Satra**), *Borassus madagascariensis* (**Dimaka**, **Marandravina**, **Befelatanana**, (Figure 3), *Bismarckia nobilis* (**Satrapotsy**) and *Dyopsis ampasindavae* (**Lavaboka**). Apart from *Cocos nucifera*, all species were native and some were endemic to Madagascar (Table 2).

Toaka gasy and **betsabetsa** were mostly made from sugarcane (*Saccharum officinarum*), or fruits including pineapple (*Ananas comosus*), jackfruit (*Artocarpus heterophyllus*), litchi (*Litchi chinensis*), banana (*Musa acuminata*), cashew (*Anacardium occidentale*), and mango (*Mangifera indica*). Sometimes cereals including rice (*Oryza sativa*), and maize (*Zea mays*) were used. Sugarcane was frequently cited by informants (with frequency index FI 24%) as raw material for the production of **toaka gasy** and **betsabetsa** (Table 2), followed by banana (*Musa acuminata*) (FI 10%). One informant mentioned using fruits of *Hyphaene coriacea* for **toaka gasy**, and three participants cited honey as raw material for the manufacture of **betsabetsa**.

Useful Plants: Additives (**Iaro**) for **Toaka Gasy** and **Betsabetsa**

Fifty-five plant species from 25 plant families were

Table 2 75 taxa in 35 plant families associated with the manufacture of Malagasy Traditional Alcoholic Beverages, with the type of alcohol produced, the use of the taxon, plant part, number of citations (N), regions cited, life-form of taxon and endemicity status indicated. Please see Supplementary Document 3 for local name and references.

Taxon	Voucher	Type¹	Uses²	Part³	N	Region⁴	Form	Status⁵
Anacardiaceae								
<i>Anacardium occi-</i> <i>dentale</i> L.	Manjakahery 13	Toaka gasy	Raw material	F	1	So	Tree	Nat.
<i>Mangifera indica</i> L.	Randrianarivony 1202	Toaka gasy	Bitterant, starter, enhancer	B	4	So	Tree	I
<i>Sclerocarya birrea</i> subsp. <i>caffra</i> (Sond.) Kokwaro	Andriamihajarivo 535	Toaka gasy	Additive, starter	B	1	An	Tree	I
Anisophylleaceae								
<i>Anisophyllea schatzii</i> Li Bing Zhang, X. Chen & H. He	H. Perrier de la Bâthie - 14142	Betsa	Sweeten- er, starter	F	1	Al	Tree	E
Annonaceae								
<i>Monanthes taxis</i>		Betsa	Additive, starter	F	1	Aj		
<i>Uvaria ambongoen-</i> <i>sis</i> (Baill.) Diels	Razakamalala 1835	Betsa	Additive, starter	St	2	So	Shrub	E
Arecaceae								
<i>Bismarckia</i> <i>nobilis</i> Hildebrandt & H. Wendl.	Gardiner 407	Trembo	Raw material	S, I	2	Me, At	Tree	E
<i>Borassus madagasca-</i> <i>riensis</i> (Jum. & H. Per-	Noblick 5055	Trembo	Raw material	S, F	4	Me, Bo, Mn	Tree	E
<i>Cocos nucifera</i> L.		Trembo	Raw material	F	5	Di, Aj	Tree	I
<i>Dyopsis ampasindavae</i> Beentje	Birkinshaw 82	Trembo	Raw material	I	1	Di	Tree	E
<i>Dyopsis decaryi</i> (Jum.) Beentje & J. Dransf.	Beentje 4614	Trembo	Raw material	I	1	An	Tree	E
<i>Hyphaene coria-</i> <i>cea</i> Gaertn.	Busmann - 18794	Sora, Trembo Toaka gasy	Raw material Cover	S, I L	2 2	Me, Sv So	Tree Tree	E E
Asphodelaceae								
<i>Dianella ensifolia</i> (L.) Redouté	Rasoafaranaivo 52	Toaka gasy, Betsa	Additive, starter, enhancer	R	1 4	Aj, Aa, Ai	Herb	Native

¹*Toaka gasy* – distilled; *Betsa* – cane wine; *Trembo* – palm wine

²Starter – used to start fermentation, enhancer – used to make stronger, cover – used to cover mixture

³B – Bark, F – Fruits, R – Roots, S – Sap, St – Stem, Se – Seeds, L – Leaves, Lt – Leafy twigs, T – Trunk, I – Inflorescence

⁴So – Sofia; An – Anosy; Al – Alaotra-Mangoro; Aj – Analanjirofo; Me – Melaky; At – Atsimo andrefana; Bo – Boeny; Mn – Menabe; Di – Diana; Aa – Atsimo-Atsinanana; Ai – Atsinanana; Vf – Vatovavy-Fitovinany; It – Itasy; Sv – Sava; Hm – Haute Matsiatra; Ad – Androy; Ih – Ihorombe; Ao – Amoron'i Mania; Am – Analamanaga

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Taxon	Voucher	Type	Uses	Part	N	Region	Form	Status
Asteraceae								
<i>Brachylaena ramiflora</i> var. <i>bernieri</i> (Baill.) Humbert	Service Forestier (SF) 12494	Toaka gasy	Additive, starter	B	1	Ai	Tree	Native
Bignoniaceae								
<i>Stereospermum euphoroides</i> DC.	Keraudren 470	Toaka gasy	Alembic	T	2	At	Tree	E
Bromeliaceae								
<i>Ananas comosus</i> L.		Betsa	Raw material	F	2	Aj	Herb	I
Burseraceae								
<i>Commiphora simplicifolia</i> H. Perrier	Mankakahery 274	Toaka gasy	Additive, starter, enhancer, container	B	1	At	Tree	E
Clusiaceae								
<i>Garcinia orthoclada</i> Baker	Ravelonarivo 203	Toaka gasy	Additive, starter	B	1	Sv	Tree	E
<i>Symphonia louveli</i> Jum. & H. Perrier	Rakotonandrasana 681	Toaka gasy	Additive, starter, enhancer	B	1	Aj	Tree	E
Combretaceae								
<i>Terminalia fatraea</i> (Poir.) DC.	Ratovoson 1822	Toaka gasy	Additive, starter	B	3	An	Tree	E
<i>Terminalia ombrophila</i> H. Perrier	Lehavana 191	Toaka gasy, Betsa	Additive, starter	St	17	So	Tree	E
Elaeocarpaceae								
<i>Elaeocarpus subserratus</i> Baker	Rakotozafy 214	Toaka gasy	Additive, starter	B	1	Vf	Tree	E
Euphorbiaceae								
<i>Givotia madagascariensis</i> Baill.	Manjakahery 135	Toaka gasy	Alembic	T	3	At	Tree	E
Fabaceae								
<i>Cajanus cajan</i> (L.) Huth	Randrianasolo 445	Toaka gasy	Additive, starter, enhancer	R	14	So, It	Shrub	Nat.
<i>Crotalaria laevigata</i> Lam.	Rabenantoandro 958	Betsa	Fragrance, sweetener, starter, enhancer	R	22	So	Shrub	E
<i>Dalbergia</i> L. f.		Toaka gasy	Alembic	T	3	At		
<i>Delonix floribunda</i> (Baill.) Capuron	Randrianarivony 951	Toaka gasy	Alembic	T	1	At		E
<i>Eriosema psoraleoides</i> (Lam.) G. Don	Randrianarivony 557	Betsa	Additive, starter	R	1	So	Herb	Native

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Taxon	Voucher	Type	Uses	Part	N	Region	Form	Status
<i>Tamarindus indica</i> L.	Bernard 2453	Toaka gasy	Additive, starter	F	20	An, At, So	Tree	Native
<i>Vachellia farnesiana</i> (L.) Wight & Arn	Decary 2039	Betsa, Toaka gasy	Additive, starter	St	2	So	Shrub	Nat.
Gentianaceae								
<i>Tachadenus carinatus</i> (Desr.) Griseb.	Ramananjanahary 546	Toaka gasy	Additive, starter	R	1	An	Herb	E
Kirkiaceae								
<i>Kirkia leandrii</i> (Capuron) Stannard	Razakamalala 4451	Toaka gasy	Fragrance, starter	B	1	Me	Tree	E
Lauraceae								
<i>Cryptocarya agathophylla</i> van der Werff	Andriatsiferana 2204	Toaka gasy	Additive, starter	B	1	Al	Tree	E
Loganiaceae								
<i>Strychnos madagascariensis</i> Poir.	Randrianarivony 571	Toaka gasy	Bitterant, starter	F	1	So	Shrub	I
<i>Strychnos spinosa</i> Lam.	Rakotovao 6020	Betsa, Toaka gasy	Additive, starter, enhancer	F	6	So	Shrub	I
Malpighiaceae								
<i>Acridocarpus excelsus</i> A. Juss.	Randrianarivony 539	Toaka gasy	Bitterant, starter	B	3	So	Tree	E
Meliaceae								
<i>Neobeguea mahafaliensis</i> J.-F. Leroy	Andriamihajarivo 1148	Toaka gasy	Alembic	T	6	At	Tree	E
Moraceae								
<i>Artocarpus heterophyllus</i> Lam.		Betsa, Toaka gasy	Raw material	F	1	Aj	Tree	I
Musaceae								
<i>Musa acuminata</i> Colla		Betsa	Raw material Cover	F L	7 3	Aj, So	Herb	I
Myrtaceae								
<i>Syzygium aromaticum</i> (L.) Merr. & L.M. Perry		Betsa	Additive, starter	B	1	Aj	Tree	I
<i>Syzygium cumini</i> (L.) Skeels	Andriamihajarivo 2199	Toaka gasy	Additive, starter	B	2	Vf	Tree	Nat.
<i>Syzygium emirnense</i> (Baker) Labat & G.E. Schatz	Randrianasolo 575	Betsa, Toaka gasy	Additive, starter	B, Lt	3	Aj, At	Tree	E
<i>Syzygium jambos</i> (L.) Alston		Betsa	Additive, starter	F	1	Ai	Tree	I
Poaceae								
<i>Nastus</i> Juss.		Toaka gasy	Container	St	2	So		
<i>Oryza sativa</i> L.		Betsa	Raw material	Se	1	Di	Herb	I

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Taxon	Voucher	Type	Uses	Part	N	Region	Form	Status
<i>Saccharum officinarum</i> L.		Toaka gasy, Betsa	Raw material	St	24	10 regions	Herb	Nat.
Rhamnaceae								
<i>Ziziphus mauritiana</i> Lam.	Rakotovao 6011	Toaka gasy	Sweetener, starter	F	6	So	Tree	Nat.
Rubiaceae								
<i>Breonadia salicina</i> (Vahl) Hepper & J.R.I. Wood	Randrianarivony 479	Toaka gasy	Additive, starter	B	2	An, Aj	Tree	Native
<i>Breonia chinensis</i> (Lam.) Capuron	Rabarimanarivo 12	Betsa	Fragrance, starter	B	2	Ai, Vf	Tree	E
<i>Hyperacanthus</i> E. Mey. ex Bridson		Betsa, Toaka gasy	Additive, starter	L, B	1	Ai		
<i>Razafimandimbisonia minor</i> (Baill.) Kainul. & B. Bremer	Razanatsima 1131	Toaka gasy	Additive, starter	B	1	Hm	Shrub	E
<i>Sabicea diversifolia</i> Pers.	Randriatsivery 90	Betsa	Additive, starter	Lt	2	Ai	Shrub	E
Rutaceae								
<i>Cedrelopsis grevei</i> Baill.	Andriamihajarivo 495	Toaka gasy	Additive, starter	B	21	Ad, An, Bo, At, Mn, Sv, So	Tree	E
<i>Cedrelopsis longibracteata</i> J.-F. Leroy	Ramananjahary 809	Betsa, Toaka gasy	Sweetener, starter	B	13	Aj	Tree	E
<i>Cedrelopsis rakotzafyi</i> Cheek & Lescot	Rakotonandrasana 1046	Betsa	Additive, starter	B	1	Di	Tree	E
<i>Cedrelopsis trivalvis</i> J.-F. Leroy	Antilahimena 777	Betsa	Additive, starter	B	6	Di, An, Ih	Tree	E
<i>Melicope bakeri</i> T.G. Hartley	Rasoazanany 308	Betsa	Additive, starter, euphoric	B	1	Al	Tree	E
<i>Melicope balankazo</i> (H. Perrier) T.G. Hartley	Rakotondrajaona 1765	Toaka gasy	Additive, starter	B	1	Al	Tree	E
<i>Melicope belahe</i> (Baill.) T.G. Hartley	Roger Bernard 1689	Betsa, Toaka gasy	Additive, starter	B	7	Vf, Sv, Ai, Aj	Tree	E
<i>Melicope discolor</i> (Baker) T.G. Hartley	Ravelonarivo 3201	Toaka gasy	Additive, starter	B	1	Al	Shrub	E
<i>Melicope fatraina</i> (H. Perrier) T.G. Hartley	Ramanantoavolana 18	Toaka gasy	Additive, starter	B	2	Al, Ai	Tree	E
<i>Melicope</i> J.R. Forst. & G. Forst.		Toaka gasy, Betsa	Fragrance, starter	B	13	Sv, So, Al, Aj, Ai, An, Hm, Vf		
<i>Melicope sambiranensis</i> (H. Perrier) T.G. Hartley	Ravelonarivo 1172	Betsa	Fragrance, starter	B	1	So	Tree	E

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Taxon	Voucher	Type	Uses	Part	N	Region	Form	Status
<i>Vepris polymorpha</i> (Danguy ex Lecomte) H. Perrier	Randrianarivony 173	Betsa	Fragrance, starter	B	1	An	Tree	E
Salicaceae								
<i>Homalium parkeri</i> Baker	Razanatsima 942	Toaka gasy	Additive, starter	Lt	1	Ai		
Sapindaceae								
<i>Litchi chinensis</i> Sonn.		Betsa	Raw material	F	1	Aj	Tree	I
Sarcolaenaceae								
<i>Leptolaena pauciflora</i> Baker	Raharimampionona 478	Toaka gasy	Fragrance, starter	B	2	Vf, Ao	Tree	E
<i>Perrierodendron quartzitorum</i> J.-F. Leroy, Lowry, Haev., Labat & G.E. Schatz	Razafitsalama 3	Toaka gasy	Additive, starter, enhancer	R	1	Ao	Shrub	E
<i>Schizolaena cauliflora</i> Thouars	Randriatsivery 195	Betsa	Additive, starter	B	2	Ai	Tree	E
<i>Xerochlamys bojeriana</i> (Baill.) F. Gérard	Rabarimanarivo 513	Toaka gasy	Fragrance, starter	R (B)	1	Am	Shrub	E
Scrophulariaceae								
<i>Buddleja madagascariensis</i> Lam.	Razanatsoa 425	Toaka gasy	Additive, starter	Lt	2	Al	Shrub	E
Simaroubaceae								
<i>Quassia indica</i> (Gaertn.) Noot.	Razafitsalama 496	Toaka gasy, Betsa	Bitterant, starter, enhancer, fragrance	B	3	Me, So	Tree	Native
Stemonuraceae								
<i>Grisollea myriantha</i> Baill.	Rakotoarivelo 517	Betsa	Additive, starter	B	1	Ai	Tree	Native
Stilbaceae								
<i>Nuxia oppositifolia</i> (Hochst.) Benth.	Rakotoarivelo 858	Toaka gasy	Additive, starter	B	1	An	Tree	I
Strelitziaceae								
<i>Ravenala madagascariensis</i> Sonn.	Rakotovao 5205	Toaka gasy	Cover	L	2	So, Aj	Tree	E

cited by informants as additives into the traditional alcoholic beverages. Among them, 29 plant species were used as additives for *toaka gasy* and 16 were cited as additives for *betsabetsa*. Ten species were cited as additives for both *toaka gasy* and *betsabetsa*. Participants reported that additives were both used as enhancer to activate the fermentation process of MTABs, and to add flavor, to sweeten or to make MTABs bitter, to give a pleasant aroma and to improve taste of MTABs.

Of species used as additives, Rutaceae was the most prominent family with 12 species, followed by Rubiaceae, Myrtaceae, Fabaceae and Sarcolaenaceae (Supplementary Document 3). Additives were mostly trees (70%), and the bark was the most frequently cited part used (Table 2, Supplementary Document 4).

About 65% of additives are endemic to Madagascar, and 4 plant species belonged to the Madagascar-endemic family Sarcolaenaceae:



Figure 3 Process of production of **trembo** a) main material *Borassus madagascariensis* b) collecting the sap of palm c) **Trembo** ready for sale (Photos by Rabotovao 2015)

Xerochlamys bojeriana (**Hatsikana, Fotona, Voaloro, Kitoto**), *Schizolaena cauliflora* (**Valotra**), *Perrierodendron quartzitorum* (**Kitoto, Kitotovavy**) and *Leptolaena pauciflora* (**Foto, Fotona, Fotondahy, Tambarasaha**). Among additives, 65% are forest plant species and 25% are collected from open area, savannah and degraded forest.

Among the 55 plant species mentioned as additives, eight species were frequently cited by informants (with frequency index FI > 10%): *Crotalaria laevigata* (FI 22%), *Cedrelopsis grevei* (FI 21%), *Tamarindus indica* (FI 20%), *Terminalia ombrophila* (FI 17%), *Dianella ensifolia* (FI 14%), *Cajanus cajan* (FI 13%), *Melicope* (FI 13%) and *Cedrelopsis longibracteata* (FI 13%).

Different plant species were used as additives in each region in Madagascar (Table 2). More than 10 plant species were used in Analanjirofo, Anosy, Atsinanana and Analamanga. Ten species were more generally cited as additives from more than one region in Madagascar: the most widely cited were *Cedrelopsis grevei* which was used in 7 regions, and *Melicope belabe*

in 4 regions. People from drier regions in the southern and western Madagascar (Antsimo-Andrefana, Androy, Boeny, Melaky, Menabe and the dry part of Anosy) often cited *Cedrelopsis grevei* or/and *Tamarindus indica* as additives of MTABs, while *Melicope belabe* or/and *Dianella ensifolia* were mostly cited in the four humid regions (Analanjirofo, Atsinanana, Atsimo-Atsinanana, Sava). Different species like *Syzygium emirnense*, *Leptolaena pauciflora* and *Cajanus cajan* were cited from the highlands (Analamanga, Itasy, Amoron'i Mania and Vakinkaratra). *Mangifera indica*, *Terminalia ombrophila*, *Crotalaria laevigata*, *Melicope sambiranensis* and *Cedrelopsis trivalvis* were frequently cited by informants from the northern regions (Sava, Diana and Sofia).

People from Analanjirofo and Analamanga regions reported that some species used as additives were rare. *Melicope belabe*, *M. fatraina* and *Syzygium emirnense* are locally threatened by overharvesting for their use as additives.

Useful Plants: Utensils and Tools

In Madagascar, TABs are produced manually using locally available utensils and tools. In some regions, trunks of *Dalbergia* spp., *Delonix* spp., *Givotia madagascariensis*, *Neobeguea mahafaliensis*, *Stereospermum euphoroides* were cited for the construction of traditional alembics. Leaves of *Ravenala madagascariensis*, *Hyphaene coriacea* and *Musa acuminata* were used to cover the mixture of all materials during the fermentation process. Bamboo stems were used as containers for the final product after the distillation.

Discussion

Demographics

The strong gender difference we observed in our survey from this study is borne out by previous literature, which mentions that only 28% of women are alcoholic beverage consumers in Madagascar (Razanamihaja et al. 2013). This difference was apparent among producers of MTABs (only 6 women in our study), and contrasts with other countries where alcoholic beverages are traditionally prepared by women or girls (e.g., Chaves-López et al. 2014).

Main Materials

The most popular main material to make MTABs is **fary** [sugarcane, *Saccharum officinarum* (Poaceae)]. In Malagasy culture, **fary** represents masculinity and generational succession (Beaujard 2014). Traditional rum produced from **fary** is considered sacred water

(*rano mahery*) and is also used by elders when they give blessings. The plantation of *fary* for the production of *toaka gasy* and artisanal sugar is practiced over the 22 regions of Madagascar occupying in total 69,820 ha of cultivated areas and has been represented in governmental planning since 2013 (WWF 2011; Gouvernement Malagasy 2013). However, there are also conservation concerns. Irwin and Ravelomanantsoa (2004) stated that illegal traditional rum production at Tsinjoarivo threatened the health of lemur population in this forest.

Trembo Palm Wine – Biogeography and Conservation

Trembo has a very short shelf-life of only one or two days, unless it is refrigerated. As the process of preparation is similar to that of “toddy” or palm wine (FAO 2011), it can be considered the palm wine of Madagascar. Apart from *Cocos nucifera*, all species for *trembo* are native and some are endemic to Madagascar. *Dyopsis ampasindavae*, a local endemic species from the Ampasindava Peninsula categorized as Critically Endangered, was also heavily exploited as building materials and for its edible palm fruits (MBG 2015; Rakotoarivony and Dransfield 2012).

Cocos nucifera and *Hyphaene coriacea* were cited in eastern and northern coast of Madagascar. *Borassus madagascariensis* was cited for the production of *trembo* in western part of Madagascar and *Dyopsis decaryi* (*Iafa*) in Taolagnaro in the Anosy region of southern Madagascar. Production of *trembo* may have a negative impact on endemic species such as *Borassus madagascariensis*, *Bismarckia nobilis*, and *Dyopsis ampasindavae*, as the plants perish after the collection. In other world regions where palm wine is made, non-destructive harvest techniques have been developed (Bernal et al. 2010), which could be explored in Madagascar to avoid extinction of useful plant species.

Laro Additives – Biogeography and Conservation

Our findings showed that additives were mostly trees (70%), and the bark was the most important part used (Table 2). In some studies from other countries, plants used as starters for the fermentation of traditional beverages were mostly herbs and shrubs (He et al. 2019). Barks of the aromatic plant families (Rutaceae, Myrtaceae) collected from the forest remnant natural forests were the most used additives. That shows the importance of those remnant natural forests for the collection of plants used as additives

for traditional alcoholic beverages, as for many other resources.

People from Analanjirofo and Analamanga regions reported that some species used as additives were rare. *Melicope belabe*, *M. fatraina* and *Syzygium emirnense* are locally threatened by overharvesting for their use as additives. Collection of bark of plants used as additives of TABs not only impacts species themselves but also forest regeneration (Irwin and Ravelomanantsoa 2004). Andriamahazo et al. in 2004 noticed many dead trees of *Melicope madagascariensis* (*Fatraina*) and *Dalbergia* spp. (*Manary*) in the corridor forest of Fianarantsoa because barks of these endemic plant species are used as ingredients in the manufacture of traditional Malagasy rum.

Some species cited as additives including *Perrierodendron quartzitorum*, *Uvaria ambongoensis* and *Anisophyllea schatzji* are categorized among endangered species. *Terminalia ombrophila* are known only from two to five localities in Madagascar. In some cases, substituting introduced species can be helpful to prevent loss or even extinction of used endemic species in their natural habitat. However, even widespread species may be threatened: *Cedrelopsis grevei* and *Crotalaria laevigata* are widespread, but are also highly sought for their uses as medicine, construction and forage. Even *Tamarindus indica* is nowadays threatened by charcoal production in the southern Madagascar.

Chemical compounds of at least 15 species of *laro* additives have been studied (Randriamisetra 2016; Rasolomampionona 2010; Razafindrazaka 1997). However, many more plant species documented here as *laro*, even including those frequently cited, have yet to be explored for their chemical compounds.

Knowledge change

Several species of *Melicope* including *M. bakeri*, *M. balankazo*, *M. fatraina*, and *M. sambiranensis* as well other species including *Acridocarpus excelsus*, *Syzygium emirnense* and *Quassia indica* were rarely cited by participants in our study, but had been recorded 50 years ago as additives of MTABs (Boiteau et al. 1968; 1971). Thirteen species (*Brachylaena ramiflora*, *Cassinopsis madagascariensis*, *Clematis mauritiana*, *Ficus lutea*, *Flacourtia ramontchi*, *Harungana madagascariensis*, *Kirkia leandrii*, *Morella salicifolia*, *Pauridiantha paucinervis*, *Perriera madagascariensis*, *Perriera orientalis*, *Petchia*

madagascariensis, and *Senna septemtrionalis*) previously mentioned in literature (Boiteau et al. 1971; Gallé et al. 2015), were not cited by informants during this study. This may show change and evolution of use of plants, connected to their availability in the wild, and or reflect regional and local diversity of practice. Similarly, we received only a few reports of *betsabetsa* made from honey, although this is documented historically (Jaonina 1986).

Conclusion

Production of alcoholic beverages in a traditional way will remain an illegal activity in Madagascar until a recent law proposed by the Malagasy parliament, to allow free sale of the traditional rum, is accepted and implemented. However, Malagasy people in many regions have for generations and continue to produce MTABs for different events, especially in traditional contexts. The superlative richness of plant species in Madagascar offers a rich, highly endemic, and still incompletely documented array of plant uses. Plants connected to MTAB's are no exception. The plant uses we document extend beyond the main materials of MTABs — *Saccharum officinarum* for the preparation of *toaka gasy* and *betsa* and palm species like *Hyphaene coriacea* and *Borassus madagascariensis* for production of *trembo* — to a diverse group of species and plant parts used as additives across the island or with regional specificity, including *Crotalaria laevigata*, *Cedrelopsis grevei*, *Tamarindus indica*, *Terminalia ombrophila*, *Dianella ensifolia*, *Cajanus cajan*, *Melicope* and *Cedrelopsis longibracteata*. Better understanding of this unique body of tradition allows its protection and can inform sustainable management and use that also preserves Madagascar's biodiversity. As collection of MTAB additives impacts plant populations, we propose the inclusion of important plant species for tree planting activities and encourage non-destructive ways of harvesting of plants.

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