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### ► To cite this version:

François Chassagne, Jean-François Butaud, Frédéric Torrente, Eric Conte, Raimana Ho, et al.. Polynesian medicine used to treat diarrhea and ciguatera. *Journal of Ethnopharmacology*, 2022, 292, pp.115186. 10.1016/j.jep.2022.115186 . hal-04007662

**HAL Id: hal-04007662**

**<https://ut3-toulouseinp.hal.science/hal-04007662v1>**

Submitted on 22 Jul 2024

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1 Polynesian medicine used to treat diarrhea and ciguatera: an  
2 ethnobotanical survey in six islands from French Polynesia

3

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13

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## 22 Introduction:

23  
24 In French Polynesia, diarrhea can be caused by a variety of microbial pathogens and  
25 toxins. Among the microbial pathogens, bacteria are one of the main causes of diarrhea.  
26 From 2008 to 2013, several outbreaks of *Salmonella enterica* serotype *enteritidis* infections were  
27 reported and contaminated about a hundred of persons (Le Hello et al., 2015). In 2020, 40  
28 cases of acute gastro-enteritis were recorded, among which 35 were due to *Salmonella* species  
29 contamination (BSS, 2021). To a lesser extent, *Escherichia coli* is also known to induce bacterial  
30 diarrhea in French Polynesia (BSS, 2021). Viruses are another important cause of diarrhea in  
31 the area. Hubert (2001) reported that rotaviruses represent one of the major causes of medical  
32 consultations in children in the French Polynesian territory. Also, the high prevalence of  
33 various human enteroviruses in the wastewater and surrounding seawater of Tahiti is  
34 potentially responsible for gastroenteritis (Kaas et al., 2019).

35 Besides diarrhea from microbial origin, ciguatera poisoning represents another cause  
36 of gastro-intestinal disorders in the area. Ciguatera is highly prevalent in French Polynesia,  
37 and its annual incidence varied from 26.3 to 41.9 per 10 000 person-years from 1992 to 2001  
38 (Chateau-Degat et al., 2007). More recently, 253, 348 and 333 new cases were reported in  
39 2019, 2018, 2017 respectively (Institut Louis Mallardé, n.d.). Marquesas islands is one of the  
40 most impacted area with an annual incidence of about 100 per 10 000 person-years in 2017  
41 (Chinain et al., 2019). Ciguatera is caused by eating seafood (especially fish) contaminated  
42 with ciguatoxins produced by dinoflagellates of the genus *Gambierdiscus* and *Fukuyoa*.  
43 Clinical manifestations of ciguatera are highly complex and diverse with about 175 reported  
44 symptoms (Chinain et al., 2021). It mainly includes gastrointestinal, cardiovascular and  
45 neurological disorders lasting from a few days (e.g., nausea, diarrhea) to months or even  
46 years (e.g., paresthesia, dysesthesia, asthenia, anxiety, depression). To date, no specific  
47 treatments are available, and therapeutic management relies mainly on symptomatic and  
48 supportive care, with mannitol being the only therapy evaluated by rigorous clinical trials  
49 (Friedman et al., 2017).

50 To treat these gastro-intestinal disorders, Polynesians might rely mainly on their  
51 plant biodiversity. Polynesian traditional medicine is still used today to manage various  
52 ailments. This is explained by cultural reasons, geographic isolation, and poor health  
53 infrastructure in some islands. Although there are existing documents detailing the local  
54 traditional medicine and reporting the use of medicinal plants in French Polynesia, most of  
55 them date back from the 20th century, and do not focus on specific ailments (Grépin and  
56 Grépin, 1984; Lemaitre, 1985; Maclet and Barrau, 1959; Panoff, 1966; Pétard, 2019 (1986)).  
57 Regarding the recent and known herbal medicines used for diarrhea and ciguatera, Girardi  
58 et al. (2015) reported seven plants for treating ciguatera in the Marquesas archipelago; and  
59 Quenon (2020) mentioned the use of six plants for diarrhea in the Leeward Islands  
60 archipelago. Not only the number of plants described recently for treating diarrhea and  
61 ciguatera is scarce, but there is no data providing an evaluation of the benefit-risk balance for  
62 each remedy. This lack of data is an obstacle to the establishment of the Polynesian  
63 pharmacopeia and its integration into the official health care system.

64 Out of the five archipelagos of French Polynesia, the Society Islands and the  
65 Marquesas Islands are the two archipelagos with the richest plant biodiversity, with 545 and  
66 314 native vascular plants respectively, and also the highest rate of archipelago endemism  
67 with 50 and 55% of endemic plants respectively (Florence and Moretti, 2013). The Marquesas  
68 archipelago is also one the most remote area in the Pacific and presents singular cultural

69 traits compared to the Society Islands (Girardi et al., 2015), which allow comparison between  
70 the two areas.

71 In this context, a study was performed in the two most biodiverse archipelago  
72 (Marquesas and Society) from French Polynesia to identify the remedies used to treat  
73 diarrhea and ciguatera, inventory the used plant species, compare ethnobotanical data from  
74 the two areas, and provide an assessment of their efficacy and toxicity in order to help their  
75 integration into the official health care system.

# 76 **Materials and Methods:**

## 77 78 **1. Study site**

79  
80 French Polynesia is an overseas collectivity of the French Republic which covers 3,521  
81 km<sup>2</sup> in the South Pacific Ocean and is located between 7°-28° south and 134°-155° west. It  
82 comprises 118 islands and atolls inhabited by almost 280,000 persons. Geographically,  
83 French Polynesia is subdivided into five archipelagos, namely the Society islands  
84 archipelago, comprising the Windward Islands (Îles du Vent) and the Leeward Islands (Îles  
85 Sous-le-Vent), the Marquesas archipelago (Marquises), the Austral archipelago (Australes),  
86 the Tuamotu archipelago, and the Gambier archipelago (Andréfouët and Adjeroud, 2019).

87 The study was carried out in six islands of French Polynesia including one island of  
88 the Windward islands (Tahiti), two islands of the Leeward islands (Raiatea and Tahaa), and  
89 three islands of the Marquesas archipelago (Nuku Hiva, Hiva Oa, Tahuata) (**Figure 1**). Tahiti  
90 has the largest population of French Polynesia with about 200,000 inhabitants and accounts  
91 for two-third of the total population. In 2017, Raiatea and Tahaa had 12,249 and 5,313  
92 inhabitants respectively, while the population of Nuku Hiva, Hiva Oa and Tahuata was  
93 3,120, 2,348 and 671 respectively (Philippe, 2017).

94 Altogether 39 villages were visited, including 18 in Tahiti (Arue, Faaa, Faarei Hitiaa,  
95 Mahaena, Mahina, Mataiea, Paea, Papara, Papeari, Papenoo, Papeete, Pirae, Pueu, Punaauia,  
96 Taravao, Tautira, and Teahupoo), 7 in Raiatea (Avera, Faaroa, Opoa, Tehurui, Tevaitoa,  
97 Uturoa, Vaiaau), 4 in Tahaa (Faaaha, Haamene, Patio, Tapuamu), 5 in Nuku Hiva (Aakapa,  
98 Hatiheu, Hooumi, Taiohae, Taipivai), 4 in Hiva Oa (Atuona, Hanaiapa, Taaoa, Tehutu), and  
99 1 in Tahuata (Vaitahu).

## 100 101 **2. Data collection**

102  
103 The study was conducted from February to April 2021. To select informants, we  
104 either used a random approach by visiting household or street vendors in each previously  
105 cited town, or we followed the guidance of key informants (i.e., members of Haururu  
106 association and Académie Marquisienne) who helped us to find traditional healers or  
107 knowledgeable persons in the area. All the interviews were carried out by the first author of  
108 this study, and in a few cases, a translator (key informant or family member) was also asked  
109 to help.

110 A semi-structured questionnaire was used to interview each informant. This  
111 questionnaire comprised different parts, including:

112 - Sociodemographic data: age, gender, place of residence, place of birth, number of  
113 children, occupation, level of education, religion, spoken language(s).

114 - General knowledge on diarrhea: definition, types of diarrhea, associated symptoms,  
115 causes of diarrhea, recommendations and avoidance.

116 - General traditional practices: source of knowledge, type of treated patients, type of  
117 other treated disorders, type of associated remuneration and cultural practices.

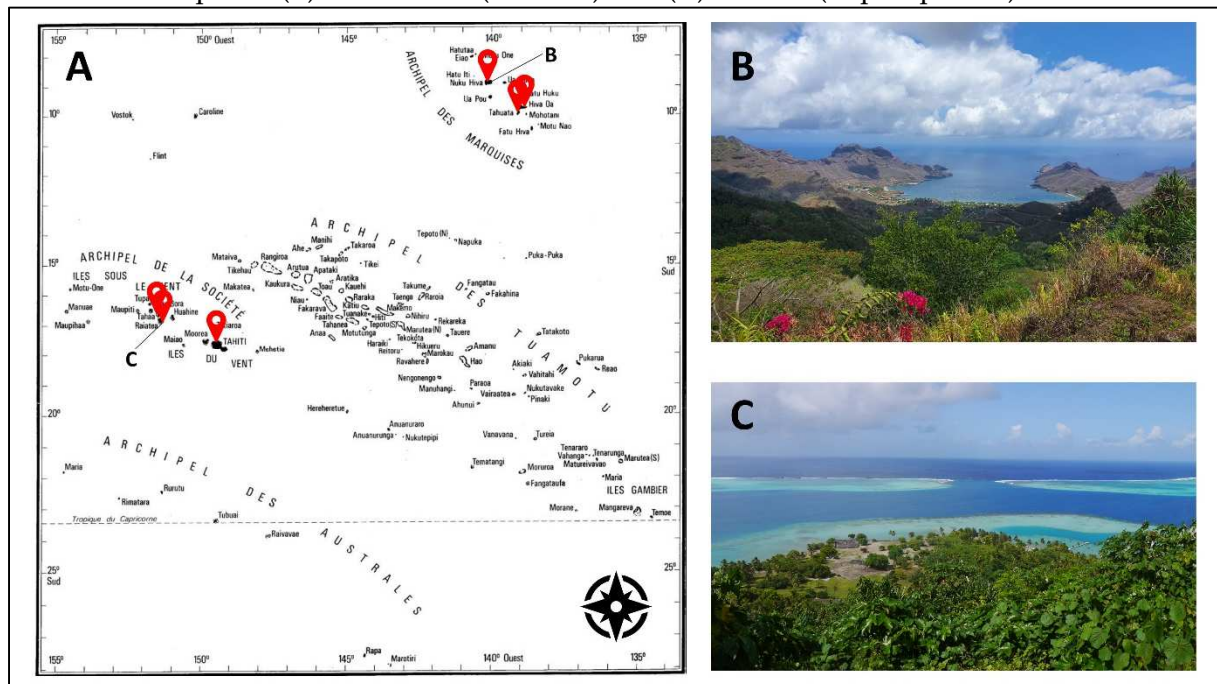
118 - Medical management of diarrhea: dietary recommendations, avoidance, advice,  
119 therapeutic management. For each cited remedy, the following questions were asked:  
120 vernacular name of plant species, part of plants used, method of preparation, method of  
121 administration, posology (including dosage and length of duration), local perception of the

122 pharmacology and toxicology of the plant.

123

124 **Figure 1:** Figure showing (A) a map of the six islands visited in French Polynesia, and

125 landscapes in (B) Nuku Hiva (Taiohae) and (C) Raiatea (Taputapuatea) islands.



126

127 Legend : Map is modified from © J-C.J. ORSTOM TAHITI (025/03-86). Note the fringing reef

128 in (C) which is the hallmark of French Polynesian islands; and the absence of reef in (B)

129 which is specific to Marquesans islands.

130

### 131 3. Ethical considerations

132

133 Before each interview, the objectives and the conduct of the study (length of the  
134 interview, data collected, etc.) was explained to each participant. Then, a prior informed  
135 consent was obtained from each informant. At the island level, local organizations  
136 (Association Haururu, Académie Marquisienne) or city officials were contacted to inform  
137 about the survey. At the government level, the Minister of Health and the Minister of  
138 Agriculture from French Polynesia were informed about the study, and the Environmental  
139 Direction (Direction de l'Environnement (DIREN)) approved the access to genetic resources  
140 and traditional knowledge associated with genetic resources (n°2238/MCE/ENV).

141

### 142 4. Botanical identification

143

144 For each new cited plant species, the informants were asked to show it in the field  
145 and photographs were taken. Then, two specimens of each plant species were collected  
146 following the methods described by Chassagne and Quave (2021). Later, the plant specimens  
147 were identified by the first author and the second author of this study. One specimen of each  
148 species was deposited at the Herbar de Polynésie française (PAP), Musée de Tahiti et des  
149 îles, Puna'auia, Tahiti, Polynésie française and another specimen was deposited at the  
150 herbarium from the Jardin Botanique Henri Gausson (TLS), Museum d'Histoire Naturelle,  
151 Toulouse, France. All plants names have been crosschecked with Plants of the World Online

152 (<https://powo.science.kew.org/>), the French inventory of natural heritage (INPN)  
153 (<https://inpn.mnhn.fr/accueil/index>), and the Nadeaud database from French Polynesia  
154 (<https://nadeaud.ilm.pf/>).

155

## 156 **5. Data analysis**

157

158         Statistical analysis was performed by using a Student's t-test (unpaired, two-tailed)  
159 for comparing mean values (numerical data), Chi-squared or Fisher test for comparing  
160 frequency (categorical data). A difference was considered statistically significant when p-  
161 value was inferior to 0.05. GraphPad Prism software version 8 was used to make figures.

162 **Results:**

163

164 **1. Sociodemographic features of informants**

165

166 A total of 133 informants were interviewed, among which 68 (51.1%) were from the  
167 Society islands, and 63 (47.4%) were from the Marquesas archipelago (**Table 1**).

168

169

170

**Table 1:** Sociodemographic features of interviewees

Characteristics		Frequency	Percent (%)
<b>Gender</b>			
	Male	35	26.3
	Female	98	73.7
<b>Age</b>			
	25-35 years	11	8.3
	36-45 years	25	18.8
	46-55 years	24	18.0
	56-65 years	33	24.8
	66-75 years	31	23.3
	76-83 years	9	6.8
<b>Residence</b>			
	Society archipelago		
	Raiatea	19	14.3
	Tahaa	7	5.3
	Tahiti	42	31.6
	Marquesas archipelago		
	Hiva Oa	31	23.3
	Nuku Hiva	28	21.0
	Tahuata	4	3.0
	ND	2	1.5
<b>Education</b>			
	None	3	2.3
	Primary School	29	21.8
	Secondary School	53	39.8
	Vocational diploma	22	16.5
	High School	18	13.5
	University	7	5.3
	ND	1	0.8
<b>Religion</b>			
	Catholic	54	40.6
	Protestant	47	35.3
	Mormon	11	8.3
	Adventist	8	6.0
	Other	11	8.3
	ND	2	1.5



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The mean age of all participants was 56.5 years old with a median of 57 years old and a range of 25-83 years old. A large majority of participants were females (98, 73.7%), and most of the informants (107, 80.5%) stopped their education before high school. The two most represented religions were Catholic (54, 40.6%) and Protestant (47, 35.3%).

Comparing informants from the Marquesas and the Society islands, we found some statistically significant differences in their sex ratio (SR) ( $SR_{\text{SOCIETY}} = 0.17$  vs.  $SR_{\text{MARQUESAS}} = 0.62$ ,  $p\text{-value} = 0.002$ ) and their religion (Catholic:  $N_{\text{SOCIETY}} = 14$  vs.  $N_{\text{MARQUESAS}} = 40$ ,  $p\text{-value} = 0.005$ ; Protestant:  $N_{\text{SOCIETY}} = 34$  vs.  $N_{\text{MARQUESAS}} = 13$ ,  $p\text{-value} = 0.02$ ). Mean age, level of education, and type of informants (see next part) were similar among the informants.

## 2. Classification of informants regarding their traditional medical practices

During the survey, the informants mentioned various traditional medical practices including: a specialization in massage therapy (six informants, 4.5%), a specialization in apitherapy (defined as therapy of musculoskeletal disorders by using local bee stings) (two informants, 1.5%), and the use of herbal remedies (123 informants, 92.4%). Out of all participants, three (2.2%) indicated that they practice traditional medicine as a full-time job with two (1.5%) specialized in massage, and one (0.8%) practicing herbalism and massage.

Among the persons using herbal medicine, only 16 (12.7%) considered themselves as expert in herbalism, while 34 (27%) knew how to treat all types of diseases with herbs, 52 (41.2%) mentioned treating people outside of their family members, and 51 (40.5%) were known by other people in the area for being able to heal. It was also noted that 51 (40.5%) participants treated only their family (but not people outside their family) with herbal medicine, two (1.6%) were able to counteract evil spells with herbal remedies, and 91 (72.2%) could treat one or a few disorders with herbs.

Altogether, six (4.5%) informants reported that they got their knowledge through dreams, four (3%) indicated that they communicate with their ancestors to make the remedy work, and five (3.7%) had a notebook of homemade remedies.

Following these heterogenous results, we decided to categorize the informants by focusing on specific criteria:

- the type of medical practices used: apitherapy, massage, or herbalism
- the ability to treat all disorders
- the fact to treat all types of patients (and not just family members)
- the reputation for being able to heal people

Getting their knowledge through dreams, communicating with ancestors, or being a full-time traditional healer were not considered as important criteria to categorize them, as only a few informants mentioned these points.

An expert in herbalism was defined as a person having all of the three criteria, that is: the ability to treat all disorders, the fact to take care of all types of patients, and a reputation of healer in the area. A knowledgeable person was defined as someone having one or two of the three criteria above-mentioned, including people in a learning process, person counteracting spell, and owner of a notebook of homemade remedies. Non-specialists were defined as people using herbal or other type of therapies for their own family, and able to treat one or a few disorders.

As a result of this classification, 70 (52.6%) informants were categorized as non-

218 specialists, 29 (21.8%) were considered as knowledgeable (including one also specialized in  
219 massage therapy), and 29 (21.8%) were classified as expert in herbal medicine (including two  
220 protestant pastors). Among the latter category, one was also specialist in apitherapy, another  
221 one was also specialist in massage, and a third one was able to catch spell. Aside the herbal  
222 specialists and non-specialists, one (0.8%) informant was classified as specialist in  
223 apitherapy, and four (3%) were classified as specialists in massage therapy.

224 Sex ratio and mean age of the three types of informants were as follows: experts in  
225 herbalism: SR = 0.27, mean age = 69.6 years old; knowledgeable persons: SR = 0.30, mean age  
226 = 57.6 y. old; non-specialists: SR = 0.4, mean age = 50.6 y. old. The mean age of experts was  
227 significantly higher than the two other groups (p-value < 0.00005 for both).

228 While the mean age of each of the three types of informants were similar in the  
229 Marquesas islands compared to the Society islands, the sex ratio showed significant  
230 differences. In the Marquesas islands, a higher number of males were found in the non-  
231 specialists' group ( $SR_{\text{MARQUESAS}} = 1.19$  vs.  $SR_{\text{SOCIETY}} = 0.03$ , p-value < 0.00001) and in the  
232 knowledgeable group ( $SR_{\text{MARQUESAS}} = 0.42$  vs.  $SR_{\text{SOCIETY}} = 0.18$ , no significant difference)  
233 compared to the Society islands, while a higher number of males were found in the expert in  
234 herbalism group from the Society islands ( $SR_{\text{MARQUESAS}} = 0$  vs.  $SR_{\text{SOCIETY}} = 0.5$ , p-value = 0.03).  
235 Overall, experts in herbalism and knowledgeable persons are mainly females in both  
236 archipelagos, but males are more represented in the Marquesas islands in the non-experts'  
237 groups.

238

### 239 3. General knowledge on diarrhea

240

#### 241 3.1. Classification and causes of diarrhea

242

243 While 64 (48.1%) informants did not mention knowing different diarrhea types, the  
244 others (69, 51.9%) reported classifying diarrhea according to several factors. Among them, 29  
245 (42%) cited their appearance and consistency (bloody [17 informants, 24.6%], watery [13,  
246 18.8%], mixed [9, 13%], green [4, 5.8%], yellow [3, 2.2%], sticky [1, 1.4%], with mucous [1,  
247 1.4%]), 28 (40.6%) mentioned their causes as the principal factor to differentiate diarrhea  
248 types (see below), 11 (15.9%) mentioned their severity (aggressive or slight [3, 2.2%], long or  
249 short [2, 2.9%], acute [1, 1.4%], high quantity excreted or not [1, 1.4%], out of control [1,  
250 1.4%]), 8 (11.6%) mentioned their associated symptoms (pain [6, 8.7%], convulsion [3, 2.2%],  
251 vomiting [3, 2.2%], gas [2, 2.9%], hemorrhoids [2, 2.9%]), and 5 (7.2%) cited the type of  
252 affected persons (babies, children or adults [5, 7.2%]). It is important to note that 15 (21.7%)  
253 interviewees mentioned more than one of the factors described above.

254 Regarding the causes cited by the informants, a total of 58 different causes was cited  
255 by 129 participants. We could categorize them into different sections including diet, drink,  
256 infection, health disorders, environment and others (**Table 2**). The most cited causes of  
257 diarrhea were food intoxication (119 citations, 89.5%) and especially rotten food (25, 18.8%),  
258 tap water (63, 47.4%), catching cold at the navel (24, 18.1%), ciguatera poisoning (22, 16.5%),  
259 diarrhea outbreak (12, 9.0%), and microbial infection (10, 7.5%). Of note, a condition called  
260 "ira" was cited in the study and was defined as a childhood illness associated with nervousity,  
261 agitation, and convulsion.

262

263 **Table 2:** Most important causes of diarrhea mentioned by informants

264

Categories	Causes cited*	Frequency	Percent (%)
Diet	Food	119	89.5
	Rotten food	25	18.8
	Dairy products (milk, ...)	8	6.0
	Fat food	4	3.0
	Papaya	3	2.3
	Too much food	3	2.3
	Fish (not fresh)	2	1.5
	Food poisoning	2	1.5
	Grapefruit	2	1.5
	New food	2	1.5
	Unhealthy	2	1.5
Drink	Tap water	63	47.4
	Beer	4	3.0
	Alcohol	2	1.5
	Seawater	2	1.5
	Wine	2	1.5
Infection	Microbes	10	7.5
	Flu	2	1.5
	Leptospirosis	2	1.5
	Viruses	2	1.5
Health disorders	Cold at the navel	24	18.1
	Ciguatera	22	16.5
	Diarrhea outbreak	12	9.0
	Diseases	4	3.0
	Ira	3	2.3
	Indigestion	2	1.5
Environment	Weather (rainy, cold)	3	2.3
Other	Teething	8	6.0
	Purge	3	2.3

\*items cited only 1 time were not included

265

266

267 When comparing the Society and Marquesas islands, no significant differences were  
 268 found in the most important causes of cited diarrhea.

269

### 270 3.2. Avoidance

271

272 Out of the 133 participants, a total of 95 mentioned different products (45 in total) or

273 situations (i.e., catching cold, air conditioning, massage, lift heavy things, smoking cigarette)  
274 to avoid when having a diarrhea. Among them, the most cited were dairy products (e.g.,  
275 milk) (29, 21.8%), followed by sour fruits (i.e., grapefruit, oranges) (18, 13.5%), mango (15,  
276 11.3%), fatty food (14, 10.5), and tap water (6, 4.5%).  
277

## 278 4. Therapeutic management of diarrhea

### 280 4.1. Remedies used for diarrhea

281  
282 A total of 414 remedies was reported to be used to treat diarrhea by the 133  
283 informants. It represented an average of 3.1 remedies cited by participants. Among these  
284 remedies, 214 were unique (meaning that these remedies did not include the same  
285 ingredient(s), or the same quantity of ingredients used if their ingredients were similar).

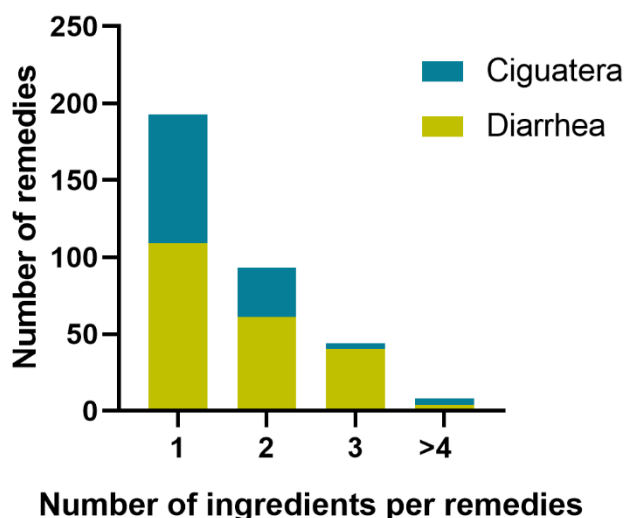
286 Most of the remedies cited for treating diarrhea were single-ingredient remedies (109,  
287 50.9%), followed by two-ingredients remedies (61, 28.5%), and three-ingredients remedies  
288 (40, 18.7%). Only a small portion of the remedies had more than three ingredients (4, 1.9%),  
289 and the maximum number of ingredients was 10 (one remedy only) (**Figure 2**).

290 Regarding the ingredients found in the remedies, they can be classified into different  
291 categories: plants, processed food (defined by any agricultural products transformed into an  
292 edible or more complex food), non-processed liquid (e.g., seawater), Polynesian cosmetic  
293 products, conventional medicine, other traditional medical products.

294 Of note, no significant differences in the number of cited remedies were found  
295 between the Society and the Marquesas islands, and between the different types of  
296 informants (experts, knowledgeable persons, and non-specialists).

297 In the following sections, we will discuss firstly the plants and then the other types of  
298 used products.  
299

300 **Figure 2:** Number of ingredients for each unique remedy cited for diarrhea and ciguatera



### 303 4.2. Plants used to treat diarrhea

304  
305 In total, 27 plant species were mentioned by the informants for treating diarrhea in

306 169 remedies (**Table 3**).

Table 3: Plant species used to treat diarrhea

Scientific name	Botanical family	Voucher No	Origin	Tahitian name	Marquesan name	Parts used	Method of preparation	Method of administration	Total number of citations	Number of persons citing the plants
<i>Annona muricata</i> L.	ANNONACEAE	FC490	Mod.	corossol, totara	korosoni, manini tota'a	Leaf	Decoction	Bath, massage	4	3
<i>Artocarpus altilis</i> (Parkinson) Fosberg	MORACEAE	FC486	Pol.	'uru, maiore	me'i	Fruit/Sap	Decoction/Fry/ Mix with water/Wood-fire cooking	Oral	6	4
<i>Carica papaya</i> L.	CARICACEAE	FC492	Mod.	'i'i'ta	kiki'e, vi papai	Leaf/Ripe fruit/Seed	Crush/Decoction/Fry/ None	Oral	9	8
<i>Catharanthus roseus</i> (L.) G.Don	APOCYNACEAE	FC518	Mod.	pervenche	ND (pervai, tihapai)	Flower	Decoction	Oral	1	1
<i>Citrus x aurantiifolia</i> (Christm.) Swingle	RUTACEAE	FC495	Mod.	taporo	hitoro/fitoro	Fruit	Press	Oral	113	80
<i>Cocos nucifera</i> L.	ARECACEAE	FC487	Pol.	ha'ari	'ehi	Coconut water/Coconut milk	Decoction/Heat/Mix	Oral	10	9
<i>Coleus barbatus</i> (Andrews) Benth. ex G.Don	LAMIACEAE	FC516	Mod.	sauge doliprane	sauge doliprane	Leaf	Decoction	Oral	1	1
<i>Cordia subcordata</i> Lam.	BORAGINACEAE	FC504	Ind.	tou	tou	Bark	Crush	Oral	1	1
<i>Cordyline fruticosa</i> (L.) A.Chev.	ASPARAGACEAE	FC484	Pol.	'auti	ti, 'outi	Leaf/Leaf bud	Crush/Decoction	Oral	23	19
<i>Erythrina variegata</i> L.	FABACEAE	FC511	Pol.	'atae	kenae (N), anetae (S)	Branch	Crush	Oral	1	1
<i>Euphorbia hirta</i> L.	EUPHORBIACEAE	FC502	Mod.	e'ae'a	'eita epau	Whole plant	Decoction	Oral	1	1
<i>Gardenia taitensis</i> DC.	RUBIACEAE	FC493	Pol.	tiare tahiti	tia'e tahiti, tia'e	Flower/Flower bud	Crush	Oral	5	3
<i>Hibiscus rosa-</i>	MALVACEAE	FC514	Pol.	'aute	koute pupu	Leaf	Decoction	Oral,	1	1

<i>sinensis</i> L.								massage		
<i>Ipomoea batatas</i> (L.) Lam.	CONVOLVULAC EAE	FC527	Pol.	'umara	kuma'a, 'uma'a	Tuber	Decoction	Oral	1	1
<i>Lantana camara</i> L.	VERBENACEAE	FC525	Mod.	lantana	ND	Flower/Leaf bud	Decoction	Oral	2	1
<i>Mangifera indica</i> L.	ANACARDIACEAE E	FC500	Mod.	vi ma'ohi, vi popaa	mako	Wood	Decoction	Oral	1	1
<i>Microsorium grossum</i> (Langsd. & Fisch.) S.B.Andrews	POLYPODIACEAE E	FC505	Ind.	metuapua'a	papamoko (N), papamo'o (S)	Rhizome/Young frond	Boil in coconut milk/Crush	Oral	4	4
<i>Morinda citrifolia</i> L.	RUBIACEAE	FC488	Pol.	nono	noni	Ripe fruit/Unripe fruit/Stipule, fruit	Maceration/Press	Oral	6	5
<i>Musa x paradisiaca</i> L.	MUSACEAE	FC491	Pol.	mei'a	me'ika	Ripe fruit	Crush/Dry/Decoction/Fry/None	Oral	15	13
<i>Oxalis corniculata</i> L.	OXALIDACEAE	FC517	Pol.	patoa 'ava 'ava	pakihi (N), kokihi (S)	Whole plant	Crush	Oral, massage	1	1
<i>Physalis angulata</i> L.	SOLANACEAE	FC499	Pol.	tamaru ha'ari	konini (N), kariri (S)	Leaf	Crush	Oral	2	2
<i>Psidium guajava</i> L.	MYRTACEAE	FC485	Mod.	tuvava	tuava	Bark/Ripe fruit/Young leaf	Chew/Crush/Decoction/None	Oral	47	39
<i>Rorippa sarmentosa</i> (Sol. ex G.Forst. ex DC.) J.F. Macbr.	BRASSICACEAE	FC506	Pol.	patoa purahi	mahi mahi	Whole plant	Crush	Oral, massage	4	3
<i>Saccharum officinarum</i> L.	POACEAE	FC520	Pol.	to	to	Young leaf/Leaf/Stem	Crush/Decoction	Oral	7	4
<i>Syzygium cumini</i> (L.) Skeels	MYRTACEAE	FC528	Mod.	pistas	pistai	Fruit	None	Oral	1	1
<i>Xanthosoma sagittifolium</i> (L.) Schott	ARACEAE	FC526	Mod.	tarua	ND	Tuber	Decoction	Oral	1	1
<i>Zingiber officinale</i> Roscoe	ZINGIBERACEAE	FC498	Mod.	re'a tinito	'eka kira	Rhizome	Crush	Oral	3	3

Legend: A slash ("/") corresponds to the term "or" ; a comma (",") correspond to the term "and"; (N) = Northern part of Marquesas islands; (S) = Southern part of

Marquesas islands; Ind. = Indigenous; Mod. = Modern introduction; ND = Not documented; Pol. = Polynesian introduction.



311 The two most represented botanical families were Myrtaceae and Rubiaceae with two  
312 species cited in each family (i.e., *Psidium guajava* and *Syzygium cumini*; *Morinda citrifolia* and  
313 *Gardenia taitensis* respectively). The other families were represented by only one plant  
314 species. The five most cited plant species were: *Citrus aurantiifolia* (113 citations), *Psidium*  
315 *guajava* (47), *Cordyline fruticosa* (23), *Musa x paradisiaca* (15), and *Cocos nucifera* (10). Regarding  
316 part of used plants, fruit ranked first (173 citations), followed by leaf (43), leafbud (31),  
317 flower (7), and whole plant (6). Out of the 169 used remedies, the three most cited methods  
318 of recipe preparation were pressing and mixing (53 remedies, 31.3%), decoction (29, 17.2%),  
319 and pressing in a cloth a previously crushed plant (28, 16.6%). Almost all the remedies were  
320 taken orally (163, 96.4%), while a few were taken in a bath (5, 2.9%). The method of  
321 administration for one remedy was not determined. The length of treatment was of 3 days in  
322 most of the cases, except for a few remedies (regardless of the used species) taken until good  
323 recovery.

324 Out of the listed 27 plants, six plants were mostly used in association with other  
325 ingredients, among which *Gardenia taitensis* (100% of remedies citing *G. taitensis* were in  
326 association with other ingredients), *Saccharum officinarum* (100%), *Citrus aurantiifolia* (91.8%,  
327 especially with cassava starch (48.2%)), *Cocos nucifera* (87.5%), *Cordyline fruticosa* (85.7%), and  
328 *Microsorium grossum* (75%).

329 Regarding their biogeographical origin, we found that 13 plant species (totalizing 82  
330 citations) were from Polynesian introduction (meaning that they were introduced by  
331 Polynesians during their migration from the Western Pacific at the end of the first  
332 millenium), 12 (184 cit.) were from modern introductions (introduced during European  
333 explorations especially from the 18<sup>th</sup> century), and 2 (5 cit.) were indigenous (**Figure 3**). The  
334 number of citations of plants from modern introduction was significantly higher than the  
335 one from Polynesian introduction (p-value = 0.03).

336 Although most of the plant species had similar number of citations in the two  
337 archipelagos, some significant differences were found. *Cordyline fruticosa* was significantly  
338 more cited in the Society islands than in the Marquesas islands ( $N_{\text{SOCIETY}} = 17$ ,  $N_{\text{MARQUESAS}} = 6$ ,  
339 p-value = 0,05), and *Artocarpus altilis* was significantly more cited in the Marquesas islands  
340 than in the Society islands ( $N_{\text{SOCIETY}} = 0$ ,  $N_{\text{MARQUESAS}} = 5$ , p-value = 0,02).

341 When comparing the plants cited by the different types of informants, we found that  
342 *Citrus aurantiifolia*, *Cordyline fruticosa* and *Cocos nucifera* were proportionally more cited by  
343 experts (28 persons) than non-specialists (70 persons) with 39 vs. 46 citations (p-value = 0.02),  
344 13 vs. 5 citations (p-value < 0.0005), and 5 vs. 1 citation (p-value = 0.01) respectively.  
345 *Microsorium grossum* and *Zingiber officinale* were proportionally more cited by knowledgeable  
346 than non-specialists, with 3 vs. 0 citation (p-value = 0.03) for both plants. And *Saccharum*  
347 *officinarum* was proportionally more cited by experts than non-specialists, with 4 vs. 0  
348 citation (p-value = 0.008).

349  
350

### 351 4.3. Products (other than plants) used to treat diarrhea

352

353 Among the products (other than plants) used for treating diarrhea, we could classify  
354 them into different categories: processed food (defined by any agricultural products  
355 transformed into an edible or more complex food, and including imported food), non-  
356 processed liquid (e.g., seawater), Polynesian cosmetic products, conventional medicine, and

357 other traditional medical products (Table 4).

358

359

360

**Table 4:** Products (other than plants) used to treat diarrhea

Categories	Products	Method of preparation	Method of administration	Total number of citations	Number of persons citing the products
Processed food/ Imported food	Rice	Boil in water	Oral	77	65
	Cassava starch	Mix with lime juice, water, sugar and/or honey	Oral	71	62
	Brown sugar	Mix with lime juice/Mix with <i>Cordyline fruticosa</i> and lime juice/Mix with cassava starch and lime juice	Oral	32	25
	Coca-Cola® (soft drink)	None	Oral	31	31
	Chocolate	None	Oral	23	23
	Carrot	Boil in water/None	Oral	14	14
	Honey	Mix with cassava starch and/or lime juice/Mix with guava/Mix with papaya	Oral	12	9
	Apple	None	Oral	8	8
	Vinegar (red)	Mix with iced water and honey, or sugar/Mix with cassava starch and brown sugar/None	Oral	4	3
	Sprite® (soft drink)	Mix with lime juice/None	Oral	3	3
	Salt	Add to boiled rice	Oral	2	2
	White sugar	Mix with water/Mix with multi-ingredients recipes	Oral	2	2
	Cookies	None	Oral	1	1
	Bread	None	Oral	1	1
	Chicken meat	Cook	Oral	1	1
	Milo®	None	Oral	1	1
	Nutella	None	Oral	1	1
	Pasta	Boil in water	Oral	1	1

	Pastis (alcohol drink)	None	Oral	1	1
	Red meat	Cook	Oral	1	1
	Whisky	Mix with a multi-ingredient recipe	Oral	1	1
Polynesian cosmetic products					
	Monoï	None	Local application	10	9
Liquid					
	Seawater	Mix with coconut water/None	Bath/Oral	4	3
	Iced water	Mix with vinegar, honey or sugar/Mix with lime juice and sugar	Oral	3	2
	Cold water	None	Bath	1	1
	Hot water	None	Bath	1	1
Conventional medicine					
	Efferalgan®	Mix with lime juice/Mix with <i>Cordyline fruticosa</i> and lime juice	Oral	4	3
	Doliprane®	Mix with lime juice/Mix with cassava starch and lime juice	Oral	2	2
Other traditional medical products					
	Chinese medicine	ND	ND	1	1

361

362 The most cited anti-diarrheal products were rice (especially water from boiled rice)  
 363 with 77 citations, followed by cassava starch (71 citations), Coca-Cola® soft drink (31),  
 364 chocolate (23), and carrot (14). Brown sugar and honey were the two most used ingredients  
 365 employed in combination (as excipients or active principles) with 32 and 12 citations  
 366 respectively.

367 When comparing the antidiarrheal products cited in the two archipelagos, only one  
 368 food product showed significant differences. Carrot was more cited in the Society islands  
 369 than in the Marquesas islands ( $N_{\text{SOCIETY}} = 11$ ,  $N_{\text{MARQUESAS}} = 2$ ,  $p\text{-value} = 0,03$ ).

370

#### 371 4.4. Types of treated diarrhea

372

373 Although most of the informants did not precise the types of diarrhea treated by the  
 374 remedies, three persons cited a mix of *Cordyline fruticosa* (leafbud), *Psidium guajava* (leafbud),  
 375 lime juice and coconut water to treat bloody diarrhea. One person also mentioned the use of

376 *Morinda citrifolia* (fruit) to treat diarrhea due to intestinal worms.

377 Eight informants mentioned using specific treatments to relieve diarrhea due to cold  
378 at the navel (*tupito*). Monoi application around the navel was considered by five informants  
379 to warm the belly and thus counteract the cold. Also, four informants cited the use of  
380 *Cordyline fruticosa* (leafbud) to treat the same disorder. During the survey, further  
381 information was obtained on the definition, causes, diagnostic, and prevention of this  
382 disorder. Participants explained that the navel is the most sensitive part of the body to the  
383 cold. Catching the cold at the navel can induce physiological disorders such as diarrhea, and  
384 can lead to convulsion if not treated. It is usually caused by staying too long in contact with  
385 cold water (e.g., wet clothes, seawater), or cold (e.g., air-conditioning, tiled floor, draft). To  
386 diagnose this disorder, people touch the navel, and can sense a contraction of the abdomen  
387 as well as the heartbeat. In prevention, they usually covered the belly of children with a  
388 cloth.

389 Three informants reported the use of specific remedies to treat a pediatric condition  
390 called “ira” that lead to diarrhea with green color. Among these remedies, one was a bath  
391 with *Annona muricata* (leaf), another one was a remedy with *Hibiscus rosa-sinensis* (flower)  
392 and *Gardenia taitensis* (leaf) taken orally and applied as a massage, and the last one combined  
393 *Microsorium grossum* (root) and coconut milk in a drink. Due to the low number of informants  
394 citing this disorder, we could not get more precise information on it.  
395

## 396 **5. Therapeutic management of ciguatera**

397  
398 In this section, we describe the therapeutic management of ciguatera, because remedies  
399 reported to be used for ciguatera (one of the most cited cause of diarrhea) are different from  
400 remedies reported to be used for other causes of diarrhea.  
401

### 402 **5.1. Remedies used for ciguatera**

403  
404 A total of 156 remedies was mentioned to be used for treating ciguatera. The average  
405 number of remedies cited per informant was about 1.2. Among these remedies, 124 were  
406 unique. A large part of the cited remedies were single-ingredient remedies (84, 67.8%),  
407 followed by two-ingredient remedies (32, 25.8%). Only a few remedies had more than two  
408 ingredients (8, 6.4%) (**Figure 2**).

409 We classified the ingredients into the following categories: plants, processed food,  
410 non-processed liquid.

411 Of note, the total number of remedies cited for ciguatera was significantly higher in  
412 the Marquesas islands than in the Society islands ( $N_{\text{SOCIETY}} = 56$ ,  $N_{\text{MARQUESAS}} = 100$ ,  $p\text{-value} =$   
413  $0,006$ ), and the average number of remedies by persons was significantly higher in the expert  
414 and knowledgeable groups than in the non-specialist group ( $N_{\text{EXPERT}} = 1,64$ ,  $N_{\text{KNOWLEDGEABLE}} =$   
415  $1,47$ ,  $N_{\text{NON-SPECIALIST}} = 0,94$ ,  $p\text{-value} = 0.02$ ).

### 417 **5.2. Plants used for ciguatera**

418  
419 A total of 24 plant species was reported to be used for treating ciguatera in 112 unique  
420 remedies (**Table 5**).

421 Five botanical families were represented by two plants species each including:

422 Anacardiaceae, Boraginaceae, Fabaceae, Malvaceae, and Zingiberaceae. The other plant  
 423 families were represented by one plant species each. *Cocos nucifera* ranked first in terms of  
 424 number of citations (38 citations), followed by *Punica granatum* (31), *Barringtonia asiatica* (20),  
 425 *Zingiber officinale* (18), and *Heliotropium arboreum* (10).

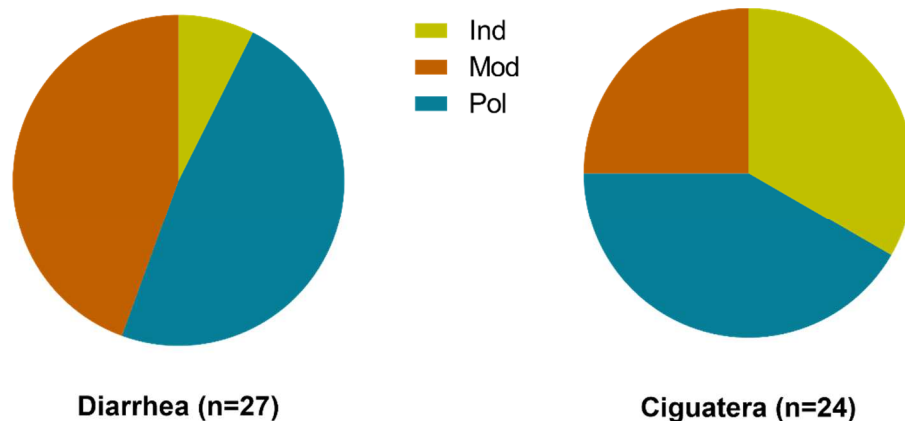
426 Fruit was the most reported part of plants (58 citations), followed by leaf (24),  
 427 rhizome (20), seed (13) and branch (12). Out of the 112 unique remedies, crushing and  
 428 filtering in a cloth to extract a juice was the most cited method of preparation (46 citations),  
 429 crushing was the second most cited method (27), and decoction was the third one (23). All  
 430 the remedies were taken orally, and for 3 days (except for a few remedies taken until good  
 431 recovery)

432 Among the most cited plant species, three were mostly used in combination with  
 433 other ingredients, including *Barringtonia asiatica* (81.3%), *Morinda citrifolia* (80.0%), and *Cocos*  
 434 *nucifera* (75.8%). For *Barringtonia asiatica*, the same two-ingredient recipe was reported 13  
 435 times, and included coconut water. At the other end, some plants were mainly included in  
 436 single-ingredient recipes, such as *Heliotropium arboreum* (100%), *Punica granatum* (88.2%), and  
 437 *Zingiber officinale* (76.9%).

438 Regarding their biogeographical origin, we found that 10 plant species (64 citations)  
 439 were from Polynesian introduction, 6 (78 cit.) were from modern introduction, and 8 (41 cit.)  
 440 were indigenous (**Figure 3**). No significant differences were found between the three  
 441 biogeographical origins of plants.

442  
 443  
 444

**Figure 3: Biogeographical origin of plant species cited for diarrhea and ciguatera**



445 Legend: Ind = Indigenous, Mod = Modern introduction, Pol = Polynesian introduction  
 446  
 447

448  
 449 Interestingly, some differences were found in the type of plant species cited between  
 450 the two archipelagos. In the Society islands, *Zingiber officinale* was less cited than in the  
 451 Marquesas islands ( $N_{\text{SOCIETY}} = 2$  and  $6$ ,  $N_{\text{MARQUESAS}} = 15$  and  $25$ ,  $p\text{-value} = 0,005$ ). Also,  
 452 *Heliotropium arboreum* was largely cited in the Society islands but not at all in the Marquesans  
 453 islands ( $N_{\text{SOCIETY}} = 10$ ,  $N_{\text{MARQUESAS}} = 0$ ,  $p\text{-value} < 0,0001$ ).

454 Regarding the type of informants, *Cocos nucifera*, *Spondias dulcis*, and *Morinda citrifolia*,  
 455 three native or Polynesian introduction plants, were proportionally more cited in the experts'  
 456 group than in the non-specialists' group, with 20 vs. 12 citations ( $p\text{-value} < 0,001$ ), 6 vs. 2

457 citations (p-value = 0.007), and 5 vs. 0 citation (p = 0.003) respectively. *Cocos nucifera* was also  
458 more cited in the experts' group than in the knowledgeable group (20 vs. 6 cit., p-value =  
459 0.01), and *Morinda citrifolia* was more cited in the knowledgeable group than in the non-  
460 specialists' group (3 vs. 0 cit., p-value = 0.03).

461

### 462 5.3. Products used to treat ciguatera

463

464 Among the products (other than plants) reported for treating ciguatera, four  
465 informants mentioned the use of rum (3 citations) or whiskey (1 citation) to mix with egg  
466 yolk. For two informants out of four, lime juice and brown sugar were also added to this  
467 recipe. A tablespoon or teaspoon of mustard absorbed orally was cited three times to treat  
468 ciguatera. Aside these two recipes, a variety of products were mentioned only by one  
469 informant each, including drinking beer, absorbing half glass of brown sugar with cold  
470 water, eating one chicken egg, drinking coffee, drinking one teaspoon of *eau de cologne*  
471 (perfume lotion), taking a steam bath with seawater previously boiled, eating two  
472 tablespoons of sweetened condensed milk, and drinking one teaspoon of vinegar.

Table 5: Plants used for treating ciguatera

Scientific name	Botanical family	Voucher No	Origin	Tahitian name	Marquesan name	Parts used	Method of preparation	Method of administration	Total number of citations	Number of persons citing the plants
<i>Artocarpus altilis</i> (Parkinson) Fosberg	MORACEAE	FC486	Pol.	'uru, maiore	me'i	Bark/Leaf bud	Crush/Crush, decoction	Oral	2	2
<i>Barringtonia asiatica</i> (L.) Kurz	LECYTHIDACEAE	FC503	Ind.	hotu	hutu	Bark/Branch/Fruit	Crush, filter in a cloth	Oral	20	20
<i>Carica papaya</i> L.	CARICACEAE	FC492	Mod.	'i'ita	kiki'e, vi papai	Flower/Fruit/Leaf/Unripe fruit	Decoction/Crush, filter in a cloth	Oral	7	7
<i>Citrus x aurantiifolia</i> (Christm.) Swingle	RUTACEAE	FC495	Mod.	taporo	hitoro/fitoro	Fruit	Press	Oral	6	6
<i>Cocos nucifera</i> L.	ARECACEAE	FC487	Pol.	ha'ari	'ehi	Bark/Ripe fruit/Unripe fruit	Grate/None/Decoction/ Crush, filter in a cloth	Oral	38	34
<i>Colubrina asiatica</i> (L.) Brongn.	RHAMNACEAE	FC515	Ind.	tutu	tutu	Leaf	Crush, decoction	Oral	2	2
<i>Cordia subcordata</i> Lam.	BORAGINACEAE	FC504	Ind.	tou	tou	Leaf	ND	ND	2	2
<i>Curcuma longa</i> L.	ZINGIBERACEAE	FC522	Pol.	re'a tahiti	'eka toka toka	Rhizome	Grate, mix	Oral	2	2
<i>Erythrina variegata</i> L.	FABACEAE	FC511	Pol.	'atae	kenae (N), anetae (S)	Branch	Grate, filter in a cloth	Oral	8	8
<i>Heliotropium arboreum</i> (Blanco) Mabb.	BORAGINACEAE	FC521	Ind.	tahinu	ND	Leaf	Decoction	Oral	10	10
<i>Hibiscus tiliaceus</i> L. subsp. <i>tiliaceus</i>	MALVACEAE	FC509	Ind.	purau	hau, fau	Flower/Stem bark (from shoot)	Crush	Oral	3	3

<i>Inocarpus fagifer</i> (Parkinson) Fosberg	FABACEAE	FC523	Pol.	mape	ihi	Wood	Burn	Oral	1	1
<i>Mangifera indica</i> L.	ANACARDIACEAE	FC500	Mod.	vi popa'a	mako	Fruit (unripe)	Grate, filter in a cloth	Oral	8	8
<i>Microsorium grossum</i> (Langsd. & Fisch.) S.B.Andrews	POLYPODIACEAE	FC505	Ind.	metuapua'a	papamoko (N), papamo'o (S)	Leaf (1 digit)	Crush	Oral	1	1
<i>Morinda citrifolia</i> L.	RUBIACEAE	FC488	Pol.	nono	noni	Fruit (with flowers on it)/Leaf/Ripe fruit	Decoction/Grate, filter in a cloth/Press	Oral/ Steam bath	8	5
<i>Pandanus tectorius</i> Parkinson var. <i>tectorius</i>	PANDANACEAE	FC496	Ind.	fara	ha'a	Aerial root	Grate, filter in a cloth	Oral	2	2
<i>Physalis angulata</i> L.	SOLANACEAE	FC499	Pol.	tamaru ha'ari	konini (N), kariri (S)	Leaf	Crush, filter in a cloth/Decoction	Oral	3	3
<i>Punica granatum</i> L.	LYTHRACEAE	FC497	Mod.	remuna	kréna (N), remuna (S)	Ripe fruit/Unripe fruit	Decoction/Grate, filter in a cloth/None	Oral	31	31
<i>Rorippa sarmentosa</i> (Sol. ex G.Forst. ex DC.) J.F. Macbr.	BRASSICACEAE	FC506	Pol.	patoa purahi	mahi mahi	Whole plant	Crush, filter in a cloth	Oral	3	3
<i>Saccharum officinarum</i> L.	POACEAE	FC520	Pol.	to	to	Stem	Crush, filter in a cloth, cook	Oral	1	1
<i>Spondias dulcis</i> Parkinson	ANACARDIACEAE	FC501	Mod.	vi tahiti	vi tahiti	Leaf/Unripe fruit	Crush, filter in a cloth/Grate, decoction	Oral	9	8
<i>Syzygium malaccense</i> (L.) Merr. & L.M.Perry	MYRTACEAE	FC510	Pol.	'ahi'a	kehika	Leaf	Crush, filter in a cloth	Oral	1	1
<i>Thespesia populnea</i> (L.) Sol. ex Corrêa	MALVACEAE	FC508	Ind.	miro	mi'o	Unripe fruit	Grate	Oral	1	1
<i>Zingiber officinale</i> Roscoe	ZINGIBERACEAE	FC498	Mod.	re'a tinito	'eka kira (N), 'ena kina (S)	Rhizome	Grate, filter in a cloth/Decoction	Oral	18	18

Legend: A slash ("/") corresponds to the term "or" ; a comma (",") correspond to the term "and"; (N) = Northern part of Marquesas islands; (S) = Southern part of



76 Marquesas islands; Ind. = Indigenous; Mod. = Modern introduction; ND = Not documented; Pol. = Polynesian introduction.

#### 477 5.4. Polynesian pharmacological actions of plants and products cited 478

479 Regarding mechanisms of action of plants and products used to treat ciguatera, nine  
480 informants cited that their remedy could act as a purge to eliminate the toxins. The purgative  
481 effect was associated with *Cocos nucifera* oil (3 citations), *Colubrina asiatica* mixed with  
482 coconut oil (2 citations), *Zingiber officinale* (2 citations), *Curcuma longa* (1 citation), *Mangifera*  
483 *indica* (1 citation), *Punica granatum* (1 citation), and *Spondias dulcis* (1 citation). The sourness of  
484 unripe fruits such as *Mangifera indica* or *Punica granatum* was also reported to help eliminate  
485 the toxins (1 citation each).  
486

#### 487 5.5. Recommendations 488

489 Some recommendations associated with ciguatera were reported by a few informants  
490 during the survey. Three informants mentioned the importance of purging the body at the  
491 beginning of the disease, three other informants reported waiting 1 to 6 months before eating  
492 fish again after the end of the symptoms. Other food to be avoided were corned beef (1  
493 citation), eggs (1 citation), and red meat (1 citation).  
494  
495

### 496 **6. Traditional medicine practices** 497

498 In this section, we present some general information on the traditional medical  
499 practices reported by the 133 informants, including the source of knowledge, the other type  
500 of disorders treated, the financial or non-financial compensation asked for their services, and  
501 the recommendations provided to the patients.

502 Regarding the source of knowledge, 109 informants (82%) reported to get their  
503 knowledge from their parents or their family, 6 (4.5%) cited friends, colleagues or  
504 acquaintances, 4 (3%) mentioned dreaming about remedies, 3 (2.3%) reported learning from  
505 themselves, 1 (0.8%) mentioned having heard voices at the church, and 1 (0.8%) cited  
506 intuition.

507 Participants reported using traditional medicine for treating 92 ailments. We  
508 classified them into different categories of disorders according to the ICPC (International  
509 Classification of Primary Care) 2<sup>nd</sup> edition (Staub et al., 2015). The most cited categories of  
510 disorders were musculoskeletal disorders (61 citations) with injury being the main type  
511 reported (37), followed by childhood illness (57), respiratory disorders (32), skin disorders  
512 (21) digestive disorders (18) and female genital disorders (18). Of note, cancer was mentioned  
513 13 times.

514 Out of the 133 informants, only two informants reported that they accept money from  
515 their patients. These two informants were full-time traditional healers, one specialized in  
516 massage therapy and another one specialized in massage and herbalism. Also, 111  
517 informants mentioned that they did not ask for money, and 20 did not respond to this  
518 question. Among the persons not asking for a financial contribution, several reasons were  
519 mentioned including that remedy comes from nature, which is a gift and free (16 citations),  
520 followed by the potential inefficiency of the remedy if money is given (10 citations), and the  
521 fact that God is the only one to be thankful (8 citations). Fifteen informants also mentioned  
522 that they accept gift or donation.

523 During the survey, different general recommendations were reported such as  
524 avoiding the concomitant use of traditional medicine and conventional medicine (6  
525 citations), being in a positive mood when treating someone (5 citations), accepting and  
526 believing in the remedy when taking it (5 citations), not using the remedy from another  
527 person without her/his consent (4 citations), not taking a remedy after 2PM or 5PM (2  
528 citations) or on Sunday (1 citation), not preparing remedies when having your period (1  
529 citation), not discussing with people when collecting plants (1 citation), throwing away  
530 plants, left after taking the remedy, at specific locations (1 citation).

531 Regarding the general avoidance when using traditional medicine, we can cite: eating  
532 canned food (3 citations), eating goat, fish from the sea, all types of meat (except chicken),  
533 salty food, soy sauce, tuna, or drinking alcohol, soda (2 citations each), eating beef, fatty  
534 food, ketchup, pig, sour fruits, spicy food, or sugar, and having sexual intercourse (1 citation  
535 each). One informant also mentioned that eating chicken or sprouted coconut is possible  
536 when taking traditional medicine.

537

538

## 539 Discussion:

540  
541 This ethnobotanical survey was performed in six islands of French Polynesia and focused  
542 on remedies used to treat diarrhea and ciguatera (a foodborne illness most commonly found  
543 in the Pacific Ocean). This is the first comprehensive study focusing on these two diseases in  
544 French Polynesia in the 21<sup>th</sup> century. A total of 27 and 24 plant species were reported to be  
545 used for diarrhea and ciguatera respectively.

546 In the following sections, we discuss the most important outcomes from this study.

### 548 1. Classification of French Polynesian healers

549  
550 Until now, only a few studies have focused on the different traditional medical practices  
551 from French Polynesians. This led us to investigate more deeply their practices and try to  
552 categorize them. W. Arthur Whistler was one of the first trying to categorize the traditional  
553 medicine from Polynesians. He worked on the systems of health care in the Cook islands,  
554 and classified their system into three categories: folk medicine, healers (including bone-  
555 setters, massage therapists, and herbalists), and psychic healers (with supernatural powers)  
556 (Whistler, 1985). Later, Paul Alan Cox added a new category (i.e., midwives) to the healers  
557 section, by studying the traditional medicine from Samoa islands (Cox, 1991). Regarding  
558 French Polynesia, two recent studies added some information to this classification. Grand  
559 (2007) proposed a classification of traditional healers into three categories: herbalists (*ta'ata*  
560 *ra'au*), massage therapists (*ta'ata taurumi*), and shamans (*tahu'a*), while Bambridge and Le  
561 Meur (2018) reported a specific feature of traditional healers: they are usually consulted by  
562 people outside of their family members. Although these categories are similar to those used  
563 in this study, some new information are emerging. First of all, a new category of healers  
564 (called knowledgeable) can be added in between the folk medicine and the healer's  
565 categories. This new category brings together people who cannot be considered as experts  
566 (due to their lack of reputation, or their narrow range of patients (family members), or their  
567 specialization for certain disorders), but have either a strong knowledge in traditional  
568 medicine and treat only their family members, or are known outside of their family to be  
569 specialized in the treatment of specific disorders. Secondly, the herbalist's category is now  
570 enriched with another type of healer: the protestant pastors. Unlike classic herbalists,  
571 protestant pastors have a syncretic knowledge in herbal medicine, and are especially known  
572 by the local protestant community as healers. Thirdly, apitherapists can be now included in  
573 the healer's category, and they can be defined as therapists of joint problems by using local  
574 bee stings. Finally, we propose in this study three criteria to help categorize the French  
575 Polynesian healers: the ability to treat all disorders, the fact to treat all types of patients (and  
576 not just family members), and the reputation for being able to heal people.

577 In the study, we found some differences between the specialists' (expert and  
578 knowledgeable) and the non-specialists' group allowing to better categorize them.  
579 First of all, some plant species were mainly used by specialists. This was the case for  
580 *Cordyline fruticosa* and *Microsorium grossum*. The first one, *C. fruticosa*, a Polynesian  
581 introduction, has various traditional uses (medicine, food, ornamental, building, religious)  
582 and is of high cultural importance. It is known to be employed by Polynesian healers due to  
583 its magical power (Pétard, 2019). Its spiritual importance could explain why a few non-  
584 specialists use it. The second plant, *M. grossum*, a native fern, is mainly used for its medicinal

585 properties such as purge, vermifuge, and against vomiting, gastric disorders, liver disorders,  
586 asthma, sprain, fracture, and headache (Girardi et al., 2015; Pétard, 2019). This fern is known  
587 to be very effective against these diseases, but previous cases of intoxications have also been  
588 reported (Pétard, 2019). This makes it a powerful and dangerous plant, which could explain  
589 its use only dedicated to specialists.

590 Secondly, we found that females are more represented than males in the expert and  
591 knowledgeable persons groups, and it occurs in both archipelagos. Previous studies in  
592 Polynesia have already demonstrated that healers were mainly females (Cox, 1991; Girardi et  
593 al., 2015; Quenon, 2020; Whistler, 1985). However, we noticed that Marquesan's males were  
594 more involved in traditional medical practices than males from the Society archipelagos. This  
595 was also found in two other ethnobotanical studies, where only one male (out of 18) was  
596 interviewed in the Society islands (Quenon, 2020), while one third of the interviewees were  
597 males in the Marquesans islands (Girardi et al., 2015). Overall, Polynesian healers are mainly  
598 represented by females, but some variations occur depending on the islands. Also, more  
599 studies are needed to confirm the predominance of females in Polynesian medical practices  
600 as, in general, males are not as available and prone to answer than females.

601 Another observation from our study is that both experts and knowledgeable persons know a  
602 higher number of remedies for ciguatera than non-specialists. Although it was not the case  
603 for diarrhea, this could reflect a better knowledge on anti-ciguatera remedies from the two  
604 specialists' group, and thus indicate a specialization in ciguatera treatment by healers.

605

## 606 **2. Diarrhea: local perception, facts and perspectives**

607

608 In our study, diarrhea was mainly reported to be caused by food intoxication and tap  
609 water drink. This is consistent with the report of 11 cases of collective food poisoning in 2020  
610 and the importance of *Salmonella* and *E. coli* contamination (BSS, 2021). In the same report, it  
611 was noted that several factors such as the break in the cold chain, and a long period of time  
612 between the preparation and the consumption could be responsible for this contamination.  
613 Regarding diarrhea due to tap water, the lack of wastewater treatment and the poor quality  
614 of drinking water in some islands (e.g., Nuku Hiva in the Marquesas archipelago) can  
615 explain this problem (Etienne and Reboud, 2009).

616 More generally, gastrointestinal disorders are expected to increase in the Pacific due to  
617 climate change and the lack of safe water supplies (Leddin and Macrae, 2020; Singh et al.,  
618 2001). Although the overall good sanitary infrastructure in French Polynesia will help to  
619 limit this issue, some islands might be more impacted than others. Also, Polynesians are  
620 highly dependent to seafood products, which make them more susceptible to changes in  
621 seawater quality (Dewailly et al., 2006). For example, ciguatera is now expanding in range of  
622 vector species with three new marine invertebrates (i.e., the giant clam, the trochus, the sea  
623 urchin) susceptible to bioaccumulate ciguatoxins (Chinain et al., 2019). These species are  
624 considered as food by Polynesians, and can represent another risk of contamination.

625 Another interesting results from this survey is the importance of some causes of diarrhea  
626 specific to the area, especially in children. First of all, catching cold at the navel was  
627 considered as an important source of diarrhea in children and adults. In other studies, this  
628 disorder was referred as "to'eto'e" or "puta to'eto'e" meaning cold or penetrate by cold in  
629 Tahitian (Lemaitre, 1985b; Panoff, 1966). It was referred as "hautete" in Marquesan (Girardi et  
630 al., 2015). Exposition to humid and cold environment is the major triggering factor, and its

631 treatment consists of warming the body (Roussey, 2018). As in our study, monoi oil was  
632 already reported to be one of the main treatment or preventive measures against cold thanks  
633 to its potential to maintain the body temperature by topical application and massages (Jost et  
634 al., 2016; Quenon, 2020). This hot-cold duality was also reported in Polynesian post-partum  
635 disorders in which cold drinks were given to pregnant woman to maintain a healthy  
636 pregnancy and prevent abortion (Baltrushes, 2006). Altogether, this hot-cold system might be  
637 reminiscent of ancient Asian medical concept from which Polynesians originate (Kayser et  
638 al., 2006; Van Esterik, 1988).

639 The other childhood illness responsible for diarrhea found in our study was a set of  
640 symptoms called “ira” in Tahitian. Lemaitre (1985b) reported 12 different types of “ira”, and  
641 mentioned that they were mainly characterized by gastro-intestinal problems such as spasms  
642 as well as neurological disorders such as convulsions and agitation. In Marquesas islands,  
643 Girardi et al. (2015) also reported the association of diarrhea with a particular “ira” called “ira  
644 niho” occurring for baby teething, and described this disorder as a restlessness in children  
645 with fever, teething, loss of appetite, and diarrhea. In our study, informants also insisted on  
646 the green color of the stools. In Central America, this type of diarrhea was also reported as a  
647 criteria to classify the diarrheal illnesses in some communities (Burleigh et al., 1990;  
648 Scrimshaw and Hurtado, 1988). From a medical point of view, green color stools have been  
649 associated with an increase in bile acid concentration possibly due to a higher bile acid  
650 excretion or a bile acid malabsorption (Gryboski and Kocoshis, 1990).

651

### 652 **3. Benefit-risk balance of the most cited treatments**

653

654 While Polynesian medicine has been used for centuries and still plays an important role  
655 in the primary health care of French Polynesian, there is a need to provide updated data on  
656 their efficacy and safety in order to assess their risk-benefit balance and make sure these  
657 remedies are effective and harmless to the population. Among the various therapeutic  
658 products cited for diarrhea and ciguatera, we provide here a pharmacological and  
659 toxicological review of the most cited treatments.

660 Aside the classic use of water from boiled rice, two main remedies were cited in the  
661 treatment of diarrhea. These include a mix of cassava starch, lime juice, water, sometimes  
662 associated with honey or brown sugar, and the use of guava leaves, fruits or bark. We  
663 present here an analysis of their efficacy and toxicity.

664 The use of cassava starch for treating diarrhea is common to the tropical countries. For  
665 example, in Madagascar, the roots or leaves can be used as a decoction in the treatment of  
666 diarrhea and dysentery (Rakotoarivelo et al., 2015). In Congo, cassava flour associated with  
667 cinchona bark is mixed in water and drunk to treat diarrhea. In Ecuador, the leaves are used  
668 for the same indication, while in Colombia, the whole plant is used (Paniagua-Zambrana et  
669 al., 2020). Cassava contains a large amount of starch which is a key anti-diarrheal product as  
670 it thickens the stools and reduce diarrhea. Other compounds could also be involved since the  
671 leaves have demonstrated an anti-diarrheal effect *in vivo* by decreasing the motricity and the  
672 intestinal fluid in rats (Bahekar and Kale, 2015). Altogether, ethnobotanical and  
673 pharmacological data support the efficacy of cassava in the treatment of diarrhea.

674 Lime juice is also involved in the pharmacological actions of this remedy, as it presents  
675 antibacterial effect, especially against *Vibrio cholerae* (Dalsgaard et al., 1997; Oikeh et al.,  
676 2016). A stem bark extract of *Citrus aurantiifolia* also showed antidiarrheal effect in rats

677 validating its use in diarrhea (Adejoh et al., 2018). Besides, the high content of vitamin C and  
678 potassium of lime juice is interesting to compensate the loss of electrolytes and minerals  
679 during diarrhea (Lim, 2012).

680 From a toxicological perspective, cassava contains cyanogenic glycosides that can induce  
681 neuropathy, goiter, cretinism and acute cyanide intoxication (Panghal et al., 2021). The  
682 concentration of these glycosides depends on the used variety, soil composition,  
683 geographical location, environmental conditions, age, and part of the plant. Specific methods  
684 of processing are needed to detoxify cassava. As French Polynesian used marketed and  
685 quality certified products, the risk seems to be low. Although rare, lime juice can induce  
686 phytophotodermatitis when in contact with skin exposed to sunlight (Hankinson et al., 2014),  
687 and can cause dental erosion when consumed frequently (Bamise et al., 2009).

688 *Psidium guajava* is one of the most used antidiarrheal plant species in tropical countries.  
689 Different parts of guava tree are used as remedies against diarrhea in Latin America (e.g.,  
690 Panama, Mexico, Peru, Caribbean), in Asia (e.g., India, China, Bangladesh, Thailand), and in  
691 Africa (e.g., Niger, Ghana, Congo, South Africa) (Chassagne, 2022; Gutiérrez et al., 2008).  
692 From a pharmacological perspective, guava leaf demonstrated antibacterial activity against  
693 *Vibrio cholerae*, *Shigella flexneri* and diarrheagenic *Escherichia coli* (Birdi et al., 2010). The same  
694 part of plant also showed anti-rotavirus activity (Gonçalves et al., 2005). In animal models, *P.*  
695 *guajava* leaf extract showed antidiarrheal and antibacterial effect in models of diarrhea  
696 infected by *Citrobacter rodentium*, *Shigella flexneri*, or pathogenic *Escherichia coli* (Gupta and  
697 Birdi, 2015; Hirudkar et al., 2020a, 2020b). Most importantly, some clinical trials confirmed  
698 the antidiarrheal potency of guava by showing a reduction of abdominal pain and stool  
699 frequency in patients with acute diarrhea (Birdi et al., 2020; Lozoya et al., 2002). All this  
700 information is in favor of the efficacy of guava leaf. The toxicological profile of guava is less  
701 known, but the different studies indicate a safe use of guava if it can be consumed  
702 immediately, at a proper dose (8-10 g of fresh leaves in 150 mL of hot water per day), and in  
703 adults' patients without hypersensitivity to guava (Morais-Braga et al., 2016). Quercetin and  
704 quercitrin have been mentioned as responsible for the antidiarrheal activity (Naseer et al.,  
705 2018; Palombo, 2006).

706  
707 Regarding treatment used for ciguatera, three plant species (*Barringtonia asiatica*,  
708 *Heliotropium arboreum*, and *Punica granatum*) are discussed below for different reasons: their  
709 high number of citations (*Punica granatum*, *Barringtonia asiatica*), their medicinal importance  
710 in the Pacific for ciguatera (*Heliotropium arboreum*) and their potential toxicity (*Barringtonia*  
711 *asiatica*).

712 The most cited plant species from our study is pomegranate fruit. It was already  
713 reported to be used in Marquesas islands and in New Caledonia as a remedy for ciguatera  
714 (Girardi et al., 2015; Laurent et al., 1993). In the study from New Caledonia, it is also  
715 mentioned as an antidiarrheal agent. Indeed, fruits of *Punica granatum* are widely used in  
716 traditional medicine for diarrhea (e.g., in Algeria, China, Mexico, Turkey), and various  
717 pharmacological tests have demonstrated its antidiarrheal activity (Qnais et al., 2007;  
718 Shaygannia et al., 2015; Zhao et al., 2018). Kumar-Roiné et al. (2011) proposed that the  
719 antidiarrheal and antispasmodic effect of pomegranate could play a role in the treatment of  
720 ciguatera. Regarding the per se anti-ciguatera potency of *P. granatum*, Boydrón-Le Garrec et  
721 al. (2005) showed a protective effect of *P. granatum* fruit extract against the action of  
722 ciguatoxin or brevotoxin in neuroblastoma cells. Later, Kumar-Roiné et al. (2009)  
723 demonstrated an inhibition of nitric oxide production of *P. granatum* fruit in RAW 264.7

724 macrophages. These two studies are a first step towards the validation of pomegranate fruit  
725 in the treatment of ciguatera. However, both are *in vitro* studies, and more *in vivo* studies  
726 should be performed to confirm its anti-ciguatera potency. From a toxicological perspective,  
727 pomegranate fruit seems to be safe if used at proper dose (2.5-4.5 g of dried pericarp per  
728 day), in adults without hypersensitivity to pomegranate (Vidal et al., 2003; WHO, 2006).

729 *Barringtonia asiatica* was the second most cited plant species for treating ciguatera in  
730 our study. Two main parts were used: seeds and branches. In Guam island, the stem bark of  
731 *B. asiatica* is infused and drink to treat ciguatera (Bourdy et al., 1992). In Marquesas islands,  
732 the root of *B. asiatica* was reported to be used for the same indication (Girardi et al., 2015).  
733 Aside these two studies, no ethnobotanical or pharmacological data are available on this  
734 species to validate its anti-ciguatera potency. More importantly, *B. asiatica* is used as an  
735 ichthyotoxic in different islands such as Car Nicobar, Marquesas islands, Samoa and  
736 Vanuatu (Bradacs et al., 2011; Cox, 1979; Girardi et al., 2015; Ravikumar et al., 2015). The  
737 most active piscicidal compound from the seed extract was isolated recently and named  
738 ranuncoside VIII (Cannon et al., 2004). Following the lack of toxicological studies in humans,  
739 the use of these plant species is associated to potential health risks and thus should be  
740 avoided.

741 Last but not least, *Heliotropium arboreum* ranked fourth in terms of citations for  
742 ciguatera. In the Pacific, it is one of the most used plant species for treating ciguatera. In New  
743 Caledonia and Vanuatu, the leaves are infused in hot water and applied locally and/or drunk  
744 (Laurent et al., 1993). In Tonga, an oral administration of infused leaves is preferred (Bourdy  
745 et al., 1992). It was also reported as a fish poisoning remedy in French Polynesia, Micronesia  
746 and in the Ryuku islands from Japan (Kumar-Roiné et al., 2011). Not only this species is the  
747 most employed in ciguatera treatment, but it is also the most studied. It has been shown that  
748 an aqueous extract of *H. arboreum* leaves can prevent ciguatoxin-induced cell toxicity, and  
749 that this action may be due to the plant's affinity for voltage-gated sodium channels by  
750 preventing the toxin from binding to them (Rossi et al., 2012). The compound responsible for  
751 this activity is rosmarinic acid. This molecule, also present in other plants of the  
752 Boraginaceae, Lamiaceae and Apiaceae families, has demonstrated anti-inflammatory, anti-  
753 allergic, hypotensive and neuroprotective activity, which could also explain its action in the  
754 treatment of ciguatera (Braidy et al., 2014; Luo et al., 2020; Nadeem et al., 2019). One of the  
755 main problems is the presence in the plant of pyrrolizidine alkaloids (namely indicine and its  
756 derivatives) that are known to induce hepatotoxicity (El-Shazly and Wink, 2014). One study  
757 tried to demonstrate that these compounds are not present in the aqueous extract of  
758 senescent leaves of *H. arboreum* obtained by decoction, but further investigations are needed  
759 to confirm this result (Rossi, 2014). Altogether, the leaves of *Heliotropium arboreum* present  
760 good ethnobotanical evidence of efficacy, as well as some pharmacological data confirming  
761 its use in the treatment of ciguatera. However, further studies are needed to confirm its  
762 safety, then more research should be performed to move towards the development of a  
763 standardized phytomedicine.

764 To further analyze the role of the ten most cited plant species for ciguatera and diarrhea,  
765 we have described their ethnobotanical uses in French Polynesia and other Polynesian  
766 islands, along their bioactive compounds potentially responsible for the antidiarrheal and  
767 ciguatera protective effect (Table 6).

768



**Table 6:** Ethnobotanical uses and bioactive compounds of the ten most cited plant species used for ciguatera and diarrhea

Scientific name	Reported for ciguatera (C) and/or diarrhea (D)	Ethnobotanical uses in French Polynesia	Ethnobotanical uses in other Polynesian islands	Bioactive compounds and relevant pharmacological activities	References
<i>Artocarpus altilis</i>	C, D	Fermented fruit: bewitchment Fruit: miscarriage Leaf (bud): asthma, chest disorders, cough, eye disorders, liver disorders, miscarriage, neuralgia, otitis, vaginal discharge Sap: contusion, fracture, joint pain	Leaf (ashes): pain, rash, sprain [Cook islands] Leaf (young): abdominal pain [Cook islands] Sap: broken limbs, injured muscles [Cook islands], cut [Hawaii]	morusin (antinociceptive), oxyresveratrol (anti-inflammatory and neuroprotective), starch (antidiarrheal)	de Souza et al., 2014; Girardi et al., 2015; Horowitz, 2001; Jagtap & Bapat, 2010; Panoff, 1966; Pétard, 2019; Whistler, 1985
<i>Barringtonia asiatica</i>	C	Fermented fruit: hemorrhoids Leaf: dislocation and sprain Leaf, seed: rheumatism Seed: contusion, lower back pain, sprain	Seed: burn [Cook islands]	ranuncoside VIII (ichthyotoxic)	Cannon et al., 2004; Girardi et al., 2015; Pétard, 2019; Whistler, 1985
<i>Carica papaya</i>	C, D	Flower: hypertension Fruit: liver disorders Leaf, seed: diabetes, gout, hypertension Seed: anthelmintic	Fruit (immature): boil, carbuncle, cut, sore [Cook islands] Seed: intestinal worms [Cook islands] Stem: increase lactation [Tonga]	carpaine (anthelmintic, reduce heart rate, blood pressure, and intestinal peristaltis)	Girardi et al., 2015; Haldar et al., 2020; Panoff, 1966; Pétard, 2019; Singh et al., 1984; Whistler, 1985

<i>Citrus x aurantiifolia</i>	C, D	<p>Fruit (immature): ovarian insufficiency, testicular pain</p> <p>Fruit (mature): hernia, liver failure</p> <p>Fruit, leaf: postnatal antiseptic, prevention of puerperal infection</p> <p>Leaf: cold, convulsion, headache, influenza, sore throat, tuberculosis</p> <p>Leaf, seed: hemorrhoids</p>		<p>citronellal (antinociceptive), limonene, linalool (antimicrobial), quercetin (anti-inflammatory, antimicrobial)</p> <p>ascorbic acid (anti-oxidant)</p>	<p>Batiha et al., 2020; Girardi et al., 2015; Panoff, 1966; Pétard, 2019; Weimer et al., 2021</p>
<i>Cocos nucifera</i>	C, D	<p>Fruit: hemorrhage</p> <p>Fruit, seed: expicent, liver disorders, tooth decay</p> <p>Root: contusion, dislocation, fracture, skin ulcer, sprain</p>	<p>Bark, husk: fracture, sprain [Cook islands]</p> <p>Fruit: severe bleeding in early pregnancy [Tonga]</p> <p>Leaf: filariasis [Cook islands]</p>	<p>sterile and sweet water (rehydration), coconut oil (anti-inflammatory and anti-toxins)</p>	<p>Girardi et al., 2015; Lisboa-Neto, 2017; Panoff, 1966, Pétard, 2019; Singh et al., 1984; Whistler, 1985</p>
<i>Cordyline fruticosa</i>	D	<p>Fruit: flatulence, stomach cramp, umbilical hernia</p> <p>Leaf (young): abscess, anti-emetic, chest pain, gastric disorders, hernia, nail infection, nasal mucus, otitis, stomach pain with chest tightness, ulcer</p>	<p>Flower, leaf (young): asthma [Hawaii]</p> <p>Leaf: fever, nasal problems [Hawaii], neck pain, sore throat [Cook islands]</p> <p>Leaf (young): burn [Cook islands, Samoa]</p>	<p>steroidal saponins</p>	<p>Girardi et al., 2015; Guillaumin et al., 1946; Horowitz, 2001; Pétard, 2019; Ponou et al., 2019; Whistler, 1985</p>
<i>Erythrina variegata</i>	C, D	<p>Bark: stonefish sting</p> <p>Leaf: postnatal antiseptic, postpartum care, prevention of puerperal infection</p>	<p>Bark: infertility [Tonga]</p>	<p>alkaloids: erysotrine, erysodine, erythraline (neuromuscular blocking effect, smooth muscle relaxant, anticonvulsivant)</p>	<p>Ghosal et al., 1972; Girardi et al., 2015; Pétard, 2019; Singh et al., 1984</p>

<i>Heliotropium arboreum</i>	C	Leaf (young): stonefish sting		rosmarinic acid (anti-inflammatory, neuroprotective, protective effect against ciguatoxin cytotoxicity)	Pétard, 2019; Rossi et al., 2012
<i>Mangifera indica</i>	C, D	Fruit: abscess, respiratory disorders, sore throat, wound	Leaf: insufficient rest during the puerperium, giving rise to fever, chills, dizziness, lower abdominal pain [Tonga]	mangiferin (analgesic, anthelmintic, anti-allergic, anti-inflammatory, neuroprotective), epigallocatechin gallate, gallic acid, and quercetin (anti-inflammatory)	Ediriweera et al., 2017; Quenon, 2020; Singh et al., 1984
<i>Microsorium grossum</i>	C, D	Leaf: asthma, headache, migraine, sinusitis, vertigo, woman infertility Leaf, rhizome: dislocations, fall, fracture, hematoma, purge, sprain, shock Rhizome: anti-emetic, leucorrhea		phytoecdysteroids: ecdysone, 20-hydroxyecdysone (steroid-like effect)	Girardi et al., 2015; Ho et al., 2010; Pétard, 2019
<i>Morinda citrifolia</i>	C, D	Flower (bud), fruit: burn, hemorrhoids, skin allergy, wart Fruit: abscess, nail infection, sore throat, stonefish sting Leaf: chest pain, gastric disorders, stomach pain with chest tightness, ulcers Leaf, fruit: backache, enteritis, joint problem, osteoarthritis, rheumatism	Fruit: abdominal swelling, hernia, urinary disorders [Cook islands], diabetes, digestive disorders, hypertension, skin conditions [Hawaii], tuberculosis [Pacific islands] Leaf: breast cancer, dysuria, postpartum disorders [Tonga], ringworm [Fiji] Root: stonefish sting [Cook islands]	quercetin (anti-inflammatory), rutin and scopoletin (antidopaminergic)	Abou Assi et al., 2017; Dixon, 1999; Girardi et al., 2015; Horowitz, 2001; Panoff, 1966; Pétard, 2019; Singh et al., 1984; Torres et al., 2017; Whistler, 1985

<i>Musa x paradisiaca</i>	D	Leaf (young): elephantiasis, filariasis, zona Sap: lymphangitis	Fruit (peel): wound [Hawaii] Stem (juice): cutaneous sore [Cook islands]	pectin and starch (antidiarrheal), quercetin (anti-inflammatory)	Girardi et al., 2015; Horowitz, 2001; Imam and Akter, 2011; Pétard, 2019; Whistler, 1985
<i>Psidium guajava</i>	D	Bark, leaf: breast cancer, hemorrhoids, painful periods Fruit: hemorrhoids Leaf (bud): headache, infertility, miscarriage, urinary disorders, wasp sting, wound	Leaf: abdominal pain, cuts, postpartum disorders [Cook islands]	quercetin and quercitrin (antidiarrheal)	Girardi et al., 2015; Naseer et al., 2018; Palombo, 2006; Panoff, 1966; Pétard, 2019; Whistler, 1985
<i>Punica granatum</i>	C			gallic acid, punicalagin and quercetin (anti-inflammatory), rutin (antidopaminergic)	Ranjha et al., 2021
<i>Saccharum officinarum</i>	C, D	Juice, leaf: genital disease, girl's intimate hygiene, leucorrhea, vaginal discharge	Juice: cut [Hawaii] Shoot (young): reattach severed limbs and prevent scarring [Hawaii]	gallic acid, quercetin (anti-inflammatory), quercitrin (antidiarrheal), rutin (antidopaminergic)	Abbas et al., 2014; Girardi et al., 2015; Horowitz, 2001
<i>Spondias dulcis</i>	C	Fruit: food poisoning, liver disorders, neuralgia Leaf (bud): hemorrhagia after miscarriage, sore throat	Bark: metrorrhagia [Tonga], thrush [Samoa] Leaf: thrush, urinary disorders [Cook islands]	quercetin (anti-inflammatory), rutin (antidopaminergic)	Panoff, 1966; Pétard, 2019; Sameh et al., 2018; Singh et al., 1984; Whistler, 1985
<i>Zingiber officinale</i>	C, D	Rhizome: stomach pain with chest tightness, ulcer		gingerols and shogaols (anti-inflammatory, antinausea), zingerone (antidiarrheal)	Ali et al., 2008; Girardi et al., 2015

#### 771 4. Geographic and cultural origin of medicinal plants

772  
773 All plants mentioned by the informants are common or widespread species, with no  
774 conservation issues. No endemic species have been cited to be used in this study, and the  
775 plants used are mainly introduced species. This is a distinctive feature of the traditional  
776 Polynesian medicine: most of their pharmacopeia rely on widespread and introduced plants  
777 so called “canoe plants” brought during their migration across Pacific Ocean and  
778 settlements. This was already noted by previous authors such as Girardi et al. (2015), and  
779 Jost et al. (2016). Indeed, Polynesian history is based on their migrations from islands to  
780 islands. It is known that Polynesians originate from Asia where they started their long  
781 journey by boats about 4500 years ago, and then settled from islands to islands in the Pacific  
782 (Conte, 2019; Kirch, 2017). They first arrived in the Society islands about 1000 years ago, then  
783 settled in the Marquesans islands between 700 to 900 years ago (Ioannidis et al., 2021).  
784 During their migrations, they brought various plant seeds and shoots with them for food,  
785 building, clothing, and medicine purposes (Whistler, 2009). Therefore, their traditional  
786 medical knowledge is mainly based on introduced plants, and indigenous species represent  
787 a small portion of their pharmacopeia.

788 Interestingly, we found some differences between the biogeographical origins of  
789 plants used for diarrhea and ciguatera. For diarrhea, a similar number of plants were either  
790 introduced by Polynesians or by Europeans. However, a highest number of citations was  
791 found for plants from modern introduction (e.g., *Citrus aurantiifolia*, *Manihot esculenta*,  
792 *Psidium guajava*), indicating that these species might be more effective to treat diarrhea than  
793 plants introduced by Polynesians. For example, cassava replaced the use of *Tacca*  
794 *leontopetaloides* (L.) Kuntze that was historically a great source of starch for Polynesians but  
795 needed more thorough preparations to eliminate the toxins than cassava (Pétard, 2019). It  
796 could also indicate that diarrhea became more frequent with the arrival of the Europeans.  
797 The latter is supported by Martin and Combes (1996) who noted that Polynesians “never  
798 heard of dysentery before” European explorations who were the starting point of various  
799 infectious epidemic diseases. Regarding ciguatera, a similar number of citations was found  
800 for the three different biogeographical origins (modern introduction, Polynesian  
801 introduction, indigenous). It could indicate that Polynesians have tried, since their  
802 settlement in these islands, the different types of plants around them in a trial and error  
803 process, in the hope to find a cure to an ancient and endemic disease.

804 Another interesting point is the total absence of citations for *Heliotropium arboreum* in  
805 the treatment of ciguatera in the Marquesas islands. As detailed above, *H. arboreum* is  
806 widely known throughout the Pacific as an effective anti-ciguatera remedy. Rossi (2014)  
807 noted that the plant is not present in the Marquesas islands. It could be explained by  
808 ecological factors as this species prefers soils mixed with coral sand or pure coral sand  
809 substrate which are very scarce in the Marquesan islands (Lorence D. H., pers. com.). It  
810 illustrates the particularity of the Marquesan pharmacopeia compared to other Polynesian  
811 pharmacopeias, and the link to its geobiodiversity. In other ethnobotanical studies from  
812 Marquesas islands, three and four endemic species to Marquesas islands were reported  
813 respectively by Girardi et al. (2015), and Jost et al. (2016). It thus confirms the originality of  
814 the Marquesan pharmacopeia despite the high use of introduced species.

815 **Conclusion:**

816

817 This is the first survey focusing on diarrheal diseases and ciguatera in French Polynesia in  
818 the 21th century. A total of 38 different medicinal plants were cited to treat diarrhea and  
819 ciguatera. In this study, a new classification of traditional healers was proposed, and some  
820 cultural perceptions of diarrhea were discussed. We also present updated information on the  
821 efficacy and toxicity of the most common used remedies. Altogether, Marquesas and Society  
822 islands present great traditional knowledge that should be preserved, because cultural  
823 traditions such as traditional medicine are important for the Polynesian identity and  
824 heritage. However, more studies are needed to evaluate the pharmacological and  
825 toxicological activity of Polynesian remedies as natural does not mean safe, and risky  
826 practices can lead to health problems. This is especially necessary if we want to officially  
827 recognize the Polynesian medicine and make it an integral part of our official health system.

828 **Acknowledgements:**

829

830 We would like to thank all the participants for their kindness, their patience and for sharing  
831 their knowledge with us. Our warmful thanks go to the Association Haururu and the  
832 Académie Marquisienne for their time, their fruitful feedback, and their help on the field.  
833 Special thanks to Maiana Teihotu, Sylvana Tiatoa, Jenny Torea, and Yvette Temauri for being  
834 such great facilitators in the field. We are thankful to David H. Lorence (senior researcher at  
835 NTBG) for providing us some information on Marquesan plant species. This study was made  
836 possible thanks to the support from the Maison des Sciences de l'Homme du Pacifique  
837 (MSHP) through an early-stage researcher award obtained by the first author.

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# POLYNESIAN MEDICINE



133 informants  
6 islands



## Diarrhea

27 plant  
species



*Psidium guajava*



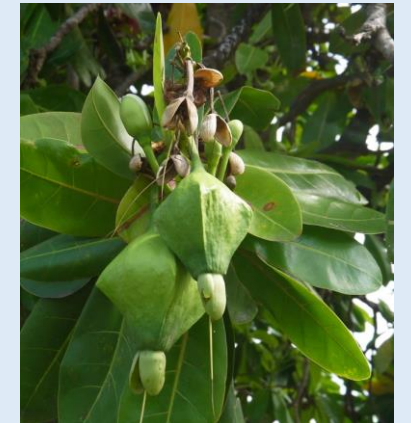
*Cordyline fruticosa*

## Ciguatera

24 plant  
species



*Punica granatum*



*Barringtonia asiatica*