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The taxonomy, ecology, leaf anatomy and utilization of *Freycinetia macrostachya*, *Pandanaceae* in New Guinea

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Abstract. *Freycinetia macrostachya* is a *Pandanaceae* species that was first published by Martelli in 1910. The species occur majority on Coastal Forest in both northern and southern bird's head Papua until East New Guinea. Many species of *Freycinetia* have only narrowest distribution and become dying on the open area, It is different to *F. macrostachya*. This species has ability to live both on primary and secondary forest. Purposed of the study were to obtain delimitation of species concepts, to know the phylogenetic classification of the species and relationship among other New Guinea *Freycinetia* species, to understanding more about ecological aspect and the ability to live on the extreme habitat, and to know about nutrient contain for developing food product from the species. Method of the study is descriptive method with revision of taxonomy as a step working and phylogenetic analysis using PAUP program with *Sararanga* as an out group, survey as a research technique to ecological study and it was followed by collected some specimen for anatomy leaf study. Analysis of nutrient content of *F. macrostachya* bracts, i.e. moisture content, ash, crude fat (soxhlet extraction), and protein (micro kjeldahl), while carbohydrates was determined using by difference method. The result showed that the species has three layers of epidermis tissue compare to other species like *F. javanica* that only has one layer. This is why the species could be living on the open forest. New Guinea *Freycinetia* have 4 groups below the genus, the first group name *F. macrostachya* are belonging to the imbricate leave species, now have about 40 species and the group name was given because of *F. macrostachya* is an older name of all species in the group. Phylogenetic analysis trees showed that this species become an old species among all New Guinea *Freycinetia* species. Analysis proximate of bracts show that the carbohydrate inside is about 77 %, it is meaning that we can make many food products from bracts.



1. Introduction

Pandanaceae is a family of the five genus namely *Pandanus*, *Freycinetia*, *Sararanga*, *Martelidendron* and *Benstonea*. New Guinea has four genera except *Martelidendron* and the genus *Sararanga* is only present in New Guinea and Philiphine, the species are *Sararanga sinuosa* and *Sararanga philipinensis*. New Guinea also has many endemic species of *Pandanus*, *Benstonea* and *Freycinetia*. *Freycinetia* is the only genus that is climbing species in the Family and have membranous earlike appendages near the base leaf, we called auricle. The genus also different in the way to produce flowers. Other *Pandanaceae* are dioecious but this genus is monoecious, the axillary or terminalia flowers of female and male flowers present closely on the trunk. *Freycinetia* is occur in Srilangka through Southeast Asia, New Guinea until Northern Australia.

Stone (1973-1976) [1,2] said that approximately about 60 species of *Freycinetia* occur in New Guinea. Sinaga NI (2011) [3], found about 91 species of *Freycinetia* occur in West New Guinea, one of the endemic species is *Freycinetia macrostachya*. This species was described first in 1910 by Martelli from Papua New Guinea, Fly Rivers, De Albertis.

Traditional people in New Guinea using the leaves of *Freycinetia macrostachya* as a wrapping material to burn sago palm, the aerial root to make traditional bags, fish trap and sandals. The fruits and the biggest bracts are an edible. In South Sorong children often eat the bracts. This bracts and fruits also eaten by marsupials like *Phalanger* sp, insect, and birds. The fruit and bracts also good as a food but not easy to reach them because of the natural position that usually hanging on the big trunk of trees, but Maori people in New Zealand using forked stick to collected this. The terminalia inflorescence make the species more difficult to reach, after first flowering the second two to three branching will appears terminalia and when the next flowering time comes the flowers will appears in this three terminalia but higher than before.

Utilization of the *Pandanacea* family is increasing now because the benefit that is given to us is more knowing than before, according to the result of research in this decade for example *Pandanus conoideus* and *Pandanus tectorius* [4]. Foods, medicine, furniture, fibers, beauty things, source of renewable energy are produced by *Pandanacea* species. One of the potentially species is *Freycinetia macrostachya*, but many information of this species is still unknown like ecology and taxonomy aspect, also the utilization. In fact, this information are useful in silvicultural and agricultural works to reach industrial purpose like sustainability of row material stock. Purposed of the study were to obtain delimitation of species concepts, to know the phylogenetic classification of the species and relationship among other New Guinea *Freycinetia* species, to understanding more about ecological aspect and the ability to live on the extreme habitat, and to know about nutrient contain for developing food product from the species.

2. Material and method

Material that is used in this research are both specimen herbarium and the living plant in field work location in New Guinea. Herbarium specimen from field work area was made to study completely later. The leaves for anatomy study was collected from the field area too. Method of this study is descriptive method with carefully study of specimen herbarium in few herbarium namely MAN (herbarium manokwariense) in Manokwari, West Papua Provinse, LAE (herbarium LAE) in LAE PNG, BO (herbarium Bogoriense) in Cibinong, L (Leiden Herbarium) in Netherland and K (Kew Herbarium) in Kew, Royal British Herbarium. Followed by filed work in many places in New Guinea and botanical Garden in Bogor, Kew, Leiden and Port Moresby. Beside morphological, the anatomical study was also done at LIPI Biology Cibinong.

2.1. Analysis taxonomy

All specimen from many places are deeply investigate to understand completely about the species characters. The first publication is a type for all. Some differences that is appear due to ecological aspect are carefully considering to put in the species limitation or out from the species. Finally, the *F. macrostachya* species are clear analysis and all specimen in the concept has written as the name. The research is a part of the New Guinea *Freycinetia* species study so in the same way the other species concept was build until we found the four *Freycinetia* group in the area and give the old name *Freycinetia macrostachya* as a name of the one bigger group. In all group the place of this species could be seen and give more information about the evolution in New Guinea *Freycinetia*. Terminology used follows Harris and Harris 1954 and Radford 1986 [5,6]. Step activities followed those as described by [6,7]. Phylogenetic analysis using PAUP Program version 32 with *Sararanga* as an out group.

2.2. Analysis ecology and anatomy

The information about ecological aspect in the notes of specimen herbarium are collected to collaborate with the field study. Where was species living, the place, elevation and the habitat give information to understanding ecological aspect of the living species. The leaves from the study area was used to make transverse section of the leaf that was study microscopies later in LIPI Biology Cibinong.

2.3. Analysis of nutrient content

Analysis of nutrient content of *Freycinetia macrostachya* bracts, i.e. moisture content, ash, crude fat (soxhlet extraction), and protein (micro kjeldahl) (AOAC, 2005)[8], while carbohydrates was determined using by difference method (FAO, 2003)[9]. The research was done in PAU (Pusat Antar Universitas) IPB Bogor.

3. Result and discussion

3.1. Taxonomy aspect

Freycinetia macrostachya is a species under *Freycinetia* genus and Pandanaceae family. This species was first published by Martelli in *Webbia Journal* 3 (1910) 175 with Type is *Beccari s.n* from PNG, Fly river, De Albertis. In 1941 Kanehira was published a new species from Dalmann, Nabire Papua Indonesia region with name *F. inouei* Kanehira in *Bot. Mag., Tokyo*, 4 (1941) 254, this species now according to the research are put as a same species as a *F. Macrostachya*. *Freycinetia macrostachya* is an old species of the groups of imbricate leaves *Freycinetia* that also have a bigger organs like stem, leaves, flowers and fruit compare to the other members of *Freycinetia*. According to [3] the genus *Freycinetia* have 4 groups namely *Freycinetia macrostachya* group, *Freycinetia funicularis* grup, *Freycinetia marantifolia* group and *Freycinetia angustissima* group. All vegetative characters are mention before is an open character to understanding the machrostachya group, include the variously colored of the auricle. The orange, red, salmon, yellow, pale green, purple with the kontras color of the nerves are belong to the species in group. Thus, the spadix bears several bracts, called cauline leaves: the lower ones are leaflike with variously green color mixed salmon, white, red, yellow, purple and others. The next higher are true bracts in two levels of the three outer and three inner fleshly bracts followed by male or female flower inside. The cauline leaves with white, orange and green color of *Freycinetia macrostachya* could be seen in Figure 2.

The Semi imbricate leaves is belong to the funicularis group. This species in group is easy to recognized by the axillary inflorescences. The group doesn't have the lower leaflike bracts, but they have 7 to 10 level of smaller lower bracts before the next higher true bracts. The smaller bracts in each level have three bracts in the circle with variously color. The color of smaller and the true bracts in common is same but the shape different.

Marantifolia group have a terminalia inflorescences like macrostachya group but the leaves doesn't arranged imbricate and the auricle in common is transparent or green and easy to fallen. The leaf is not linear or obovatus and ovatus but in many variously shape like oblongus, ellipticus, ensiformis, ovatus, rarely linear and much of them has shorter leaves may less than 15 cm long compare to 1 m of *Freycinetia macrostachya* leaves. The true bracts is similar to macrostachya group but different in size, the biggest ones is 3-7x 4-8 cm compare to *F. macrostachya* that have 20-25 x 15-20 cm bracts.

The remain angustisimma group doesn't have leaflike bracts but a true bract with the apex of bracts is true leaves, we called a half bract leaves. But inner bracts is true bracts. The species here is a smallest species of *Freycinetia* with the leaves less than 7 cm in long and less than 1.5 cm in wide, the leaves.

Characters from the stem, branching, leaves, flowers and fruits are using to analysis phylogentic trees of the New Guinean *Freycinetia* species. About 50 species were investigated. The result show that the *Freycinetia* has a fourth group. The tree of the PAUP analysis of the New Guinean *Freycinetia* species is showed in Figure 1.

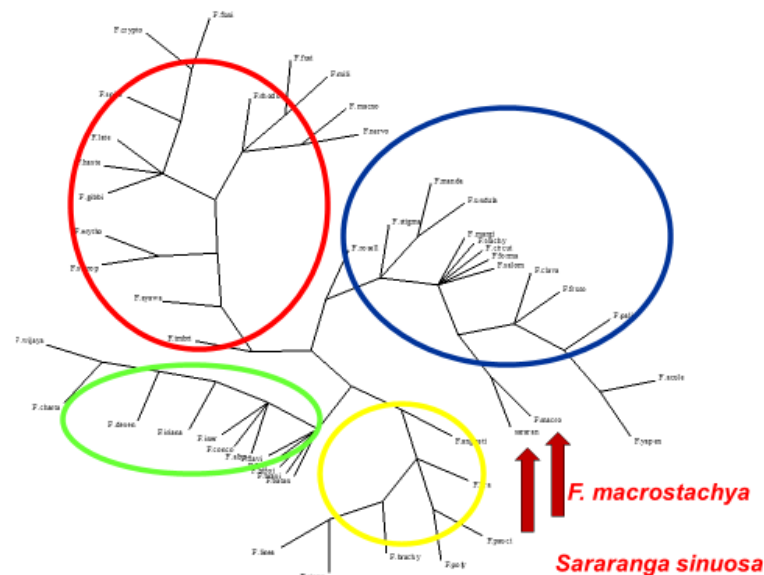


Figure 1. The PAUP Analysis phylogentic of morphological characters from New Guinea *Freycinetia* species. The blue color is *F. macrostachya* group, red color is *F. funicularis* grup, green color is *F. macrostachya* group and the yellow is *F. angustisimma* group.

The phylogenetic analysis of the species New Guinea *Freycinetia* showed that *F. macrostachya* with the all imbricate leaves species are joint together on the same group that we called now as a *F. macrostachya* group. Using *Sararanga sinuosa* as an out group species have been done because of the endemic New Guinea species. The tree phylogentic showed that *F. macrostachya* put near the out group species is means that the species may as an older species off all *Freycinetia* species. In evolution tree characters is belong to primitive species than climbing one. *Freycinetia macrostachya* group is a biggest group of *Freycinetia*, now it is more than 40 species under this group. Sinaga (2011) [3] said that the *F. macrostachya* group have robust habit and are high climbers. Stem robust, hard, rarely branched, 2-4 cm

diameter. Leaf imbricate, linear or lanceolate, margin with sharp and hard spines, 20-120 cm long, 1.5-7 cm wide; cauline leave colorful in common, basically leaf with yellow, orange, red or mixed color, consist of 2-3 whorls; Infructescence terminal, ternate, sometimes with 4, 8 to 12 cephalia, spirally to umbel arranged. Prophyll bracts never found. Cephalium large, 3-20 cm long, 2-6 cm wide. Berries numerous, thin, stout; stigmatic remains 1-3 or 5-6, rarely 8 or 12, one species with 32. Seeds linear or ellipse, usually longitudinally arranged.

3.2. Species description

Revision of the West New Guinea *Freycinetia* species showed that the *Freycinetia inouei* Kanehira is the sinonim species of *F. macrostachya* and the charcters of this species is described bellow

3.2.1. *F. macrostachya* Martelli. *F. macrostachya* Martelli in Webbia 3 (1910) 175- Type: *Beccari s.n.*, PNG, Fly river, De Albertis (Herb. Beccari)

3.2.2. *F. inoue* Kanehira. in Bot. Mag., Tokyo, 4 (1941) 254-Type: *Kanehira-Hatusima 12163*, Papua, Nabire, Dallmann (Holo: Tokyo). Big climbing pandan, hanging with rarely branching on the tree trunk. *Stem* terete, 2 - 3 cm in diameter 2 cm internodes. *Leaves* linear, 73 - 100 cm long, 5 cm base wide, 5 middle wide, 3.5 cm wide apex, base fold until a half lamina, margin spiny at the base to 1/3 margin lamina, apex cuspidate, leave slightly fleshy, dark blackish green; abaxial has longitudinal nerves, shortly transversal nerves shadow, covered by lenticellate; adaxial has longitudinal nerves. *Auricle* truncated, 15 - 17 by 1.5 - 2 cm, 9 - 10 longitudinal nerves, has shortly transversal nerves, make small squares, membranaceous, margin revolve especially at the base, purple to dark purple. *Cauline Bracts* consist of 2 whorls; pinkish red to whitish orange on base lamina, orange beneath but apex green. *Bracts* consist of 3 whorls; exterior cimbiform, 10 by 5 - 6 cm, apex acuminate, margin entire, white; interior bracts cimbiform 9 by 4 - 5 cm, white, fleshy when mature; centre bracts lanceolate, 8 by 1 cm, fleshy, smell like candy; *Inflorescence* terminalia. *Staminate Flower* 4 spadix, peduncle terete, 3 by 1.5 cm, pedicle semi terete, 3 - 4 by 0.4 cm; rachis 6 by 0.4 - 0.5 cm, very pale yellow; filament flat, 4 times bigger than anther, anther ovate; *Pistillate Flower* have peduncle terete, 3 by 3 cm; pedicle semi terete, stout, 4 by 1 cm, glabrous, pale yellow; ovary cylindric, 7 by 1 mm, 2 heads; stigma button black, 1 or 2 (3 - 4), put on the centre, surrounded by areola. *Fruit* slightly cylindrical, 12 by 3 - 4 cm; berry looks like needle, numerous, some berries fusion.

- a. Distribution. New Guinea, Papua in Sorong to Manokwari, Nabire until Cyclop Mountains in Jayapura and PNG in Lae.
- b. Ecology. Climbing together with *Kortahlsia* a rattan species on matoa stem an other big trees. Growth on secondary to primary forest from low land at 5 m to mountains 1220 m asl.
- c. Specimen Examined. New Guinea, Papua, Sorong, Roufaer river, 80 m als. Nov 17 1912. *A.Pulle 391*; Jayapura, Cyclop Mountains, alt. 1220 m asl. fl. June 21 1961. *Van Royen & H. Sleumer 5925*; Manokwari: Nuni, Asai river, alt. 20 m asl. fr. Augst 15 1995. J. Dransfield, S. Zona & R. Maturbongs; Mupi, alt. 5 m asl. fl. fr. Sep 3 2006. *Sinaga NI 4053*. PNG. Lae, Western District near Ingembit village, alt. 480 ft asl. June 8 1967. *NGF 31794*.



Figure 2. The *Freycinetia macrostachya* that is living on the trunk of Palm Oil at Prafi, nearby the Arfak mount in Manokwari, West Papua Province. The white, orange, green of the cauline leaves could be seen here. The green inside bracts is the three female flowers.

3.3. Ecological aspect and leaf anatomy

Freycinetia macrostachya is a species with widely distribution. This species present in both West and East New Guinea. It is occur in Sorong, Manokwari, Nabire, Sarmi, Jayapura, Madang, Morobe until Port Moresby (Figure 3). But this species only have fond majority in the Northern Part of New Guinea island, in Southern part the species only have found in Timika. In common *Freycinetia* prefer a humid condition, that is way easy to find the genus near the water or river or surrounding lake but rarely found on open area, and also missing in secondary forest but *Freycinetia macrostachya* living well on both secondary and primary forest. In Manokwari it has been found under the canopy of oil palm at Prafi.

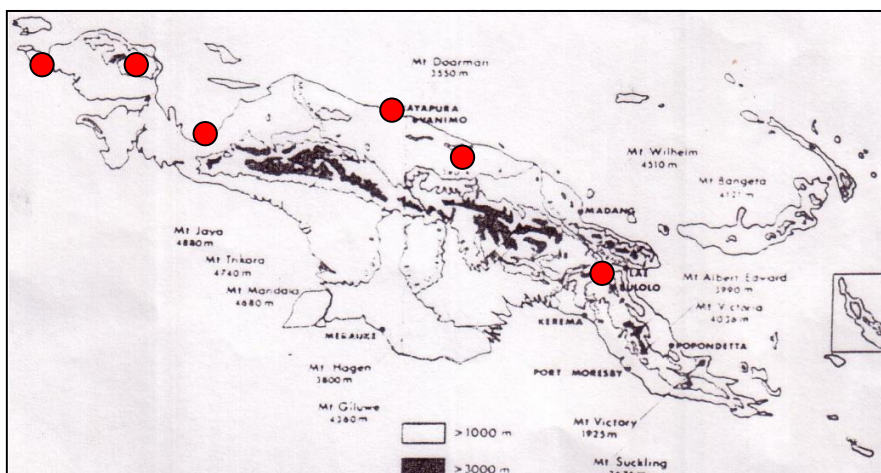


Figure 3. Distribution of *F. macrostachya* Martelli in New Guinea Island

Freycinetia marostachya is one of the *Freycinetia* species that has widely distribution because of the ability to live not only under canopy area but also at open area where many species of *Freycinetia* will die. If we look carefully the leaves of *F. macrostachya* is succulent than other *Freycinetia* species, it means that the saving water inside leaf should present. The anatomy of the leaf of *F. macrostachya* showed that between epidermis and hypodermis tissue present two layer of additional epidermis tissue, it is different from other *Freycinetia* for example *F. javanica* that has only single layer of tissue epidermis

[10]. Pictures of the transverse leaf section of *F. macrostachya* is showed at the Figure 4. The leaf is covered on both surfaces by a three-layered epidermis. It is in commonly present in Dicotyledon plants. One function of the epidermis is the protection of the soft internal tissue of the leaf from the mechanical injuries. Sometimes in the xerophytic leaves the epidermis cells become radially elongated and somewhat lignified, and another has multi-layered epidermis. Beside multi-layered epidermis *F. macrostachya* has elongated epidermis cells especially at the second and third layers (letter E in Figure 4). Pandanaceae species have calcium oxalate inside leaf, not silica, and this *Freycinetia* also have calcium oxalate inside, it is raphides (letter E in Figure 4). The vascular bundle in *Freycinetia* in common is circular but this *Freycinetia macrostachya* has a bowling-ball like vascular bundle.

This species has higher tolerance to the changing of the environment, so it is not surprise to find the species living on the rock or fallen wood even on the forest floor while many species prefer the stem and canopy covering of the forest.

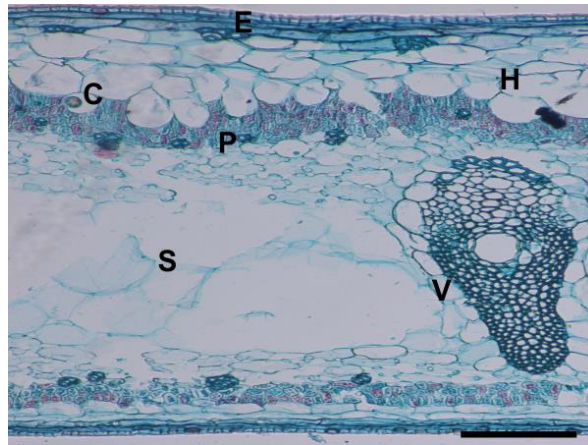


Figure 4. Transverse leaf section of *F. macrostachya* C: raphide CaCO_3 crystal inside the idioblast; E: epidermis in three-layers; H: hypodermis; P: palisade; S: sponge; and V: vascular bundle. Bar 50 μm .

Cutting forest especially on the low land area for many utilities like home, building, industrial garden and making a new office for increasing of a new government administration and other purpose make a pressure for *Freycinetia* living. Some species die but *F. macrostachya* still a live. Open forest area in Papua have made some species die like *F. andajensis* and *F. arfakiana* that used to be live at Andaj village and Arfak mountain in Manokwari and one species in Hamblot bay in Jayapura. Now, We never found again this three *Freycinetia*. Unsimilar to all the *Freycinetia* species, *F. macrostachya* is still growing on the new habitat like the secondary open forest in Manokwari even on the telling area in Timika, Papua.

Not only *F. macrostachya* have ability to leave on both dry and wet area, but also this species have ability to leave near the beach until the higher place in the mountains. In Manokwari we found the species near the beach until 200 m asl in Arfak mountain. In Sorong, Wasior, and Biak, the species is always found near the beach until 80 m asl, it is similar to the species that has found at 200-300 m asl in Lae PNG, but in Jayapura at Cyclop mountain the *F. macrostachya* occur until 1,250 m asl.

3.4. Utilization of *F. macrostachya*

Freycinetia's fruit and flower petals (bracts) are known for their delicious taste. New Zealand's Maori use *Freycinetia Banksia*, which is an endemic species of *Freycinetia*, as food. The flowers can be made into vegetables with a delicious taste, and have been developed in the food industry as canned vegetables. The fruits and petals (bracts) of these plants are also processed into juice or fresh drinks and canned.

In China, traditional people use flower petals from *F. cumingiana* as a coloring agent for traditional drinks such as wine. Meanwhile in Papua, the indigenous peoples of South Sorong use *F. macrostachya* leaves to wrap sago spices before cooking or grilling; while the air roots are used to make traditional bags, rings, bracelets and fish traps. The fruit and flower petals are also consumed by traditional people. Birds and bats are also attracted by their edible petals and by the pollen carried in the edible oil wax matrix. Bats and ants also consume Freycinetia.

The male flowers of *F. macrostachya* are shown in Figure 5. As previously study conducted with the *Pandanus tectorius* fruit, fruit and bracts of *F. macrostachya*, an analysis was first carried out to understand its nutritional content. Proximate data including ash, fat, protein and carbohydrate content of *Freycinetia macrostachya* flower petals, compared with fruit from the *Pandanacea* and Mangrove groups found in Papua are presented in Table 1.

Table 1. Nutritional content of *Freycinetia macrostachya* bract compared to some fruits of *Pandanus tectorius* *Pandanus conoideus* and *Bruguera gymnorizha*

Species	Water content (%, wb)	Ash (%, db)	Protein (%, db)	Fat (%, db)	Carbohydrate (%, db)
Bracts of <i>F. macrostachya</i>	84.1	7.12	4.02	1.15	79.13
Fruit of <i>Pandanus tectorius</i> *	76.9	6.79	4.82	0.44	87.96
Fruit of <i>Pandanus tectorius</i> **	79.5	5.93	3.49	0.39	90.20
Fruit of <i>Pandanus conoideus</i> (local name Monsor)***	53.7	4.72	2.55	55.22	37.49
Fruit of <i>Pandanus conoideus</i> (local name Memeri)***	34.6	5.03	2.59	55.58	36.78
Fruit of <i>Bruguera gymnorizha</i> ****	60.6	1.07	4.67	0.61	93.66

- wb (wet base); db (dry base)

*) Ripe fruit, from Mansinam Island, Manokwari [11]

**) Ripe fruit, from North Beach (Pantai Utara), Manokwari [11]

***) Ripe fruit, from Experimental Farm of Papua University, Amban beach (Amban Pantai), Manokwari [12]

****) Ripe fruit, from Supiori island, Biak [13]

The ash content indicates the amount of mineral elements contained in the of *F. macrostachya* bracts around 7.12%. This data is similar to the ash content in the fruits of the *Pandanus* group (*P. tectorius* and *P. conoideus*) which ranges from 4.72- 6.79% (db); but higher than *Bruguera gymnorizha* fruits (Table 1). This difference can be influenced by the type or cultivar of the fruit, the level of maturity and the location where it grew. Piscopo *et al.* (2010) [14] also reveals that the level of mineral calcium in almonds nut was affected both by cultivar and harvest time. Meanwhile, according to [15], the mineral content of the fruit is more influenced by the composition of the soil where it grows.

Similarities were also found in the protein content of the bracts of *F. macrostachya* (4.02%) with *Pandanus tectorius* fruit, which ranged from 3.49-4.31% (db) and *Bruguera gymnorizha* fruit (4.67%, db). Meanwhile, the lowest *P. conoideus* protein levels ranged from 2.55-2.59% (db). Another difference was seen in the fat content of *F. macrostachya* bracts of 1.15% (db); higher than *P. tectorius* (0.39-0.44% db)

and *B. gymnorizha* (0.61% db). Meanwhile *P. conoideus* fruit has the highest fat content in the range of 55.22-55.58% (db), which is why this species of *Pandanaceae* is known as producing oil.

The carbohydrate content dominates the bracts of *F. macrostachya*, whose levels are similar to that of *P. tectorius* (in the mature phase) around 78.68-90.20% (db). Meanwhile, the pulp of *B. gymnorizha* was dominated by starch and cellulose so that it contained the highest carbohydrate content of 93.66% db [13]; so that it can be processed into flour as a raw material for various cakes. It was also added that the fruit of *P. tectorius* which is ripe has its carbohydrates converted into sugar so that it has a sweet, acidic taste and is light yellow to orange in color and has a distinctive pandan aroma, so that it has been used to be processed into various food products such as jam, dodol and syrup [16]. It was also reported that slightly ripe fruit can be processed into flour and processed into additional ingredients in the processing of cake and pastry products. On the other hand, *P. conoideus* fruit has the lowest carbohydrate content (36.78 - 37.49%), because it is dominated by fat. Therefore, in the processing process, the oil of *P. conoideus* can be extracted [12]. However, the pulp can also be used as fruit pulp and used as raw material in various food products such as sauces, jams, dodol, and various cakes such as sponge cake [17].

Based on the data in Table 1, it can be seen that the bracts of *F. macrostachya* have a fairly balanced nutritional content including minerals, fats, proteins which are dominated by carbohydrates, and have similarities with *P. tectorius* fruit. Therefore, the flower petals of *F. macrostachya* also have the same potential as *P. tectorius* fruit to be developed into various food products.

The white bracts of the *F. macrostachya* species are shown in Figure 5, has the potential to be developed as an alternative food material in the future. For that we need an in-depth study of aspects of cultivation and utilization.



Figure 5. The Male Flower of *Freycinetia macrostachya*, it is a delicacy vegetable

4. Conclusion

Freycinetia macrostachya is a *Pandanaceae* species that occurs majority on Coastal Forest in both northern and southern bird's head Papua until east New Guinea. Many species of *Freycinetia* have only narrowest distribution and become dying on the open area but *F. macrostachya*. This species has ability to live both on primary and secondary forest. The anatomical study has showed that the epidermis of *F. macrostachya* have a three layers epidermis tissue compare to other *Freycinetia* that has only one layers in common. This genus is divided in fourth groups and *F. macrostachya* put on imbricate group, now are named as *F. macrostachya* group because the older species on the group is *F. macrostachya*. People in South Sorong using leave of the species to wrap sago but the bracts and fruit and inflorescence of the species are edible. We could drink fresh juice from *F. macrostachya* bracts and the inflorescence could be

cook as a good vegetables. Analysis proximate of bracts show that the carbohydrate inside is about 77 %, it is meaning that we can make many food products from bracts.

Acknowledgments

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