Market Development Facility

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SAMOA HERBS

"KAVALACTONE CONTENT AND PROFILES OF SAMOAN NOBLE 'AVA VARIETIES".

Report prepared by the:
Scientific Research Organization of Samoa (SROS)

for the
Market Development Facility (MDF)

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Executive Summary

To capitalize on the lucrative ‘ava export market, Samoa must consistently supply high-quality ‘ava. This premium product is derived from noble ava varieties, harvested at the right maturity, and processed in line with public health and safety guidelines. Despite the approval of a National Standard for ‘Ava, educating farmers, processors, and exporters on these standards is crucial to addressing quality challenges. This study validated Samoa’s noble ‘ava varieties, detailing their kavalactone contents, chemotype profiles, and optimal maturity for harvesting and processing. Additionally, the study determined the pH, ash, and moisture contents for each ‘ava variety at various maturity stages—quality parameters stipulated in the national ‘Ava standard.

The 2018 study documented five known noble varieties of ‘ava in Samoa: ‘Ava Le’a, ‘Ava La’au, ‘Ava Loa, ‘Ava Talo, and ‘Ava Mumu (Pacific Horticultural and Agricultural Market Access et al., 2018). However, there was uncertainty about the presence of one variety, ‘Ava Loa, which needed verification to determine if it is truly a noble variety found in Samoa. Additionally, there is limited information on the chemotype profiles and kavalactone contents of these noble ‘ava varieties. ‘Ava farmers also raised concerns and debated the optimal maturity for harvesting cultivars to ensure high-quality products with elevated kavalactone levels.

The report confirmed that no ‘Ava Loa variety was found after consultations and sample collections from farmers in Upolu and Savai’i. The noble ‘ava varieties identified were ‘Ava Le’a, ‘Ava La’au, ‘Ava Talo, and ‘Ava Mumu. ‘Ava La’au was the most cultivated (50%), followed by ‘Ava Talo (22.97%), ‘Ava Le’a (21.62%), and ‘Ava Mumu (5.41%). A new variety, ‘Ava Ofe, was discovered at one location, requiring further investigation.

The data confirmed that total kavalactones in roots (13.14%) were significantly higher than in stumps (7.14%). ‘Ava Le’a had the highest average total kavalactones (roots 14.67%, stumps 7.49%), followed by ‘Ava Mumu (roots 13.94%, stumps 7.29%). ‘Ava La’au (roots 12.65%, stumps 7.12%) and ‘Ava Talo (roots 12.69%, stumps 6.73%) had similar levels. No significant differences were found in kavalactone content among farm locations or maturity stages.

Kavain (KAV) was the major kavalactone, making up 52.85% of the total kavalactones in the four Samoan ‘ava varieties studied. KAV content was significantly higher than the sum of dihydrokavain (DHK, 12.80%) and dihydromethysticin (DHM, 7.47%). ‘Ava with high KAV and low DHK and DHM is considered noble and more valuable, suitable for human consumption. Thus, the four Samoan ‘ava varieties are noble and of premium quality.

For chemotype profiles, ‘Ava La’au contained 462153, 461253, 462513, 416253, and 426153, with 462153 being dominant. ‘Ava Talo had three profiles: 462153, 462513, and 461253, with 462153 and 462513 being major. ‘Ava Le’a had 462513 and 416253 profiles. Both ‘Ava Mumu and ‘Ava Ofe shared the 462513 chemotype.

Among the chemotypes identified in the four ‘ava varieties, the dominant kavalactones were 4 (Kavain), 6 (Methysticin), and 2 (Dihydrokavain), or 462. According to the Samoa ‘Ava Standard, noble varieties should have a chemotype with 2, 4, and 6 as the first three components in any order. Thus, ‘Ava La’au, ‘Ava Le’a, ‘Ava Talo, ‘Ava Mumu, and the new variety ‘Ava Ofe was confirmed as noble varieties.

The ‘ava samples used in the study met all quality standards for pH, ash, and moisture as per the Samoa ‘ava standard. The average pH values were 5.30 for roots and 5.00 for stumps. Moisture content was 7.72% for roots and 8.24% for stumps. Ash values were 1.70% for roots and 1.30% for stumps.

This is the first comprehensive study in Samoa to determine the kavaloctone contents and chemotype profiles of all noble ‘ava varieties. The results are crucial for enhancing the market value of Samoa’s ‘ava industry and confirming the noble varieties. The study also built SROS’s capacity for kavalactone testing, improved staff knowledge on ‘ava chemotypes, and supported the use of Near Infrared Spectroscopy (Kavalactis) for preliminary kavalactone profiling.

Table of Content

List of Tables

List of Figures

1 Introduction

‘Ava (*Piper methysticum*) holds a significant place in Samoa's cultural and social heritage as a traditional beverage produce from the dried ava roots (Va'a, 2010). That cultural importance which makes it a vital traditional beverage to welcome distinguished guests or seek God’s guidance and his wisdom prior any important meetings. Likewise, an important drink after meetings and special projects to thank God Almighty for his blessings that resulted in a successful meeting or completion of a complicated works. Nevertheless, ‘ava is a perennial crop in Samoa and the Pacific region with a high economic significance.

'Ava cultivation dates back approximately three thousand (3000) years, with significant trade occurring both regionally and internationally. Samoa has been estimated to contribute around 1% of the total 'Ava production and export within the region, indicating potential for market share growth if ‘ava commodity is well market and promoted. Apart from exports, the domestic 'ava beverage market in the country consumes substantial quantities of locally produced 'ava. However, due to the lack of detailed statistics, accurately assessing the size of the domestic market remains challenging.

The latest data on 'ava growers shows that approximately 67% are located in Savaii, where production is extensive, with the remaining grown predominantly in Upolu, specifically in the districts of Fagaloa (Samoa Bureau of Statistics, 2021). The number of 'ava growers has experienced a slight adjustment due to the labor mobility scheme, with some growers participating in seasonal worker programs. Amongst the ‘ava growers, the majority of them (around two-thirds) rely on ‘ava cultivation for income, with ninety-eight percent (98%) engaging in subsistence farming. The Ministry of Agriculture and Fisheries (MAF) with its stakeholders and donor partners such as the Market Development Facility, a program of the governments of Australia and New Zealand are providing assistance to expand and promote the ‘ava industry so that it sustainably supplies both the local and overseas markets.

The future of Samoa's ‘ava industry depends on creating a sustainable export market, focusing on consistent supply and premium quality for high-value opportunities. Currently, there is insufficient of information on the quality, characteristics, kavalactone contents, and chemotype profiles ava varieties grown in Samoa. These are essential information to validate and confirm for

farmers, processors, and exporters to know and understand about the range of noble 'ava varieties grown in Samoa.

Funded by MDF Phase 2, this research study focused on analyzing ava varieties, distribution and kavalactone. It aimed to enhance the ‘ava value chains in Samoa by collaborating with ‘ava growers, Samoa Herbs, and the MAF to collect data on noble ‘ava varieties, their kavalactone contents and chemotype profiles. The study also aimed to enhance SROS testing capacity for kavalactones analysis and develop a simple, quick method for screening ‘ava’s kavalactone contents and chemotype profiles. .

2 Background

’Ava in Samoan, is a traditional South Pacific beverage made from the cold water extraction of *Piper methysticum* roots and stumps (Sigh, 1992). It is used in Samoa for social and ceremonial occasions to promote relaxation while maintaining mental alertness (Gautz et al, 2006). The psychoactive and medicinal effects of kava are due to kavalactones (KLs). There are 20 kavalactones and 9 kavalactone dimers identified (Zhang et al, 2018), with six major kavalactones constituting around 96% of the total lipid extract from kava (Lebot et al, 1997). These six are desmethoxyyangonin (DMY), dihydrokavain (DHK), yangonin (YAN), kavain (KAV), dihydromethysticin (DHM), and methysticin (METH). The quality of kava is determined by the content of these kavalactones. Their content is influenced by growing conditions, local environment, and agricultural techniques (Siméoni & Lebot, 2002). Additionally, kavalactone content and chemotype analysis offer a robust qualitative method for characterizing kava cultivars based on the presence and relative amounts of the six major kavalactones.

Samoa’s ‘ava could thrive in premium quality, low-volume markets with a strengthened value chain focused on improved productivity and quality. This study aims to identify noble ‘ava varieties in Samoa and investigate their kavalactone content and chemotype profile. The Kavalytics, a Near-Infrared Spectroscopy based technology, was used for preliminary screening of dried ‘ava of different varieties and maturities for kavalactone content and profiles. The values from the Kavalyctis screening were then confirmed using High Performance Liquid Chromatography (HPLC), a method developed in-house by SROS.

The Near-Infrared Spectroscopy (Kavalytic) method for kavalactone content and chemotype profiling has not yet been widely adopted by ‘ava farmers in Samoa and the Pacific. This study examined the efficiency of this method and confirmed its potential to enhance quality practices among farmers in Samoa. The data obtained will help assess the quality of ‘ava throughout the value chain, allowing for the implementation of appropriate interventions to improve ‘ava production in Samoa.

2.1 Objectives

The Market Development Facility (MDF) contracted the SROS to conduct the following activities for ‘ava research and development:

i. To identify and confirm the ‘ava varieties grown in Samoa

ii. Investigate the quality of different ‘ava varieties grown in Samoa.

iii. Suggest a methodology to determine the potential kavalactone contents and profiles at farm gate.

The specific objectives of the study were;

i. To validate and confirm that the 'ava grown in Samoa are noble varieties by analyzing their kavalactone content and chemotype profile.

ii. To determine the optimal harvest maturity stage of 'ava by analyzing kavalactone content.

iii. To validate the Kavalytic portable device for screening 'ava kavalactone content at farm gate by comparing its Near Infrared Spectroscopy (NIR) data with High Performance Liquid Chromatography results.

3 Methodology & Research Design

3.1 Collection of ‘Ava Samples

The 'ava samples for the study were collected after meetings with Samoa Herbs and the Ministry of Agriculture and Fisheries (MAF) to confirm the list and contacts of 'ava growers in Samoa.

The known noble ‘Ava varieties grown in Samoa, are namely ‘Ava Le’a, ‘Ava La’au, ‘Ava Loa, ‘Ava Talo and ‘Ava Mumu (Samoa Ava Standard 2018). Fresh 'ava roots samples were collected from various districts in Upolu and Savai'i, with three samples per variety at different maturity stages (**Table 1)**. The proposed study estimated at least 120 samples.

Table 1: Number of 'ava samples collected per variety at different maturity stages.

Ava Variety	Maturity stages								Total
	1st year		2nd year		3rd year		4th year		
	Roots	Stumps	Roots	Stumps	Roots	Stumps	Roots	Stumps	
Le’a	3	3	3	3	3	3	3	3	24
La’au	3	3	3	3	3	3	3	3	24
Talo	3	3	3	3	3	3	3	3	24
Mumu	3	3	3	3	3	3	3	3	24
Loa	3	3	3	3	3	3	3	3	24
Total	15	15	15	15	15	15	15	15	120

‘Ava sampling and collection were conducted in September 2023, and January, February, and March 2024 in Savai’i and Upolu **(Table 2).** In Savai’i, total of 24 farmers across 16 villages provided 48 'ava samples. In Upolu, 7 farmers from 3 villages provided 12 samples. Additionally, Samoa Herbs contributed 17 dried 'ava samples for the analysis.

3.2 Identification of Noble ‘Ava Variety in Samoa

The identification of ‘ava variety were guided by farmers' traditional knowledge and a set of morphological descriptors employed to distinguish and identify morphotypes within the same ‘ava varieties.

3.2.1 Farmer's Traditional Knowledge:

The interviews and questionnaires were conducted and distributed to farmers with expertise, experiences and knowledge on different 'ava varieties grown in Samoa. The questions were aim to gather information about distinguishing traits, cultivation practices, and historical knowledge about different 'ava varieties.

3.2.2 Morphological Descriptors

Detailed photographs of the 'ava plants were taken, focusing on various morphological features such as;

- Plant appearance (regular, erect, prostrate, dwarf),
- Stem color (light green, dark green, dark green with a purple tinge, purple and dark purple),
- Relative internode length and thickness (short and thick, short and thin, long and thick, long and thin),
- Lenticel distribution on stems (regularly spaced, irregularly spaced, concentrated near nodes),
- Leaf color (dark green, light green, yellow, green with a purple tinge)

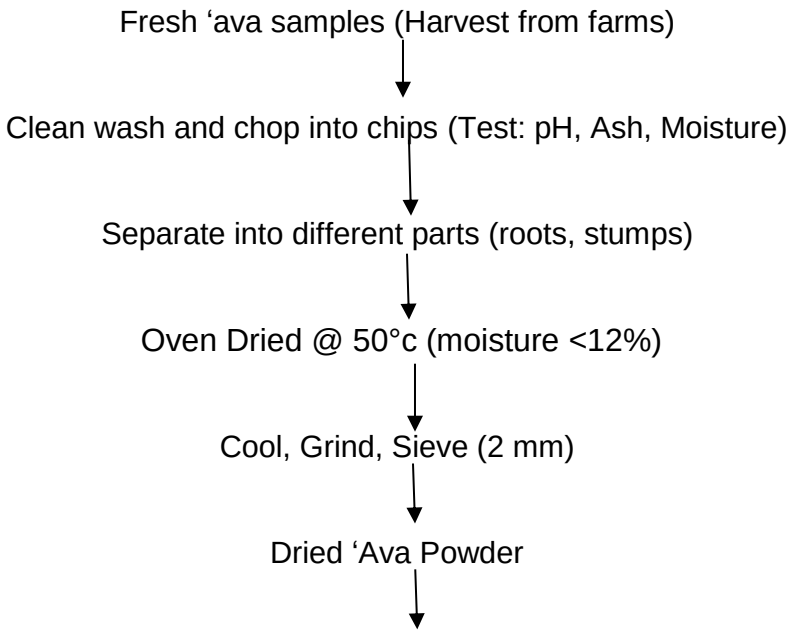
  Photos were used to captured and record morphological descriptors, comparing them among different morphotypes.

Table 2: ‘Ava varieties at different maturity stages collected from farmers.

Variety/Maturity (years after planting)	1	2	3	4	5	6	**Total**
‘Ava La’au	6	17	10	3	0	2	38
‘Ava Le’a	2	0	3	0	0	1	6
‘Ava Talo	1	5	1	4	0	0	11
‘Ava Mumu	2	1	1	0	0	0	4
‘Ava Ofe	1	0	0	0	0	0	1
‘Ava Loa	0	0	0	0	0	0	0
Total	12	23	15	7	0	3	60

3.3 Sample Preparation for Analysis

The main sample matrices analyzed in this study were roots, classified into lateral (uso) and basal (a’ano tipi) parts. After harvesting, the roots were washed, sliced into 2mm x 2mm chips, weighed, oven-dried at 50°C until moisture content was below 12%, and weighed again. The dried roots were then manually pounded and sieved through a 2mm aperture for analysis.



Analysis of kavalactone (NIR and HPLC)

Figure 1: Project Implementation Process Outline

3.4 Analytical Test Methods

The following quality tests were conducted on fresh 'ava roots and stem.

3.4.1 pH

To determine the plant pH, 10 ml of freshly squeezed 'ava tissue sap was mixed with distilled water and measured three times using the H19816 Waterproof Food Care pH Meter.

3.4.2 Ash content

Ash content serves as an important indicator of mineral levels in ‘ava samples. To determine the ash content the values are calculated as a percentage of sample wet weight. The method is from AOAC Official Methods of Analysis, 20th Edition (2016).

3.4.3 Moisture content (Kavalytic)

The model predicts moisture content in powdered kava root samples using a machine learning algorithm applied to NIR data (900nm-1700nm) from these samples.

3.5 Kavalactone Extraction

3.5.1 High Performance Liquid Chromatography Analysis

An in-house method, developed with minor modifications based on Single-Lab Validation for Determination of Kavalactones and Flavokavains in Piper methysticum (Kava) (Liu et al., 2018), was used to analyze the kavalactone content in 'ava samples. Analytical grade solvents were employed for

quantification using High-Performance Liquid Chromatography (HPLC). The analysis utilized a Shimadzu Prominence Series Liquid Chromatograph with an Ultra Aqueous C18 column (250 x 4.6 mm, 5 µm, Restek, USA).The dried root samples were ground into a fine powder. A 1 g 'ava powder sample was mixed with 40 ml of 97% food grade ethanol in a 50 ml centrifuge tube. The mixture was shaken for at least 60 minutes, then centrifuged at 4000 rpm for 10 minutes. The solution was filtered through a 0.45 µm nylon membrane filter disc into an HPLC vial for analysis..

3.5.2 Stock Standard

Kavalactone standards were purchase from Scientific Hub Services Pte Ltd (Singapore).A set of standards 1000, 500, 200,100 ppm were used to prepare the standard calibration curve. Samples and standards (5 µl) were injected into the HPLC system. A fluorescence detector was used and set at excitation and emission wavelengths of 240 nm, respectively was used for detection and quantification of kavalactones.

3.5.3 Mobile Phase

The mobile phase was isocratic acetonitrile: methanol: water: acetic acid (20: 20: 60: 0.1 v/v) at the flow rate of 1.0 ml/min. Injection of 10 µl were made using a Valco valve and sample detection was made at 220 nm. Total run time was 45 minutes. Calculation of the components was made as follows:

$$\% \text{ Individuals Kavalactone} = \frac{(R.K)\ (A.IK)}{(C.S)} \times 100$$

R.K – response factor to kavain calibration 32455 (r2 was 0.9938)

A.IK – area of Individual kavalactone

C.S – concentration of sample solution

3.6 Near Infrared Spectroscopy (Kavalytics)

Kavalytics scanner is taken by shining Near-Infrared light of wavelengths onto the ava sample, then measuring the intensity of the light that is reflected back to the spectrometer. The infrared light is absorbed by the chemical bonds between atoms in the sample, with each different type of bond absorbing in its own characteristic pattern across the wavelengths. In this way, the shape of the resulting absorbance spectrum contains information about the sample's chemical composition.

3.6.1 Kavalactones in Powdered Kava Roots

This model predicts the chemotype and the Total Kavalactones of powdered kava root samples, and also predicts the moisture content and whether the kava is "Beverage Grade" or "Non-Beverage Grade". It is built using a machine learning algorithm applied to NIR data (900nm-1700nm) from kava root samples.

3.6.2 Instrumentation and calibration

The Kavalytics NIRS scanner was connected on an iPad device utilizing Sagitto's iOS app to automatically link the scanner to the online database. Kavalytics (NIRS) calibration was performed prior scanning each sample using a white material block within a plastic bag provided by the Kavalytics Company. Kavalytic scanner window was attached to fit on the white block and scan to obtain calibration curve.

3.6.3 Sample measurements

100 g of dried ‘ava roots powder packed in clear plastic bag, total of 10 scan per sample using Kavalytics scanner the results were extrapolated on an NIRS graph and sent to the Sagitto database for determination of the six main kavalactones and chemotype.

4 Results

Table 3: Summary Analysis of pH and Ash Content

Part	Tests	Mean	Min	Max
Lateral Root	pH	5.3	4.6	5.7
	Ash (%)	1.7	1.15	2.33
Basal Root	pH	5.0	3.8	6.1
	Ash (%)	1.3	1.06	1.87
Stem	pH	4.2	3.5	5.8
	Ash (%)	3.5	2.08	5.72

4.1 pH

The data indicate; Lateral roots tend to have a pH around 5.3 with relatively low variability, Basal roots have a pH around 5.0 with one outlier at 3.8 and Stem parts have the lowest pH on average, around 4.2.

4.2 Ash Content:

Lateral roots have a mean ash content of about 1.7%, with values ranging from 1.15% to 2.33%. The Basal roots consistently have lower ash content than the lateral roots and stems, with a mean of about 1.3%. Stems have the highest mean ash content, around 3.5%, suggesting higher mineral content in the stem.

Table 4: Moisture Content of Oven Dried Roots

Part	Mean	Min	Max
Lateral Root	7.72	6.30	10.00
Basal Root	8.24	3.90	11.80

4.3 Moisture Content

The mean moisture content for the lateral root was 7.72%, while the basal root, was 8.24%. The basal part have slightly higher moisture content compared to the lateral. The minimum moisture content observed in the lateral root was 6.30%, and the basal was 3.90%. The maximum moisture content recorded on the lateral root parts was 10.00%, whereas for the basal part, was 11.80%. Overall moisture content are below 12% indicates the range are fall within the moisture standard for dried ‘ava powder.

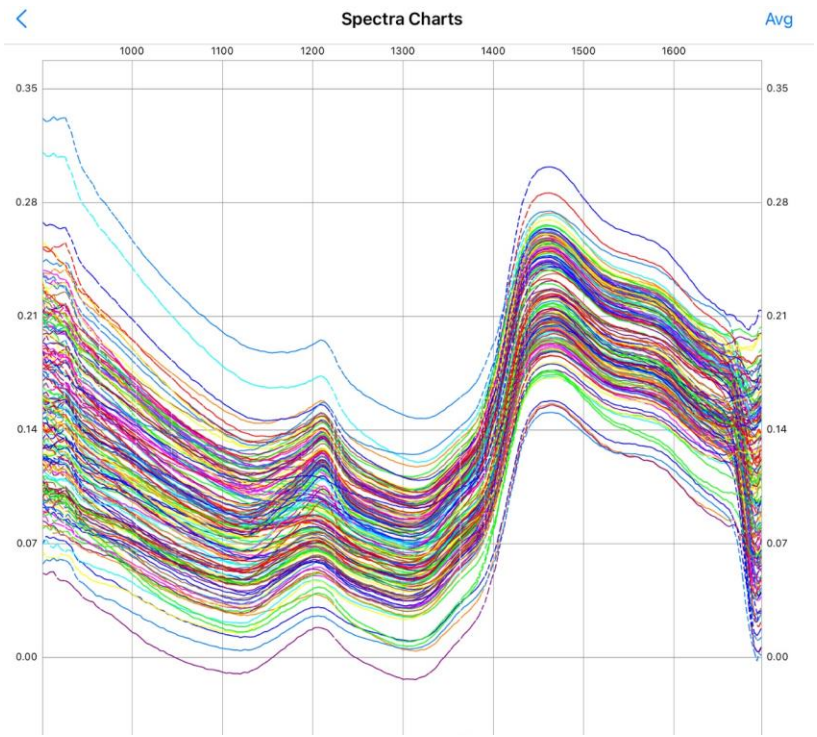


Figure 2: NIR spectra wavelength and absorption of 157 root samples in 900 to 1,700 nm.

Table 5: Summary of Total Kavalactone of Lateral and Basal Root.

	Lateral Root (TK %)	Basal Root (TK %)
Mean	7.67	5.29
Std.Dev	1.44	1.17
Min	5.2	3.1
Max	10.7	7.8

The average kavalactone for lateral roots (7.67%) appears to be higher than the basal roots (5.29%). The median values for both lateral roots (7.9%) and basal roots (5.3%) are relatively close, indicating the central tendency of the data. The standard deviation for lateral roots (1.44%) is slightly higher than that of basal roots (1.17%), the minimum kavalactone value for basal roots (3.1%) is lower compare to the lateral roots (5.2%). The maximum kavalactone value for lateral roots (10.7%) was higher than basal roots (7.8).

Table 6: Summary of Chemotype count for Lateral and Basal Roots.

Chemotype	Lateral Root	Basal Root
243	1	1
245	4	15
246	4	6
264	1	2
423	10	1
425	0	2
426	24	15
436	3	1
452	0	3
456	1	2
462	8	18
463	23	10
465	0	2
624	0	2

Data show the lateral roots 426 chemotype is the most dominant with 24 counts follow by 463 with 23 count, while the 462 chemotype is the most dominant with 18 count follow by 245 and 426 chemotype equally at 15 count for the basal

roots. This means chemotype 426 is the most frequently in the combined dataset of lateral and basal roots with (39) counts.

4.4 Ava Variety Kavalactone Profile Summary (Kavalytics)

***'Ava Le'a*:**

Lateral roots with Chemotype 426 were found to occur five times, while basal roots of the same chemotype occurred six times. As the lateral roots mature, the average total kavalactone percentage generally remains high from 1,4, and 6 years, where the highest TK% values were observed. The average TK% for basal roots varied, showing higher values at a maturity stage of 6 years. Statistical analysis revealed that the TK% for lateral roots (8.84%) higher that of basal roots (5.43%), indicating that lateral roots exhibit a notably higher kavalactone content compared to basal roots.

***'Ava Talo*:**

The Chemotype 426 predominates among lateral roots, while basal roots are primarily associated with Chemotype 245, followed by Chemotype 462. Additionally, chemotypes 246, 264, 465, and 624, are observed only in basal roots, while chemotype 423 and 436 only appear in lateral roots.

***'Ava Laau*:**

The Chemotype 426 and 462 are present in both roots while 245 is the most common in basal roots and 425 and 426 are the most common in lateral roots.

***'Ava Mumu*:**

The Chemotype 423 appears twice in the lateral roots while Chemotype 245 and 246 appears once in the basal roots and 463 appears in both lateral and basal roots.

Overall the average TK% for lateral roots was 8.5%, with values ranging from 7.8 to 9.3% and average TK% for basal roots is 5.9%, with values ranging from 5.2 to 6.7%. Certainly, the TK% values for lateral roots tend to be higher on average compared to basal roots. The variability in TK% values appears to be similar for both types of roots.

Table 7: HPLC Analysis Results of 50 Root Samples

Origin	Variety	Maturity	Parts	K(4)	M(6)	DHM(5)	DHK(2)	Y(3)	DMY(1)	KL%	Chemotype
Taelefaga	Ofe	3	Roots	7.82	2.36	0.80	1.66	0.04	0.86	13.53	462
		3	Basal	3.45	1.06	0.64	1.14	0.04	0.36	6.69	426
Falealupo	Laau	1	Basal	3.33	1.04	0.47	0.96	0.03	0.71	6.53	462
		1	Roots	6.10	2.01	0.55	1.22	0.03	1.75	11.65	461
Neiafu	Talo	2	Basal	2.89	1.20	0.66	1.00	0.10	0.71	6.55	462
		2	Roots	5.96	2.51	0.87	1.45	0.14	1.91	12.84	462
Neiafu	Talo	4	Basal	3.05	1.16	0.41	0.69	0.13	0.34	5.78	462
		4	Roots	10.18	3.11	0.79	1.39	0.28	1.66	17.42	461
Papasataua	Laau	2	Basal	3.78	1.11	0.53	1.17	0.02	0.74	7.35	462
		2	Roots	6.14	1.94	0.64	1.43	0.04	1.59	11.78	462
Safuge	Laau	1	Basal	3.84	1.41	0.50	0.91	0.26	0.32	7.24	462
		1	Roots	8.03	2.76	0.71	1.32	0.16	0.73	13.71	462
Safuge	Laau	2	Basal	3.53	1.28	0.48	0.91	0.22	0.46	6.89	462
		2	Roots	5.41	2.04	0.51	0.99	0.15	1.13	10.24	462
Safuge	Laau	3	Basal	3.65	1.50	0.49	0.84	0.14	0.31	6.93	462
		3	Roots	5.57	2.37	0.56	0.96	0.13	0.59	10.18	462
Safuge	Laau	4	Basal	2.79	1.29	0.40	0.61	0.01	0.25	5.37	462
		4	Roots	6.91	3.19	0.73	1.10	0.25	0.75	12.93	462
Taelefaga	Laau	3	Basal	2.47	0.78	0.35	0.72	0.03	0.34	4.68	462
		3	Roots	3.65	1.15	0.52	1.05	0.03	0.73	7.12	462
Taelefaga	Laau	4	Basal	4.32	1.44	0.87	1.55	0.03	1.22	9.44	426
		4	Roots	7.17	2.36	0.86	1.75	0.03	2.24	14.40	462
Taga	Laau	6	Basal	3.77	1.63	0.45	0.74	0.10	0.99	7.70	461
		6	Roots	5.76	2.62	0.61	0.99	0.22	2.29	12.49	461
Falealupo	Laau	3	Basal	3.35	1.43	0.96	1.41	0.01	0.35	7.52	462
		3	Roots	8.63	2.29	0.79	1.70	0.05	2.31	15.77	416
Sataua	Talo	3	Basal	2.88	1.17	0.82	1.25	0.07	0.84	7.02	426

		3	Roots	8.63	1.91	0.99	1.82	0.09	1.97	15.41	462
Sataua	Laau	2	Basal	2.83	0.94	0.34	0.68	0.04	0.52	5.34	462
		2	Roots	5.11	1.72	0.55	1.14	0.05	1.38	9.96	462
Asau	Lea	1	Basal	4.95	1.63	0.90	1.62	0.22	0.50	9.82	462
		1	Roots	11.99	3.33	1.23	2.36	0.28	1.09	20.28	462
Asau	Lea	6	Basal	4.58	1.67	0.79	1.31	0.03	0.44	8.81	462
		6	Roots	11.02	3.24	1.00	1.75	0.05	0.84	17.90	462
Avao	Laau	7	Basal	3.91	1.35	0.69	1.20	0.19	1.06	8.39	462
		7	Roots	7.00	2.23	0.92	1.83	0.26	2.56	14.80	462
Gataivai	Mumu	2	Basal	4.74	1.77	0.99	1.71	0.22	0.47	9.89	462
		2	Roots	7.78	2.81	1.16	2.12	0.29	0.82	14.99	462
Gataivai	Talo	2	Basal	4.51	1.65	0.70	1.21	0.05	0.69	8.81	462
		2	Roots	7.81	2.65	0.87	1.58	0.07	1.53	14.50	462
Patamea	Lea	3	Basal	2.46	1.00	0.46	0.71	0.04	1.08	5.76	416
		3	Roots	5.42	2.13	0.66	1.13	0.07	2.61	12.02	462
Tufutafoe	Laau	2	Basal	4.08	1.42	0.58	1.07	0.15	0.76	8.06	462
		2	Roots	6.72	2.51	0.78	1.41	0.27	1.83	13.52	462
Tufutafoe	Laau	3	Basal	2.71	0.91	0.41	0.76	0.19	0.30	5.28	462
		3	Roots	6.55	2.22	0.58	1.22	0.40	0.83	11.80	462
Taga	Laau	2	Basal	2.44	0.85	0.35	0.69	0.05	0.65	5.03	462
		2	Roots	3.38	1.34	0.36	0.70	0.05	1.36	7.19	416
Vaisala	Laau	2	Basal	4.00	1.46	0.52	0.92	0.25	0.40	7.55	462
		2	Roots	5.61	2.04	0.87	1.50	0.31	1.75	12.08	462
Min				2.44	0.78	0.34	0.61	0.01	0.25	4.68	
Max				11.99	3.33	1.23	2.36	0.40	2.61	20.28	
Mean				5.25	1.82	0.67	1.23	0.13	1.04	10.20	
Std.Dev				2.31	0.69	0.22	0.40	0.10	0.66	3.86	

K, kavain; M, methysticin; DHM, dihydromethysticin; DHK, dihydrokavain; Y,yangonin; DMY, desmethoxyyangonin; KL, total kavalactone; SD, standard deviation; SEL, standard error; CV, coefficient of variation.

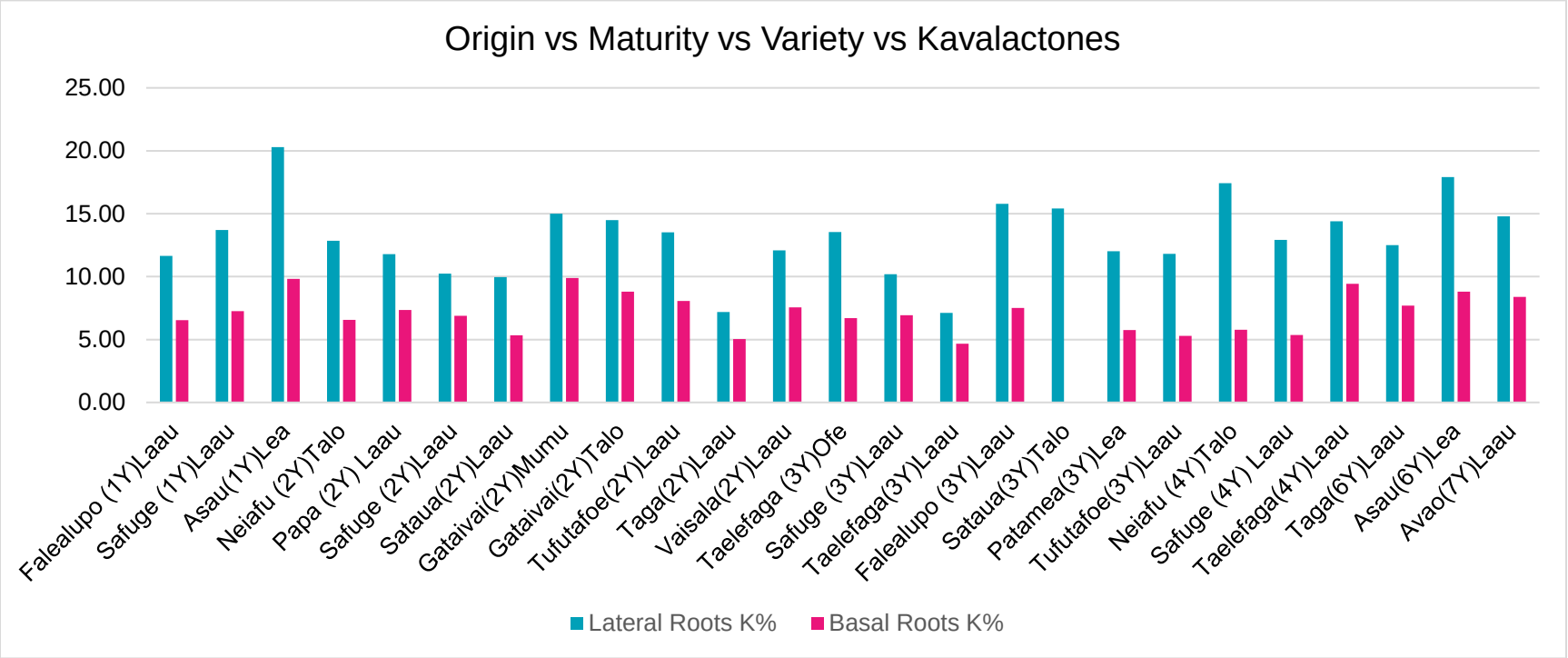


Figure 3: Distribution of kavalactones between organs of different varieties and maturities.

Table 8: Summary of Total Kavalactone of Lateral and Basal Root in different varieties.(HPLC)

	Lateral Root (TK %)	Basal Root (TK %)
Mean	13.14	7.09
Min	7.11	4.68
Max	20.28	9.89
Std.Dev	3.042	1.50

The data indicated the lateral roots has higher TK compared to basal roots. The mean average TK was (13.14%) for the laterl roots and (7.09%) for the basal roots. The highest TK content observed in lateral roots (20.28%) is also much greater than in basal roots (9.89%), showing a wider range of variability in lateral roots.

Table 9: Summary of Chemotype count for Lateral and Basal Roots in different varieties.

Chemotype	Lateral Root	Basal Root
416	2	1
426	0	3
461	3	1
462	20	20

The Chemotype 462 was the predominant profile in both lateral and basal roots. Other chemotypes show variations, with 461 and 416 more common in lateral roots, while 426 is exclusive to basal roots.

Table 10: Distribution of kavalactone between organs of different varieties.

			Lateral Root		**Basal Root**	
Origin	Variety	Maturity	K%	Chemotype	K%	Chemotype
Taelefaga	Ofe	3	13.53	462	6.69	426
Falealupo	Laau	1	11.65	461	6.53	462
Neiafu	Talo	2	12.84	462	6.55	462
Neiafu	Talo	4	17.42	461	5.78	462
Papa	Laau	2	11.78	462	7.35	462
Safuge	Laau	1	13.71	462	7.24	462
Safuge	Laau	2	10.24	462	6.89	462
Safuge	Laau	3	10.18	462	6.93	462
Safuge	Laau	4	12.93	462	5.37	462
Taelefaga	Laau	3	7.12	462	4.68	462
Taelefaga	Laau	4	14.40	462	9.44	426
Taga	Laau	6	12.49	461	7.70	461
Falealupo	Laau	3	15.77	416	7.52	462
Sataua	Talo	3	15.41	462	7.02	426
Sataua	Laau	2	9.96	462	5.34	462
Asau	Lea	1	20.28	462	9.82	462
Asau	Lea	*6*	17.9	462	8.81	462
Avao	Laau	7	14.8	462	8.39	462
Gataivai	Mumu	2	14.99	462	9.89	462
Gataivai	Talo	2	14.5	462	8.81	462
Patamea	Lea	3	12.02	462	5.76	416
Tufutafoe	Laau	2	13.52	462	8.06	462
Tufutafoe	Laau	3	11.8	462	5.28	462
Taga	Laau	2	7.19	416	5.03	462
Vaisala	Laau	2	12.08	462	7.55	462
min			7.11		4.68	
max			20.28		9.89	
mean			13.14		7.09	
Std.Dev			3.042		1.50	
CV (%)			23.15		21.15	

Table 11: Descriptive Statistic of the Calibration set composed of the 50 roots

Kavalactones(KL)	K	M	DHM	DHK	Y	DMY	TK%
Mean	5.25	1.82	0.67	1.23	0.13	1.04	10.14
Std.Dev	2.31	0.69	0.22	0.40	0.10	0.66	3.85
Min	2.44	0.78	0.34	0.61	0.01	0.25	4.68
Max	11.99	3.33	1.23	2.36	0.4	2.61	20.28
CV (%)	44.04	37.94	32.62	32.96	79.67	63.52	37.97

Table 12: Correlation Coefficient between major kavalactone and Total kavalactone content.

Kavalactones (KL)	K	M	DHM	DHK	Y	DMY
M	**+0.9238**					
DHM	**+0.7551**	**+0.7139**				
DHK	**+0.8222**	**+0.7222**	**+0.9585**			
Y	-0.4289	0.4946	-0.3747	-0.3610		
DMY	+0.5676	+0.5471	-0.4270	0.5028	-0.1902	
Total KL%	**+0.9817**	**+0.9399**	**+0.8056**	**+0.8598**	-0.4427	+0.6691

Kavain has a very strong positive correlation with Methyticin (0.9238), DHM (0.7551), Dihydrokavain (0.8222), Y (-0.4289), Desmethoxyyangonin (0.5676), and a very strong positive correlation with KL% (0.9817). Methyticin shows a very strong positive correlation with Dihydrokavain (0.7222), Yangonin (0.4946), Desmethoxyyangonin (0.5471), KL% (0.9399). Dihydromethyticin exhibits a strong positive correlation with Dihydrokavain (0.9585) and a moderate positive correlation with Desmethoxyyangonin (0.5028), KL% (0.8056).Dihydrokavain has a very strong positive correlation with KL% (0.8598). Yangonin shows a moderate positive correlation with Desmethoxyyangonin (0.5028) but a moderate negative correlation with KL% (-0.4427).Desmethoxyyangonin has a moderate positive correlation with KL% (0.6691).

4.5 ‘Ava Variety identify during the sampling.

4.5.1 Variety: *‘Ava Le’a*

<table>
<tr>
<td>  </td>
<td>  </td>
<td rowspan="2">Origin; Fiaga Aleisa, Upolu.

General Appearance: Prostrate

Stem Color: Young stem are pale green with dark green color node and the older stem have brown to white ring on the node.

Lenticels: Dark green lenticels spread over the length of internodes

Internodes: Mottled; not always the same size short and thick

Leaf Color: Dark green

“During the sampling ‘Ava Lea observed to be cultivated in ‘Asau. Aopo, and Patamea in Savaii, and Fiaga, Aleisa in Upolu”.</td>
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4.5.2 Variety: *'Ava* Talo

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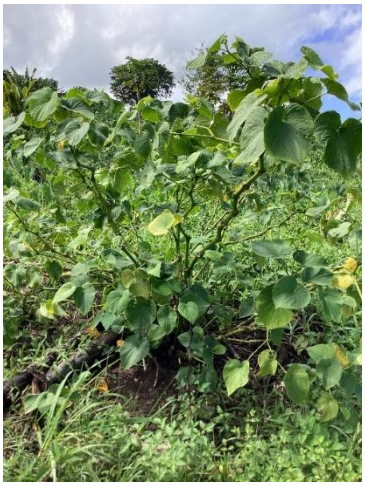
<td>  </td>
<td>  </td>
<td rowspan="2">Origin; Neiafu, Savaii

General Appearance: Normal

Stem Color: Light green

Lenticels: Few dark green lenticels spread over the length of internodes and node.

Internodes: Mottled; not always the same size short and thick

Leaf Color: Pale green

"During the sampling'Ava Talo observed to be cultivated in Neiafu, Asau, Vaisala, Sataua, Papa, Gataivai, and Foiluga in Savaii, and Afulilo in Upolu"</td>
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4.5.3 Variety: ‘Ava La ‘au

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<td rowspan="2">Origin: Vaisala, Savaii

General Appearance: Normal

Stem Color: Green

Lenticels: Many dark green lenticels over the length of internode

Internode: Speckled and uniform long and thin

Leaf Color: Green

“During the sampling ‘Ava Laau observed to be cultivated in Safuge, Taga, Patamea, Aopo, Vaisala, Sataua, Papa, Falealupo, Tufutafoe,Samauga, Avao, Falealupo, Foailuga and Foilalo in Savaii, and Talefaga,Fiaga and Afulilo in Upolu. The majority of the ava collected was ‘Ava La’au account to 63 % of the total samples”.</td>
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4.5.4 Variety: *'Ava* Mumu

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<tr>
<td>  </td>
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<td rowspan="2">Origin: Neiafu, Savaii

General Appearance: Prostrate

Stem Color: Dark Purple to black in color

Lenticels: Many dark green lenticels spread over the length of internode

Internode: Mottled and uniform short and thin

Leaf Color: Green to dark green

"During the sampling 'Ava Mumu observed to be cultivated in Neiafu, Foailuga and Gataivai in Savaii, and Fiaga, Aleisa in Upolu. Picture of a 14 months years old 'Ava Mumu".</td>
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4.5.5 Variety: *'Ava 'Ofe*

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<td>  </td>
<td>  </td>
<td rowspan="2">Origin: Taelefaga, Fagaloa, Upolu

General Appearance: Normal

Stem Color: Green with brown ring on the node

Lenticels: few green lenticels spread over the length of internode

Internode: Striated and speckled long and thin

Leaf Color: Green

"During the sampling there were only one'Ava 'Ofe observed to be cultivated in Telefaga, Fagaloa in Upolu. The local call it 'Ava Ofe cause the stem appear like a dry bamboo stick".</td>
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5 Discussion of result

5.1 Near Infrared Spectroscopy (Kavalytics)

The post-screening results of the dried ‘ava roots with Kavalytics give us insights into kavalactone content, chemotype, and moisture content of noble ‘ava in Samoa. Overall (154) roots samples indicates the Lateral Roots total lactones mean values ranged from 7.3% to 10.6%, with the highest mean observed at maturity ages fourteen months (9.3%) and the lowest mean found at maturity age seventeen months (7.3%). The standard deviation values indicate variability in lactones within each maturity ages, with higher variability observed at maturity three and four years after planting. The minimum lactones values ranged from 5.8% to 10.7%, and the maximum lactones values ranged from 7.3% to 10.6%.

The Basal roots mean lactones values ranged from 4.5% to 7.8%, with the highest mean observed at maturity age fourteen months (6.4%) and the lowest mean found at maturity age three and a half years (4.3%). The standard deviation values suggest some variation in lactones within each maturity age, with higher variability observed at maturity age three and four years.The minimum lactones values ranged from 3.1% to 6.1%, and the maximum lactones values ranged from 5.0% to 7.8%.

Lateral Roots Chemotype 426 was the highest count (24) followed by chemotype 463 with (23) count while chemotype 462 was the highest count (18) followed by chemotype 426 with (15) count on the Basal Roots.

This means chemotype 426 is the most frequently in the combined dataset of lateral and basal roots with (39) counts.

5.2 HPLC Analysis of Kavalactone

The study found that the highest total kavalactone content was obtained from the Asau 'ava Lea lateral root at 1 year maturity, reaching 20.28% (chemotype 462). In contrast, the lowest total kavalactones were observed in the Neiafu 'ava Talo variety at 2 years maturity, with a total kavalactone content of 6.55% (chemotype 462). The chemotype 462 was consistently found across various origins and

varieties. Additionally, the highest total kavalactone percentage of the stump was from the Neiafu 'ava Talo variety at 2 years maturity, with 12.84% (Chemotype 462), while the lowest was observed in the Taga (Laau) variety at 2 years maturity, with 5.03% (Chemotype 462). Chemotype 462 is dominant across both roots and stumps indicate the overall chemotype profile of the noble ava variety in Samoa, the data indicates significant variability in lactone content across different ava varieties, maturity, and plant organs.

Different 'ava varieties display high kavalactone content at different stages of maturity, indicating that the optimal harvest times differ. The consistent high kavalactone levels in the Asau (Lea) variety at both 1 and 6 years suggest for harvesting period. Similarly, Falealupo (Laau) and Neiafu (Talo) display high kavalactone contents at different maturity levels. This assessment based on maturity assists in pinpointing specific growth periods to maximize kavalactone yields. Some varieties showcase significant kavalactone content, with notable mentions being Asau (Lea), Neiafu (Talo), and Falealupo (Laau).

Asau (Lea) stands out for its remarkable kavalactone levels in early and mature stages, indicating the preferable variety for achieving high yields. Additionally, Neiafu (Talo) is significant for its high kavalactone content in roots and basal parts at particular maturity stages.

6 Conclusion

In conclusion, the study confirmed the existence of four Noble ‘ava varieties in Samoa: ‘Ava Lea, Laau, Mumu, and Talo. Among these, the most dominant chemotype was 462. The kavalactone content of the ‘ava in Samoa peaks from 19 month to 6 years of growth. This suggests that if farmers aim to harvest early, cultivating many rhizomes in one batch will result in a greater mass when harvested and dried into kava powder. The research utilizing both near infrared spectroscopy (Kavalytics) and HPLC for the analysis of kavalactones has yielded valuable insights into the profiling of six major kavalactones of Samoa noble ava varieties. HPLC has provided us with detailed information on the specific identification and quantification of kavalactones, offering high precision and accuracy in the analysis. On the other hand, near infrared spectroscopy has proven to be a rapid and non-destructive method, allowing for quick screening and analysis of kavalactones in a more efficient manner. By combining these two analytical techniques, SROS have been able to benefit from the strengths of each method, resulting in a comprehensive approach to studying ‘ava. This integrated methods not only enhances the understanding of kavalactone composition but also opens up new possibilities for further research and applications in the ‘ava industry.

In Addition, there are existing standards and regulations in place within Ava, but there is a lack of awareness among farmers, and they are not actively engaged in following these regulations. Today quality standards for kava products involve various aspects, including the kavalactones content, ensuring microbial safety to prevent contamination, and guaranteeing the absence of chemical residues or heavy metals. Exporters must also meet stringent international standards, which involve regular inspections and certifications for both the kava product itself and the processing facilities and farms involved in its production. In certain market segments, buyers may mandate adherence to specific practices such as organic cultivation or request comprehensive records detailing the cultivation and processing methods used for the kava. It is vital for kava farmers to recognize the changing market landscape and the increasing demands placed on product quality and production practices when targeting international markets. Adaptation to these changing market requirements is crucial for success in the global kava trade.

7 Recommendation and future research

This study highlighted the area that need to improve the quality of ‘ava in Samoa for market;

1. Propagation and Nursery of planting materials from the identify noble ‘ava varieties namely ‘Ava; Le’a, La’au, Talo,Mumu are suitable for growers to mass produces utilizing stems for cultivation.
2. Optimum harvesting time; Harvesting staring from 2 – 6 years after planting.
3. To maximize the kavalactone content by cultivating multiple stems nodes in a single batch can yield greater mass when process into powder, growing more cuttings (5-10) per plant.
4. HPLC method validation process.
5. Develop products prototypes from ‘ava derived products (value addition).

8 References

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9 Appendices

FIGURE 4: HPLC CHROMATOGRAM OF KAVALACTONE STANDARDS

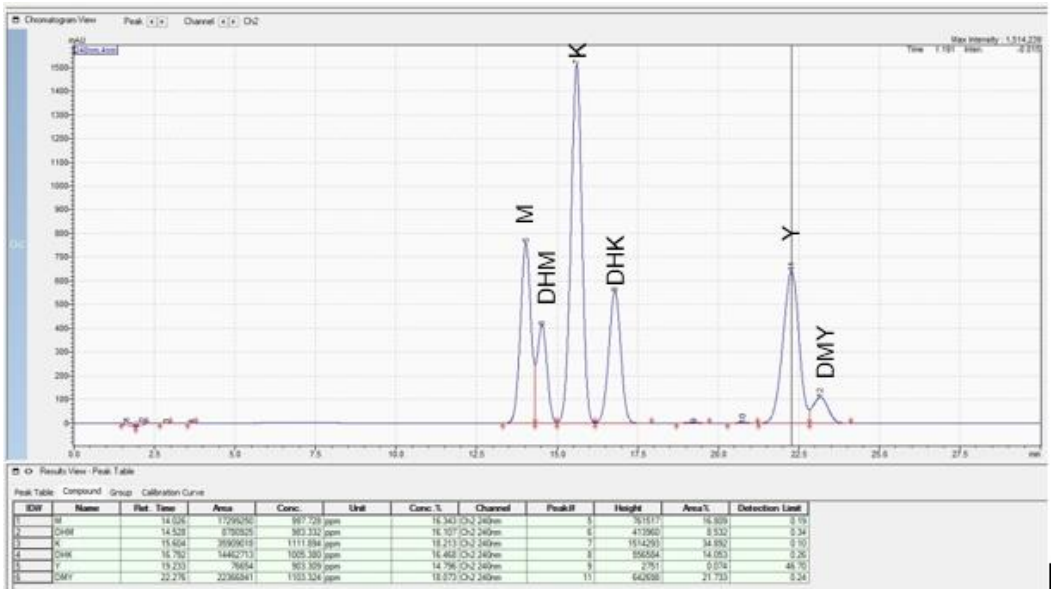
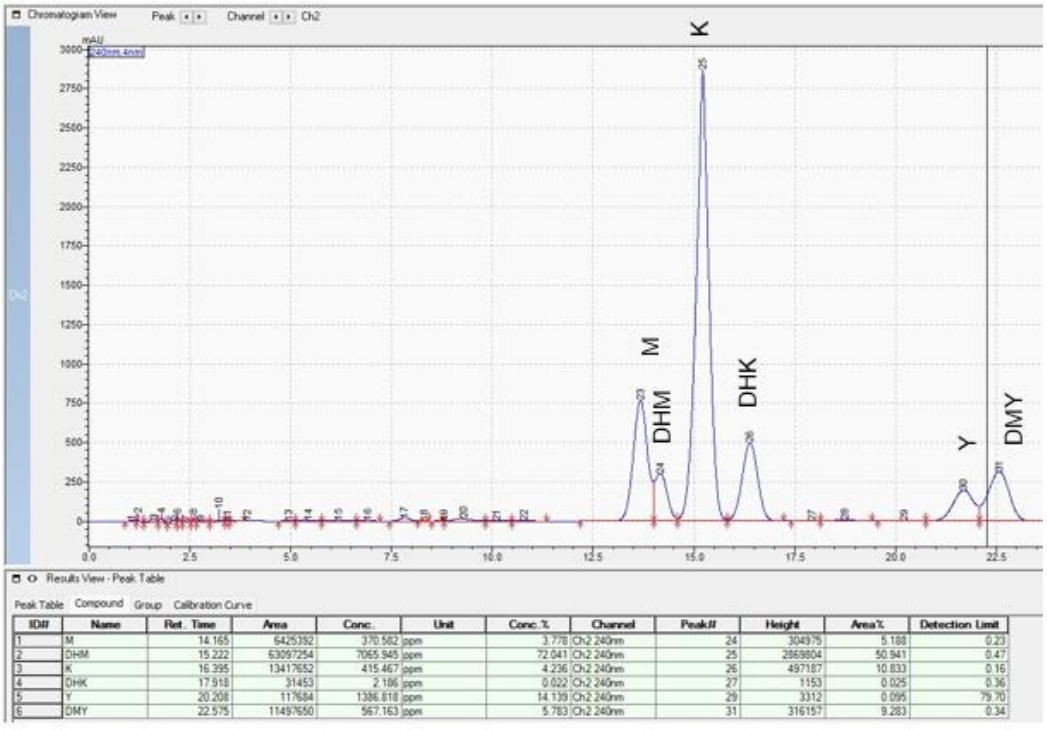
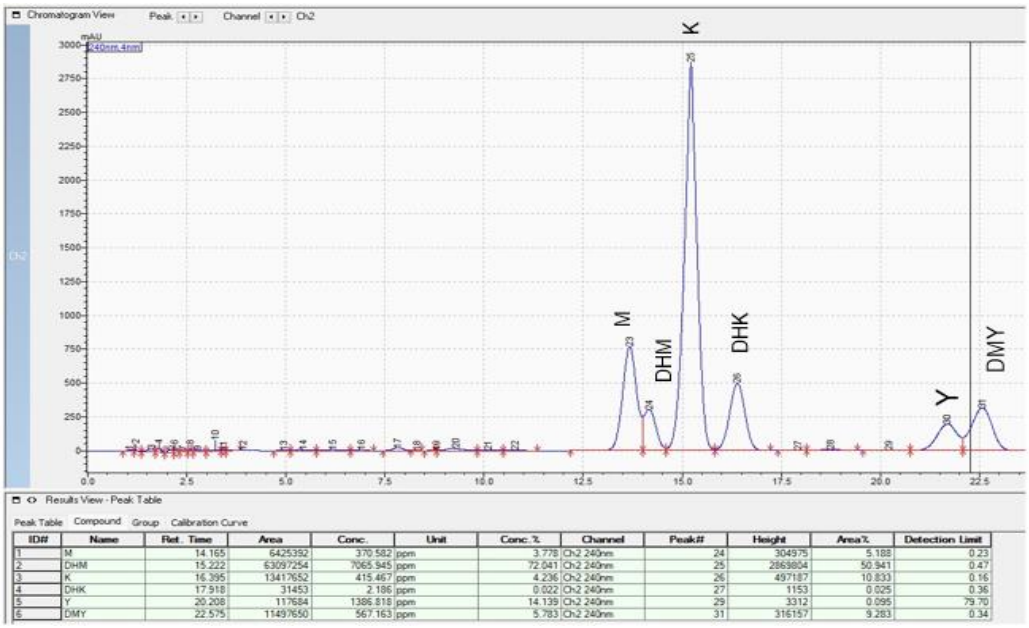


Figure 5: HPLC Chromatogram of ‘Ava Ofe Kavalactones



ID#	Name	Ret. Time	Area	Conc.	Unit	Conc.%	Channel	Peak#	Height	Area%	Detection Limit
1	M	14.165	6425392	370.582	ppm	3.778	Ch2 240nm	24	304975	5.188	0.23
2	DHM	15.222	63097254	7065.945	ppm	72.041	Ch2 240nm	25	2869804	50.941	0.47
3	K	16.395	13417652	415.467	ppm	4.236	Ch2 240nm	26	497187	10.833	0.16
4	DHK	17.918	31453	2.186	ppm	0.022	Ch2 240nm	27	1153	0.025	0.36
5	Y	20.208	117684	1386.818	ppm	14.139	Ch2 240nm	29	3312	0.095	79.70
6	DMY	22.575	11457650	567.163	ppm	5.783	Ch2 240nm	31	316157	9.283	0.34

FIGURE 6: HPLC CHROMATOGRAM OF 'AVA LE'A KAVALACTONES

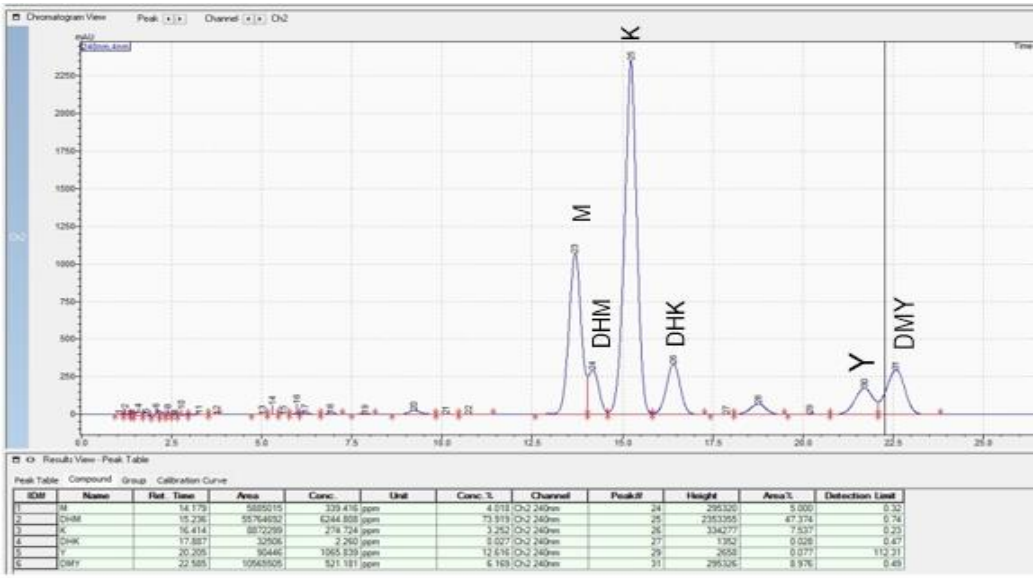


Results View - Peak Table

Peak Table Compound Group Calibration Curve

ID#	Name	Ret. Time	Area	Conc.	Unit	Conc.%	Channel	Peak#	Height	Area%	Detection Limit
1	M	14.165	6425392	370.582	ppm	3.778	Ch2 240nm	24	304575	5.188	0.23
2	DHM	15.222	63097254	7065.945	ppm	72.041	Ch2 240nm	25	2863804	50.941	0.47
3	K	16.395	13417652	415.467	ppm	4.236	Ch2 240nm	26	497187	10.833	0.16
4	DHK	17.918	31453	2.186	ppm	0.022	Ch2 240nm	27	1153	0.025	0.36
5	Y	20.208	1176584	1386.818	ppm	14.139	Ch2 240nm	29	3312	0.095	79.70
6	DMY	22.575	11497650	567.163	ppm	5.783	Ch2 240nm	31	316157	9.283	0.34

FIGURE 7: HPLC CHROMATOGRAM OF 'AVA TALO KAVALACTONES



Results View - Peak Table

Peak Table Compound Group Calibration Curve

ID#	Name	Ret. Time	Area	Conc.	Unit	Conc.%	Channel	Peak#	Height	Area%	Detection Limit
1	M	14.179	5885015	339.416	ppm	4.018	Ch2 240nm	24	295320	5.000	0.32
2	DHM	15.236	55764032	6244.808	ppm	73.919	Ch2 240nm	25	2353355	47.374	0.74
3	K	16.414	8872289	274.724	ppm	3.252	Ch2 240nm	26	334277	7.537	0.23
4	DHK	17.887	32926	2.290	ppm	0.027	Ch2 240nm	27	1352	0.028	0.47
5	Y	20.205	90446	1065.839	ppm	12.616	Ch2 240nm	29	2658	0.077	112.31
6	DMY	22.585	10565505	521.181	ppm	6.169	Ch2 240nm	31	295326	8.976	0.49

Figure 8: HPLC Chromatogram of ‘Ava La’au Kavalactones

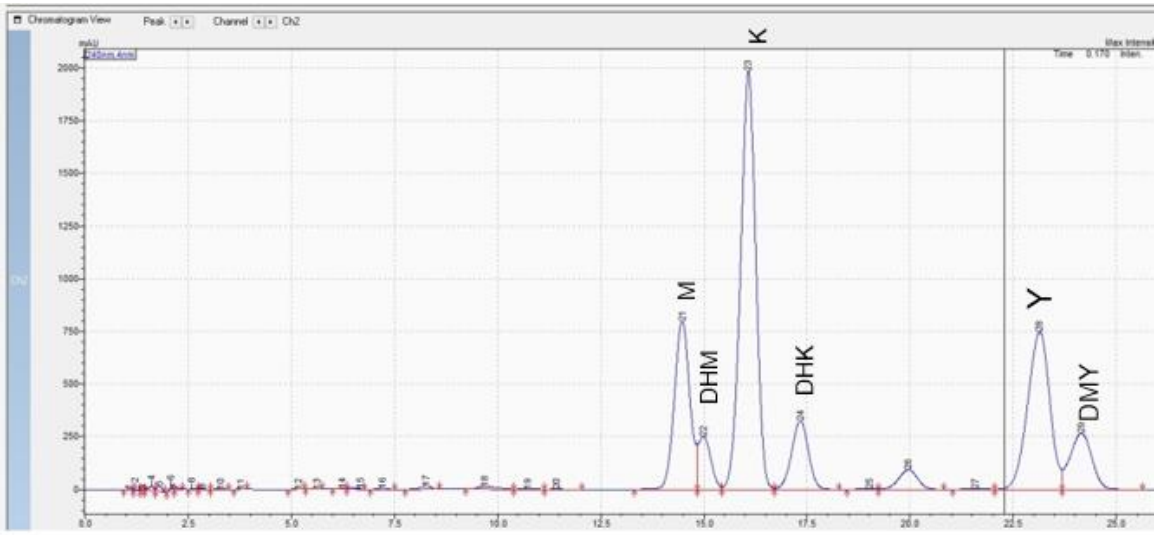


Figure 9: HPLC Comparison of all ‘Ava Varieties

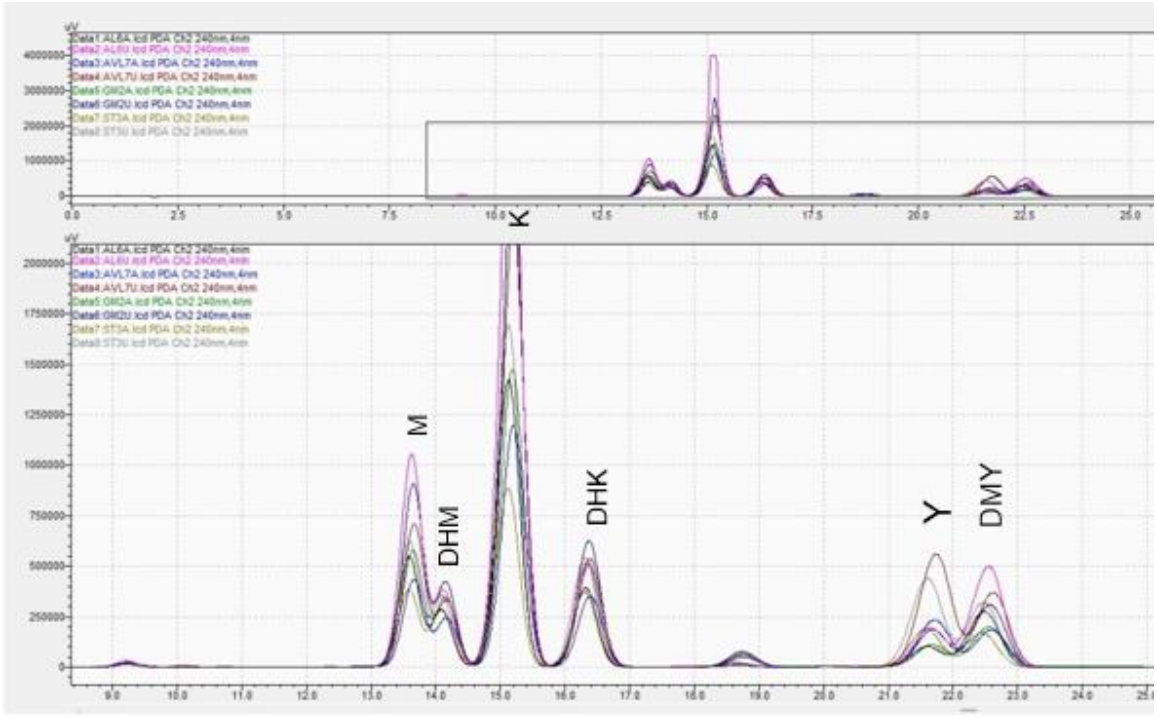


TABLE 13: LIST OF FARMS AND ʻAVA GROWER SELECTED FOR SAMPLING.

Ava Growers	Location	Time Frame
Leilua Faamanatu	Safuge, Savaii	2nd Week September, 2023
Suliasi Akoniu	Asau, Savaii	
Masaga Avea	Neiafu, Savaii	
Moti Setuala	Neiafu, Savaii	
Viliamu Simaika	Taga, Savaii	
Mauala Tutoatasi	Taga, Savaii	
Gago Masani	Taelefaga, Upolu	4th Week January, 2024
Lilo Lefu	Taelefaga, Upolu	
Patrick Rankin	Fiaga, Upolu	
Ray Vili	Taelefaga, Upolu	1st week February, 2024
Siosi Apete	Taelefaga, Upolu	
Faasosolo Vili	Taelefaga, Upolu	
Sua Brown	Afulilo, Lona, Upolu	2nd week Feburary,2024
Fui Anau	Patame, Savaii	3rd week Feburary,2024
Moelagi Palasi	Aopo, Savaii	
Valu Luatimi	Asau, Savaii	
Tauvaga Asa	Vaisala, Savaii	
Faleolo Savelio	Sataua, Savaii	
Lava Lama	Papasataua, Savaii	
Amanda Fuiono	Falealupo, Savaii	
Lilo Junior	Falealupo, Savaii	

Faiumu Fili	Gataivai, Savaii	1st week March, 2024
Faamau Eki	Foailuga, Savaii	
Romani Leau	Foailalo, Savaii	
Kelly Afulalo	Tufutafoe, Savaii	
Tony Tuaifai	Neiafu, Savaii	
Makaelina Paselio	Sataua, Savaii	
Suisala Paselio	Sataua, Savaii	
Makeki Salefu	Vaisala, Savaii	
Fui Fesili	Samauga,Savaii	
Galuvao Viliamu	Avao,Savaii	

TABLE 14: QUANTIFICATION OF SIX KAVALACTONES, CHEMOTYPE AND MOISTURE IN 157 ROOT SAMPLES

Origin	Variety	Maturity	Parts	DMY(1)	DHK(2)	Y(3)	K(4)	DHM(5)	M(6)	TK(%)	Chemotype	Moisture
Asau	Talo	4	Root	0.6	1.69	1.1	2.19	0.95	1.2	7.8	426	7.9
			Stump	0.34	1.71	0.7	1.25	1.01	0.7	5.7	245	9.6
Gataivai	Talo	2	Root	0.64	1.94	1.2	1.99	1.28	1.4	8.4	426	8.9
			Stump	0.21	1.31	0.6	1.03	1.02	0.8	4.9	245	8.5
Afulilo	Talo	1	Root	0.65	1.8	1.3	2.57	0.98	1.5	8.8	426	7.8
			Stump	0.21	1.31	0.6	1.03	1.02	0.8	4.9	245	8.5
Sataua	Talo	3	Root	0.62	1.83	1.3	1.79	1.59	1.5	8.7	245	8.5
			Stump	0.33	1.52	0.7	1.26	0.81	0.9	5.6	246	10
Fiaga	Lea	3	Root	0.55	2.46	1.5	2	1.32	1.5	9.4	243	6.4
			Stump	0.34	1.42	0.8	1.04	1.03	0.8	5.4	245	6.7
Asau	Lea	1	Root	0.73	2.61	1.8	2.84	1.08	1.5	10.5	423	6.5
			Stump	0.34	1.42	0.8	1.04	1.03	0.8	5.4	245	6.7
Asau	Lea	6	Root	0.8	2.05	1.6	2.92	0.75	1.3	9.4	423	6.6
			Stump	0.44	1.5	1.1	1.39	1.07	0.9	6.4	243	7.5
Fiaga	Mumu	1.4	Root	0.64	1.84	1.2	2.35	1.02	1.1	8.2	423	8.2
			Stump	0.36	1.5	0.8	1.03	0.91	0.7	5.3	245	9.6
Foailuga	Mumu	3	Root	0.68	1.69	1.2	2.14	0.93	1.1	7.8	423	9
			Stump	0.33	1.35	0.8	0.97	0.82	0.9	5.2	246	11
Fagaloa	Ofe	3	Root	0.55	1.6	1.3	1.93	1.1	1.4	7.9	426	8.5
			Stump	0.17	1.12	0.6	1.13	1.13	0.8	5	452	9.9
Fiaga	Laau	3	Root	0.55	2.16	1.5	1.77	1.5	1.5	8.9	245	7.1
			Stump	0.19	0.99	0.6	0.84	0.84	0.8	4.2	245	7.4
Sataua	Laau	2	Root	0.25	1.13	0.8	1.75	0.82	1	5.8	426	7.9
			Stump	0.1	0.69	0.6	0.67	0.67	0.8	3.5	624	9.9
Safuge	Laau	1	Root	0.68	0.98	1.2	2.58	0.94	1.3	7.7	463	7.7

			Stump	0.34	0.43	0.7	2.09	0.64	0.8	5.01	463	8.1
Safuge	Laau	2	Root	0.48	0.64	1	2.4	0.78	1.2	6.5	463	8.2
			Stump	0.24	0.41	0.6	1.97	0.68	0.8	4.7	465	8.1
Safuge	Laau	3	Root	0.49	0.94	1	2.55	0.65	1.2	6.8	463	8.5
			Stump	0.24	0.63	0.7	2.26	0.61	0.9	5.3	463	8.7
Safuge	Laau	4	Root	0.55	0.94	1.2	2.71	0.67	1.4	7.4	463	7.7
			Stump	0.26	0.61	0.7	2.38	0.59	0.9	5.4	463	8.3
Taga	Laau	2	Root	0.57	0.92	1	1.88	1.21	1.1	6.7	456	6.4
			Stump	0.26	0.64	0.9	2.08	0.6	0.9	5.4	436	7.8
Asau	Lea	6	Root	0.72	1.37	1.5	3.38	0.55	1.8	9.3	463	8.4
			Stump	0.41	1.59	1.1	2.88	0.7	1.2	7.8	426	8.8
Asau	Lea	3	Root	0.73	1.11	1.2	3.04	0.89	1.4	8.4	463	7.2
			Stump	0.4	1.19	1.2	2.91	0.64	1.2	7.5	462	8.5
Taga	Laau	2	Root	0.54	0.74	1.1	2.4	0.81	1.2	6.8	463	7.1
			Stump	0.3	0.79	0.8	2.13	0.61	0.9	5.5	463	7.7
Taga	Laau	6	Root	0.54	0.88	1.1	2.84	0.67	1.3	7.4	463	7.7
			Stump	0.27	0.73	0.9	2.56	0.59	1.1	6.2	463	8.8
Neiafu	Talo	4	Root	0.62	1.11	1.3	3.14	0.61	1.7	8.4	463	8.3
			Stump	0.27	0.79	0.8	2.46	0.61	1	5.9	463	8.6
Neiafu	Talo	2	Root	0.68	0.8	1	2.84	0.68	1.5	7.6	463	6.9
			Stump	0.46	0.68	1	2.62	0.79	1.2	6.8	463	7.7
Neiafu	Mumu	1.4	Root	0.77	1.25	1.5	3.28	0.76	1.7	9.3	463	7.4
			Stump	0.38	0.64	1	2.63	0.7	1.1	6.4	463	8.1
Taelefaga	Laau	2	Root	0.74	1.94	1.3	2.26	0.92	1.3	8.4	423	7
			Stump	0.44	1.65	1	1.51	1.04	1	6.6	245	7.5
Taelefaga	Laau	1	Root	0.6	1.91	1.2	2.3	0.84	1.3	8.2	426	6.9
			Stump	0.39	1.56	0.9	1.4	1.01	1.1	6.6	246	7.7

Taelefaga	Laau	2	Root	0.4	2.34	1.3	1.96	1.01	1.4	8.4	246	5.7
			Stump	0.23	1.32	0.7	1.3	0.84	0.8	5.1	245	6.7
Taelefaga	Laau	3	Root	0.59	1.85	1.2	1.89	1.03	1.3	7.9	426	7
			Stump	0.29	0.98	0.8	1.2	0.97	0.9	5.2	425	7.9
Taelefaga	Laau	4	Root	0.77	2.65	1.6	2.98	1.32	1.4	10.7	423	6.9
			Stump	0.52	1.84	1.2	1.44	1.37	1.4	7.7	245	8.2
Afulilo	Laau	1	Root	0.65	1.93	1.1	2.46	0.87	1.1	8.1	423	7.7
			Stump	0.53	1.83	1.1	1.46	1.12	1.1	7.1	245	7.8
Afulilo	Talo	2	Root	0.64	1.79	1.1	2.15	0.63	1.1	7.4	423	10
			Stump	0.29	1.41	0.6	1.03	0.91	0.7	4.9	245	8.7
Asau	Lea	3	Root	0.47	2.92	1.4	1.65	1.65	1.5	9.6	245	5.8
			Stump	0.15	0.93	0.6	1.02	0.81	0.8	4.4	426	7.3
Patamea	Laau	2	Root	0.84	2.58	1.5	2.78	1.2	1.4	10.3	423	6.9
			Stump	0.4	1.61	0.8	1.17	1.05	0.9	6	245	7.6
Patamea	Laau	3	Root	0.35	1.19	1.2	2.07	0.92	1.3	7	463	7.3
			Stump	0.05	0.72	0.6	0.8	0.8	0.7	3.6	452	8.2
Aopo	Laau	3	Root	0.37	1.21	1	1.64	1.01	1.1	6.3	426	8.4
			Stump	0.04	0.46	0.5	0.85	0.69	0.6	3.1	456	7.7
Asau	Mix	4	Root	0.22	0.89	1.2	1.85	0.89	1.3	6.4	463	8
			Stump	0.03	0.49	0.6	0.83	0.83	0.7	3.4	456	9.4
Vaisala	Laau	1	Root	0.57	1.9	1.3	2.05	0.98	1.4	8.2	426	7.7
			Stump	0.09	0.81	0.1	0.81	0.52	0.9	3.9	452	8.5
Papasataua	Laau	2	Root	0.58	1.18	1.4	2.22	0.96	1.3	7.7	436	7.2
			Stump	0.3	0.95	0.9	1.47	0.66	1	5.3	462	7.4
Falealupo	Laau	1	Root	0.47	1.21	1.4	2.58	0.76	1.5	7.9	463	8.8
			Stump	0.12	0.82	0.8	1.45	0.81	1	5	462	9.9
Falealupo	Laau	2	Root	0.39	0.8	1.3	2.44	0.8	1.4	7.1	463	8.2

			Stump	0.19	1.11	0.9	1.64	0.73	1.1	5.7	426	9.6
Falealupo	Laau	3	Root	0.54	1.56	1.6	2.01	1.26	1.5	8.5	432	7.2
			Stump	0.2	0.9	0.7	1.48	0.8	0.9	5	462	7.6
Tufutafoe	Laau	2	Root	0.27	1.75	1.1	2.25	0.82	1.3	7.6	426	9.3
			Stump	0.09	1.35	0.8	1.6	0.72	1	5.5	426	10
Vaisala	Laau	2	Root	0.34	1.12	1.2	2.12	0.65	1.3	6.7	463	8.4
			Stump	0.32	1.01	1.2	2.03	0.68	1.2	6.4	463	8.3
Avao	Laau	7	Root	0.49	2.14	1.4	2.68	0.96	1.6	9.3	426	8.6
			Stump	0.18	1.7	0.8	1.49	0.78	1.1	6.1	246	10
Foailuga	Laau	2	Root	0.66	2.25	1.6	1.76	1.22	1.7	9.2	246	8.7
			Stump	0.28	1.22	0.9	1.49	0.82	1.1	5.8	426	10.2
Foailalo	Laau	2	Root	0.19	0.68	1.1	2.26	0.47	1.3	6.1	463	10.3
			Stump	0	0.65	0.4	1.17	0.55	0.8	3.6	462	11.7
Tufutafoe	Laau	3	Root	0.06	0.75	1.3	1.75	0.44	1	5.3	436	9.4
			Stump	0.07	1	0.8	1.12	0.46	1	4.4	426	11.8
Neiafu	Laau	2	Root	0.42	1.66	1.5	2.5	0.95	1.5	8.5	423	9.8
			Stump	0.08	0.82	0.8	1.31	0.7	1	4.7	462	10.7
Neiafu	Laau	3	Root	0.3	1.31	1.2	2.32	0.69	1.4	7.1	462	10.1
			Stump	0.13	1.24	0.8	1.47	0.84	1	5.4	426	10.6
Satau	Laau	1.5	Root	0.4	1.43	1.3	2.5	0.5	1.3	7.3	426	9.9
			Stump	0.14	1.09	0.7	1.33	0.88	0.9	5	425	9
Vaisala	Laau	2	Root	0.47	1.47	1.4	1.99	0.98	1.6	7.9	462	8.8
			Stump	0.35	1.56	1.1	1.83	1.08	1.2	7.1	426	10.1
Vaisala	Laau	3	Root	0.37	1.17	1.3	2.37	0.63	1.5	7.9	463	9.9
			Stump	0.12	0.99	0.8	1.46	0.75	1	5.2	462	10.6
Samauga	Laau	3	Root	0.34	0.9	1	2.01	0.73	1.2	6.2	463	8.3
			Stump	0.11	0.91	0.7	1.31	0.65	0.9	4.6	426	9.7

Samauga	Laau	2	Root	0.28	1.07	1.1	2.34	0.71	1.4	6.9	463	10
			Stump	0.03	0.92	0.8	1.29	0.55	1	4.5	462	10.4
Avao	Laau	2	Root	0.61	2.37	1.7	2.89	1.27	1.9	10.7	426	8.8
			Stump	0.3	2.17	1	1.66	1.08	1.1	7.3	245	10.3
Patamea	Lea	3	Root	0.67	2.07	1.8	2.48	1.19	1.9	10.1	426	6.9
			Stump	0.23	1.03	0.9	1.66	0.98	1.1	5.9	462	7.5
Aopo	Lea	1	Root	0.44	1.36	1.5	1.97	1.22	1.6	8	463	7.1
			Stump	0.18	0.97	0.9	1.75	0.86	1	5.6	462	8.3
Sataua	Talo	2	Root	0.43	1.32	1.6	1.99	1.13	1.5	7.9	436	6.9
			Stump	0.11	0.67	0.7	1.4	0.87	0.9	4.7	465	8.5
Papa	Talo	4	Root	0.34	1.29	1.3	2.64	0.64	1.4	7.6	463	8.2
			Stump	0.16	0.79	0.8	1.37	0.79	1	4.9	463	8.5
Foailalo	Talo	2	Root	0.58	1.42	1.4	2.74	0.9	1.6	8.6	462	7.7
			Stump	0.25	1.21	0.9	1.62	1.05	1.1	6.2	426	9.3
Gataivai	Mumu	2	Root	0.59	1.85	1.5	2.61	0.63	1.5	8.7	426	8.4
			Stump	0.34	1.45	1.1	1.67	1.07	1.1	6.7	423	9.4
Fiaga	Lea	4	Root	0.58	1.32	1.4	2.56	1.08	1.4	8.4	463	6.3
			Stump	0.24	0.8	0.8	1.85	0.61	1	5.3	462	7.4
Fiaga	Lea	4	Root	0.67	2.17	1.5	3.13	0.99	1.7	10.1	426	6.6
			Stump	0.24	0.83	0.7	1.7	0.8	1	5.3	462	7.8
	Lea	3.5	Root	0.24	1.79	1.1	1.57	1.49	1.6	7.8	264	7.8
			Stump	0.14	1.45	1	1.04	0.95	1.3	5.9	264	3.9
Aopo	Talo	3	Root	0.4	1.34	1.2	1.24	1.11	1.5	6.8	624	7.1
			Stump	0.17	0.8	0.6	1.05	0.65	0.8	4.01	426	9
Asau	Talo	3.5	Root	0.3	1.38	1.2	1.69	1.06	1.6	7.2	462	7.2
			Stump	0.19	0.8	0.7	0.99	0.71	0.9	4.3	462	7.1
Falealupo	Talo	4	Root	0.58	1.84	1.7	2.14	1.16	1.7	9.1	426	6.3

			Stump	0.27	1.01	0.8	1.18	0.68	1	5	462	7.3
Asau	Talo	2	Root	0.43	1.22	1.1	1.73	0.83	1.3	6.5	462	7.2
			Stump	0.24	0.74	0.7	1.09	0.67	0.9	4.3	462	7.6
Falealupo	Lea	3	Root	0.61	1.54	1.3	2.12	1.01	1.5	8.1	426	7
			Stump	0.46	1.2	1	1.36	0.84	1.1	5.9	426	6.4
Asau	Talo	4	Root	0.23	1.17	0.8	1.33	0.97	1.2	5.8	462	6.7
			Stump	0.17	0.91	0.7	0.71	0.7	0.8	3.9	264	8
Asau	Lea	3.5	Root	0.34	1.75	0.9	1.68	1.3	1.4	7.4	246	6.9
			Stump	0.25	1.1	0.7	0.99	0.81	0.9	4.7	246	7.8
Falealupo	Talo	5	Root	0.61	1.68	1.1	1.9	1.02	1.1	7.4	426	7.5
			Stump	0.36	1.33	0.9	1.36	0.79	1	5.7	426	8.1
Asau	Lea	4	Root	0.86	2.33	1.7	2.38	1.57	1.7	10.6	426	6.8
			Stump	0.3	0.94	0.7	1.03	0.66	0.9	4.5	426	7.4
Fiaga	Lea	3	Root	0.67	2.39	1.5	2.13	1.49	1.7	9.9	246	5.2
			Stump	0.3	1.27	0.6	1.2	0.74	0.8	4.9	246	7.4
Fiaga	Lea	3	Root	0.49	1.04	0.5	2.56	0.59	0.9	6.1	426	7.5
			Stump	0.23	1	0.4	1.88	0.42	0.5	4.5	426	8.1
Neiafu	Talo	4	Root	0.74	1.62	1.3	3.51	0.65	1.3	9.1	426	7.1
			Stump	0.32	0.88	0.7	2.18	0.58	0.9	5.5	462	8.3
Falealupo	Talo	4	Root	0.52	2.61	1.2	1.89	1.7	1.5	9.4	245	6.9
			Stump	0.34	1.71	0.7	1.25	1.01	0.7	5.7	245	7.1
Fiaga	L&L	4	Mix	0.48	1.33	0.9	1.68	0.76	1	6.2	426	7.4
Fiaga	T&L	3	Mix	0.31	0.99	0.8	1.4	0.66	1	5.2	462	9.7
Sataua	Laau	3	Mix	0.18	0.97	1	1.68	0.69	1.1	5.6	462	8.9