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The value of regional languages in Indonesia: An acoustic analysis using Praat

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ABSTRACT

Formants are the defining frequency components of acoustic signals in human speech and play a crucial role in shaping vocal quality. This study aims to identify and describe the formant values (F1, F2, and F3) of five Indonesian regional languages: Ambon, Bugis, Nias, Sundanese, and Serui Papua. Employing a qualitative descriptive design within an acoustic phonetics framework, data were elicited from native speakers' utterances and analysed using PRAAT software to extract formant values and their distributional patterns. The findings reveal notable cross-linguistic variation. Bugis exhibits the richest vowel inventory, with 39 vowels across 12 lexical items, whereas Nias has the smallest set, with 19 vowels from 6 lexical items. Regarding acoustic measurements, the highest F1 value was observed in Ambon (1210 Hz), the highest F2 in Sundanese (2417 Hz), and the highest F3 also in Ambon (3250 Hz). Conversely, the lowest F1 was recorded in Nias (337 Hz), the lowest F2 in Serui Papua (1007 Hz), and the lowest F3 in Bugis (2171 Hz). These results confirm that cross-linguistic variation in formant distribution reflects the distinctive articulatory characteristics of each language. The study contributes to comparative phonetic research while also supporting regional language preservation through acoustic documentation, which can inform educational practice, voice recognition technologies, and language revitalisation initiatives.

KEYWORDS: formant, vowel, acoustic phonetics, Indonesian regional languages, PRAAT

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Introduction

Language is an arbitrary system of sound symbols conventionally agreed upon by a speech community for the purposes of communication and interaction. Beyond its communicative function, language also embodies cultural identity, historical continuity, and the collective thought patterns of a society. In the context of increasing globalisation and linguistic homogenisation, regional languages play a vital role in maintaining linguistic diversity and sustaining local identities. Indonesia is recognised as one of the most linguistically diverse nations in the world, ranking second only to Papua New Guinea. Kik et al. (2021) and Van den Berg (2014) report that Papua New Guinea has approximately 840 languages, while Indonesia follows with 715 languages, confirming its position as a region with remarkable linguistic heritage.

However, this richness is not proportionally reflected in the vitality of regional languages, many of which face pressure from language shift. Younger generations are less likely to use regional languages, often favouring Indonesian as the national lingua franca or, in some cases, foreign languages such as English for academic and professional mobility. Data from the Ministry of Education and Culture (2018) show that between 1991 and 2017, 652 regional languages were successfully mapped across 2,452 areas in Indonesia. Yet UNESCO records vitality data for only 143 of these languages (Seifart et al., 2018), highlighting a significant gap between the number of existing regional languages and those that have been systematically documented. In response, the government has launched the Regional Language Revitalisation Programme (Ministry of Education and Culture, 2022), which emphasises dynamic, adaptive, and community-based preservation. This initiative involves millions of students, thousands of teachers, and local communities across various provinces. Central to the programme is the availability of accurate and empirical linguistic data, which provide the basis for sustainable revitalisation strategies. Accordingly, linguistic research that foregrounds phonetic-acoustic documentation is highly relevant both academically and practically.

Within linguistics, acoustic phonetics constitutes a subfield that investigates the physical properties of speech sounds through measurable acoustic analysis. Vowels, as the nucleus of a language's phonological system, are typically analysed through their formant values, particularly F1, F2, and F3 (Mentari et al., 2024; Rai, 2017). These values are crucial in distinguishing vowel quality across languages. Ladefoged (2006) argues that formants are the principal resonance frequencies of the vocal tract that determine vowel perception (Aalto et al., 2018; Chan et al., 2016; Poon & Ng, 2014). Hence, the acoustic analysis of formant values provides an objective account of a language's phonetic profile.

Although research in acoustic phonetics has developed considerably, there is ongoing debate about the extent to which phonetic data serve as an effective instrument for language documentation. Some scholars prioritise lexical, morphological, or syntactic analyses, while others contend that acoustic phonetics is foundational for objective cross-linguistic comparison (Kim, 2020; Sofa & Febrianti, 2025; Boboqulovna, 2025). This debate becomes particularly salient in the context of endangered languages: does acoustic phonetic analysis meaningfully contribute to preservation, or is it merely technical documentation with limited practical impact?

Technological approaches also differ in the field. Praat, widely used in phonetic research (Bořil & Skarnitzl, 2016; Strömbergsson, 2016; Ali et al., 2023; Caumo et al., 2023), is often praised for its efficiency and accuracy. Yet concerns remain about the reliability of its outputs when applied to less-documented languages. While some researchers advocate for Praat as a primary tool, others recommend supplementing it with direct articulatory observations to ensure validity (Strömbergsson, 2016b; Pareniuk, 2021; Annamalai et al., 2022; Seong, 2022; Mezzedimi et al., 2016). Such debates highlight the need for critical examination of how acoustic software can be applied to the study of Indonesian regional languages.

Most studies on vowel formants have concentrated on major world languages such as English, German, and Mandarin. For example, Özek (2020) and Demir (2020) analysed vowel shifts in Turkish, while Subandowo et al. (2020) and Ulfayanti and Jelimun (2018) investigated Indonesian learners' difficulties in producing English vowels. Although valuable, these studies do not address Indonesian regional languages. The existing research gaps can be summarised as follows: (1) the scarcity of acoustic studies analysing formant values in Indonesian regional languages, (2) the lack of cross-linguistic comparisons that reveal vowel distributional variation across regions, and (3) the absence of phonetic-acoustic data integrated with revitalisation programmes, despite their potential use in teaching materials, digital dictionaries, and technology-based preservation initiatives.

Recent studies underscore the potential of formant analysis to reveal detailed information about vocal production. Bašić and Varošanec-Škarić (2023), Conklin et al. (2020), and Morris (2017), for instance, highlight its relevance in exploring socio-phonetic variation in bilingual contexts. Lee and Kreiman (2020) and Genidze (2020) emphasise the role of acoustic variation in identifying typological differences between languages. In Southeast Asia, Lobel (2021) demonstrates that formant analysis can uncover vowel phonemes in minority Philippine languages that were not previously systematically described, a finding that has implications for Indonesian contexts.

In Indonesia, research on regional languages has often prioritised sociolinguistic or morphophonemic perspectives over acoustic ones. Studies of Sundanese, for example, typically focus on phonological description without detailed formant analysis (Yulita et al., 2018; Bangga & Doran, 2021), while research on Bugis has emphasised morphophonemic aspects (Kaharuddin et al., 2024). Other studies address shifts in language use among younger speakers (Ulfa et al., 2018; Bissoonauth, 2019; Abalkheel, 2025), but again without acoustic documentation. This confirms that phonetic-acoustic research on Indonesian regional languages remains limited. Building on these gaps, the present study has three main objectives. (1) analysing the vowel formant values (F1, F2, F3) in five regional languages: Nias, Sundanese, Ambonese, Buginese, and Serui Papuan, in order to describe their distinctive acoustic characteristics; (2) examining cross-linguistic differences in vowel distribution to highlight both unique and overlapping patterns; and (3) identifying the vowels and languages with the highest and lowest formant frequencies, thereby generating comparative data relevant to phonological and typological inquiry. More broadly, this research contributes empirical data for regional language documentation, supporting revitalisation initiatives and preserving Indonesia's cultural heritage. It thus serves as a bridge between scientific phonetic analysis and the practical need to sustain linguistic diversity in a rapidly globalising context.

Method

Research Design

This study employed a qualitative descriptive design within the framework of acoustic phonetics. The design aimed to identify and describe the formant values of vowels in selected Indonesian regional languages through acoustic analysis. Such an approach was deemed appropriate because it is exploratory in nature and enables an in-depth account of vowel characteristics across languages. Using Praat software, the study sought to generate objective and quantifiable data on the distribution of formant values (F1, F2, and F3), which constitute the primary indicators of vocal quality in acoustic phonetics (Ladefoged, 2006; Ladefoged & Johnson, 2011).

Research Subjects

The subjects of this study were native speakers of five Indonesian regional languages: Ambonese, Buginese, Nias, Sundanese, and Serui Papuan. These languages were selected on the basis of ethnolinguistic considerations that capture the phonological diversity of Indonesia. The participants included doctoral students from the Indonesian Institute of the Arts (ISI) Surakarta and postgraduate students from the Department of English, University of North Sumatra, who are native speakers of these languages. Each participant was asked to produce utterances in the form of greetings and self-introductions in their respective regional languages, ensuring that the data reflected natural speech patterns.

Data Collection Techniques

The primary data consisted of recorded utterances containing vowel sounds. From these recordings, samples representing the five basic vowels of Indonesian, /a/, /i/, /u/, /e/, and /o/, were extracted. These vowels were chosen because they form the core vowel system of Indonesian and are generally present in many of its regional languages. Recordings were conducted under controlled acoustic conditions to minimise background noise and to ensure validity for subsequent analysis.

Research Instruments

The main instrument for analysis was Praat software, a phonetic analysis programme developed by Boersma (2011). Praat enables researchers to visualise and measure the acoustic properties of speech, particularly formant values (F1, F2, and F3) (Ali et al., 2023b; Xu & Gao, 2018; Cavalcanti et al., 2021; Núñez-Batalla et al., 2018;

Yilmaz et al., 2018). By generating spectrogram representations, Praat allows the identification of resonance patterns in the vocal tract and provides accurate quantitative data. Its widespread use in international phonetic studies attests to its reliability (Wang, 2024; Guo, 2025).

Data Analysis Techniques

Data analysis was conducted using the interactive model developed by Miles et al. (1988), which consists of four stages shown in Figure 1: *data collection*, *data condensation, data display,* and *conclusion drawing and verification*.

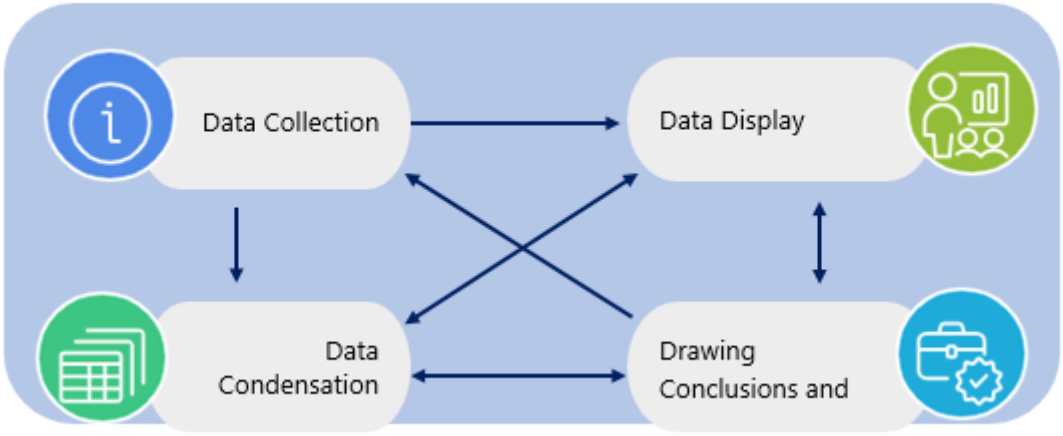

Figure 1. Interactive Model by (Miles et al., 1988)

Data Collection

The first stage involved collecting speech recordings containing the target vowels from native speakers of the selected regional languages. This process generated the primary data corpus for subsequent analysis.

Data Condensation

Following data collection, the recordings were sorted and refined to prepare for analysis. This stage involved selecting, simplifying, and organising the material to ensure that only relevant samples were retained for examination.

Data Display

The refined data were analysed using Praat to extract the formant values (F1, F2, and F3) for each vowel. The results were presented in tables and graphs illustrating the distribution of the highest and lowest formant values across the five regional languages. These displays facilitated interpretation of the emerging acoustic patterns.

Conclusion Drawing and Verification

In the final stage, the findings were interpreted to identify which regional languages exhibited the highest and lowest formant values, as well as the most frequently occurring vowels. The conclusions were then verified by comparing the observed acoustic patterns with relevant phonetic theories, providing a comprehensive account of the phonetic characteristics of the regional languages under study.

Results

Nias Language Forman Values

An acoustic analysis of the Nias language was conducted based on recordings of six words: *Yaahowu, Yaodo Nadia moroi ba Gunung Sitoli*, which means "Yaahowu, I am Nadia from Gunung Sitoli". From these six words, nineteen vowels were obtained for analysis, consisting of six /a/ vowels, six /o/ vowels, three /u/ vowels, and four /i/ vowels. All vowels were analysed using the Praat application to identify the first (F1), second (F2), and third (F3) formant values shown in Figure 2.

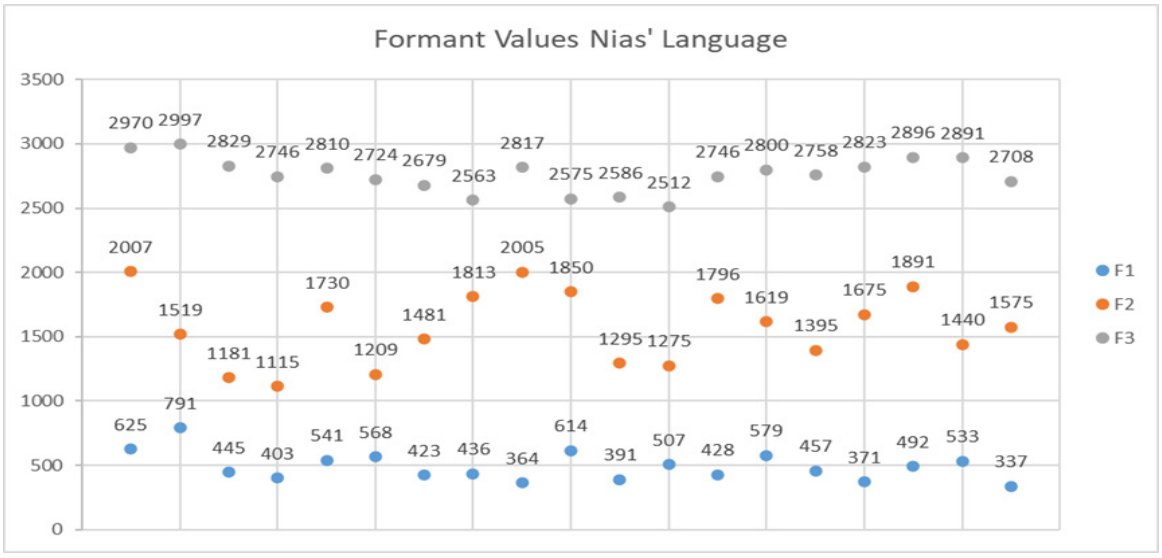

Figure 2. Formant Values Chart of the Nias Language

Value (Hz)	Yaahowu				Yaodo			Nadia			moroi			ba	Gunusitoli				
	/a/	/a/	/o/	/u/	/a/	/o/	/o/	/a/	/i/	/a/	/o/	/o/	/i/	/a/	/u/	/u/	/i/	/o/	/i/
F1	625	791	445	403	541	568	423	436	364	614	391	507	428	579	457	371	492	533	337
F2	2007	1519	1181	1115	1730	1209	1481	1813	2005	1850	1295	1275	1796	1619	1395	1675	1891	1440	1575
F3	2970	2997	2829	2746	2810	2724	2679	2563	2817	2575	2586	2512	2746	2800	2758	2823	2896	2891	2708

Table 1. Formant Values of the Nias Language

Based on Table 1, the highest F1 formant value is observed in the vowel /a/ of the word *Yaahowu* (791 Hz), while the lowest F1 value occurs in the vowel /i/ of the word *Sitoli* (337 Hz). For F2, the highest value is also found in the vowel /a/ of *Yaahowu* (2007 Hz), whereas the lowest value appears in the vowel /u/ of the same word (1115 Hz). Similarly, the highest F3 formant is recorded in the vowel /a/ of *Yaahowu* (2997 Hz), while the lowest F3 value is found in the vowel /o/ of the word *moroi* (2512 Hz).

These findings suggest that all the highest formant values (F1, F2, and F3) are concentrated in the vowel /a/ of *Yaahowu*, indicating the dominance of open vowels with maximum resonance. In contrast, the lowest formant values are distributed across different vowels F1 in /i/ (*Sitoli*), F2 in /u/ (*Yaahowu*), and F3 in /o/ (*moroi*). This pattern reflects the distinctive acoustic distribution in the Nias language, where the vowel /a/ consistently generates higher frequencies compared to other vowels.

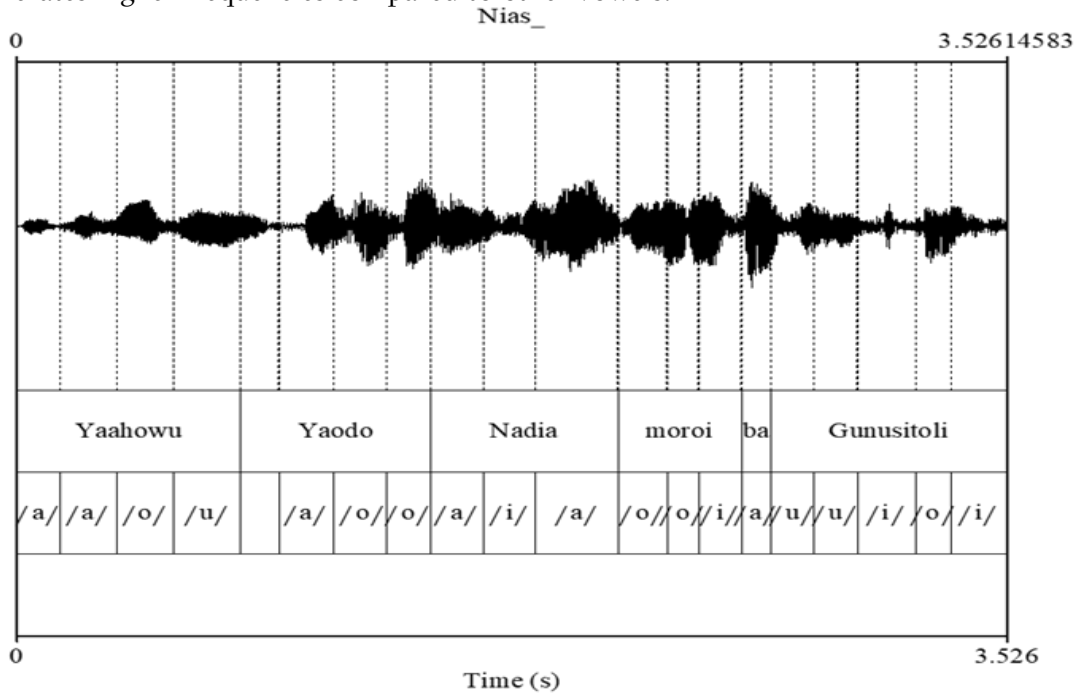

Figure 3. Visualisation of the Nias language spectrogram with Praat

Based on Figure 3, the vowel spectrum distribution in the Nias language reveals a pattern in which the open vowel /a/ occupies a dominant position, consistently exhibiting higher resonance values than the vowels /i/, /u/, and /o/.

Ambon Language

The analysis of the Ambonese language, using data obtained from native speaker samples. The objective was to examine variations in vowel formant values (F1, F2, and F3) and to describe their acoustic distribution across words representing everyday speech, as illustrated in Figure 4.

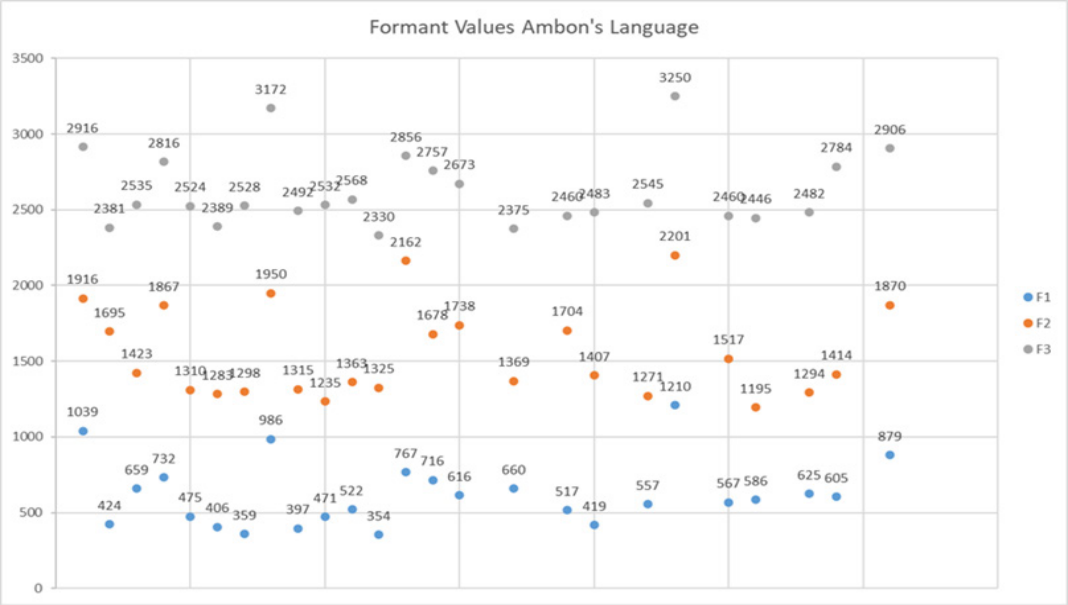

Figure 4. Formant Values Chart of the Ambon Language

Value (Hz)	Tabea			Ya	Manam		Nolsano			Latupeirissa					Ya	Anai		Nalak		Sia		Kota		Ambon	
	/a/	/e/	/a/	/a/	/a/	/a/	/o/	/a/	/o/	/a/	/u/	/e/	/i/	/a/	/a/	/a/	/æ/	/a/	/a/	/i/	/a/	/o/	/a/	/a/	/o/
F1	1039	424	659	732	475	406	359	986	397	471	522	354	767	716	616	660	517	419	557	1210	567	586	625	605	879
F2	1916	1695	1423	1867	1310	1283	1298	1950	1315	1235	1363	1325	2162	1678	1738	1369	1704	1407	1271	2201	1517	1195	1294	1414	1870
F3	2916	2381	2535	2816	2524	2389	2528	3172	2492	2532	2568	2330	2856	2757	2673	2375	2460	2483	2545	3250	2460	2446	2482	2784	2906

Table 2. Formant Values of the Ambon Language

Based on the data presented in Table 2, a total of 25 vowel tokens were obtained from 11 words in the Ambonese language. The analysed speech samples were taken from the sentence: *"Tabea, Ya manam Nolsano Latupeirissa, ya anai nalak sia kota Ambon,"* which translates as *"Tabea, I am Nolsano Latupeirissa, I come from the city of Ambon."*

The acoustic analysis revealed notable variation in vowel formant values. For F1, the highest value was found in the vowel /i/ in *Sia* (1210 Hz), while the lowest was observed in the vowel /o/ in *Nolsano* (397 Hz). For F2, the highest value also occurred in /i/ in *Sia* (2201 Hz), whereas the lowest appeared in /o/ in *Kota* (1195 Hz). For F3, the highest value again came from /i/ in *Sia* (3250 Hz), while the lowest was recorded for /e/ in *Latupeirissa* (2330 Hz).

These findings indicate that the vowel /i/ in *Sia* consistently produces the highest formant values across all three levels (F1, F2, F3), reflecting strong resonance intensity typical of high front vowels. By contrast, the vowel /o/ in *Nolsano* and *Kota* tends to yield the lowest formant values, particularly in F1 and F2, which confirms the acoustic properties of back rounded vowels.

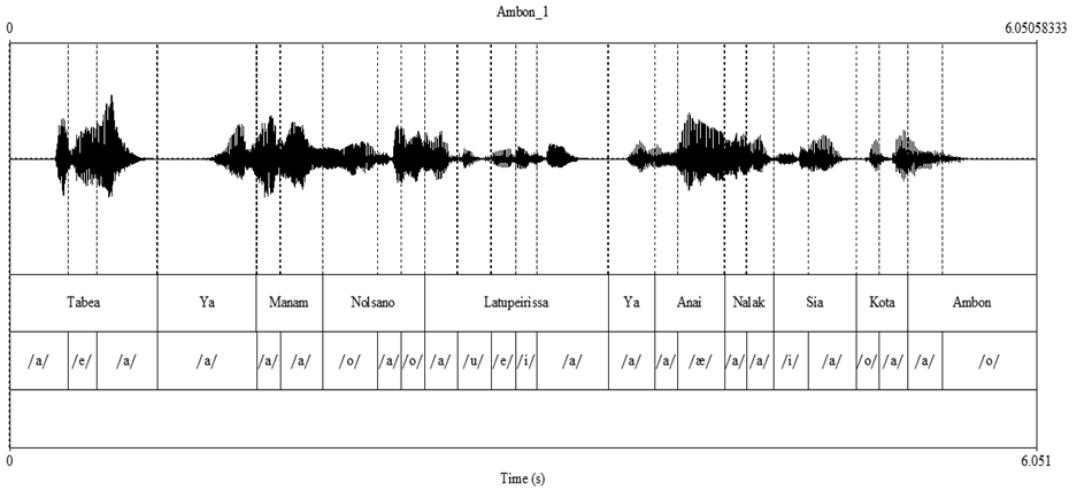

Figure 5. Praat Picture of Ambon Language

Based on Figure 5, it can be observed that the 25 vowels obtained consist of: 16 /a/ vowels, 2 /e/ vowels, 4 /o/ vowels, 1 /u/ vowel, and 2 /i/ vowels. This distribution shows the dominance of the /a/ vowel in the Ambon language utterances in the sample studied.

All of the highest formant values (F1, F2, F3) come from the same word, namely *Sia (/i/)*, while the lowest formant values in each category come from different words: *Nolsano (/o/)* for F1, *Kota (/o/)* for F2, and *Latupeirissa (/e/)* for F3. This pattern confirms the diversity of vowel distribution in the Ambon language while also revealing acoustic characteristics that can form the basis for further phonetic documentation.

Bugis Language

The Buginese language, one of the major regional languages of South Sulawesi, presents a vowel system that is particularly compelling for acoustic investigation. In this study, the analysis concentrated on identifying the formant values of vowels (F1, F2, and F3) produced by native Buginese speakers.

The processed acoustic data were subsequently visualised through graphs and tables. Figure 6 illustrates the distribution of vowel formant values in Buginese, while the accompanying table provides detailed quantitative measurements of F1, F2, and F3 for each vowel examined.

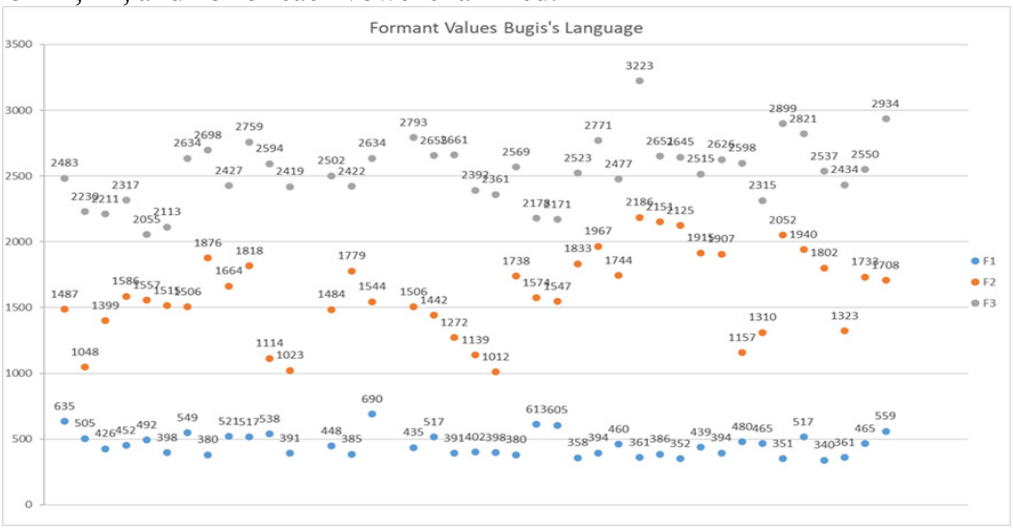

Figure 6. Chart of Formant Values of the Bugis Language

Table 3. Formant Values of the Bugis Language

Value (Hz)	Halo		aga		kareba			ia		asekku			Muhajir			silo'silong				ulle molli ka'			
	/a/	/o/	/a/	/a/	/a/	/e/	/a/	/i/	/a/	/e/	/u/	/u/	/a/	/i/	/e/	/o/	/o/	/u/	/e/	/o/	/i/	/a/
F1	635	505	426	452	492	398	549	380	521	517	538	391	448	385	690	435	517	391	402	398	380	613
F2	1487	1048	1399	1586	1557	1515	1506	1876	1664	1818	1114	1023	1484	1779	1544	1506	1442	1272	1139	1012	1738	1574
F3	2483	2230	2211	2317	2055	2113	2634	2698	2427	2759	2594	2419	2502	2422	2634	2793	2655	2661	2392	2361	2569	2178

Value (Hz)	Hajir				ia' ini ia' ie					pole ri			ugi'/mangkasa'				
	/a/	/i/	/i/	/a/	/i/	/i/	/i/	/a/	/e/	/o/	/e/	/i/	/u/	/i/	/a/	/a/	/a/
F1	605	358	394	460	361	386	352	439	394	480	465	351	517	340	361	465	559
F2	1547	1833	1967	1744	2186	2151	2125	1915	1907	1157	1310	2052	1940	1802	1323	1733	1708
F3	2171	2523	2771	2477	3223	2651	2645	2515	2626	2598	2315	2899	2821	2537	2434	2550	2934

Based on the data presented in Table 3, a total of thirty-nine vowel tokens were obtained from twelve words in the Buginese language. The analysed speech sample was taken from the sentence: *"Hello, aga kareba ia' asekku' Muhajir, silo'silong ulle molli ka' Hajir, ia' ie pole ri Ugi'/Mangkasa,"* which translates as *"Hello, I am Muhajir, you can call me Hajir, I am from Bugis, Makassar."*

The analysis results indicate that the highest F1 formant value was found in the vowel /a/ in *Halo* (635 Hz), while the lowest F1 value was observed in the vowel /i/ in *Ugi'/Mangkasa* (340 Hz). For F2, the highest value was recorded for the vowel /i/ in *ia' ini ia' ie* (2186 Hz), whereas the lowest was obtained from the vowel /o/ in *ulle molli ka'* (1012 Hz). For F3, the highest value also came from the vowel /i/ in *ia' ini ia' ie* (3223 Hz), while the lowest value was identified in the vowel /a/ in *Hajir* (2171 Hz). These findings demonstrate that the vowel /i/ in *ia' ini ia' ie* consistently yields the highest formant values for both F2 and F3, reflecting the strong resonance typically associated with high front vowels. Conversely, the vowel /a/ in *Hajir* and the vowel /o/ in *ulle molli ka'* exhibit the lowest formant values, confirming the acoustic properties of low central and back rounded vowels, respectively. The overall distribution pattern is presented in Figure 7, generated with Praat.

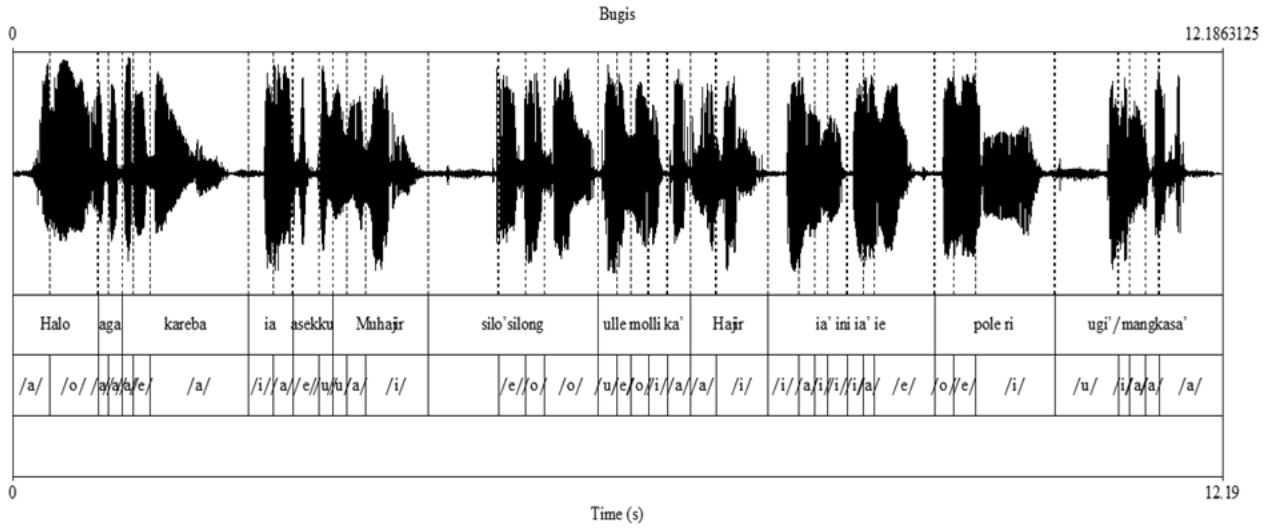

Figure 7. Praat Picture of Bugis Language

Based on Figure 7, the thirty-nine vowels obtained from the twelve words consist of fourteen instances of /a/, six of /e/, five of /o/, four of /u/, and ten of /i/. The distribution of formant values indicates that the highest F1 occurs in the vowel /a/ in *Halo*, while the highest F2 and F3 are both produced by the vowel /i/ in *ia' ini ia' ie*. Conversely, the lowest formant values are distributed across different vowels: F1 in /i/ in *Ugi'/Mangkasa*, F2 in /o/ in *ulle molli ka'*, and F3 in /a/ in *Hajir*. These findings highlight distinctive acoustic variation in Buginese vowels, with the vowel /i/ emerging as dominant in producing the highest formant frequencies, whereas /o/ and /a/ tend to occupy the lowest formant positions.

Serui Papua Language

The acoustic analysis of the Serui Papua language provides valuable insights into the distribution of vowel formant values among native speakers. The research data were obtained from an utterance consisting of seven words with a total of twenty vowels: *"Mamanengko, narindamu Yanes koyari ja aide tunuge,"* which translates into English as *"My name is Yanes, I am a man from Onate."* This sample was selected because it contains representations of the basic vowels that are essential for phonetic–acoustic analysis.

Figure 8 illustrates the distribution of vowel formant values in Serui Papua, while Table 4 presents the

corresponding numerical data for F1, F2, and F3 frequencies of each vowel analysed.

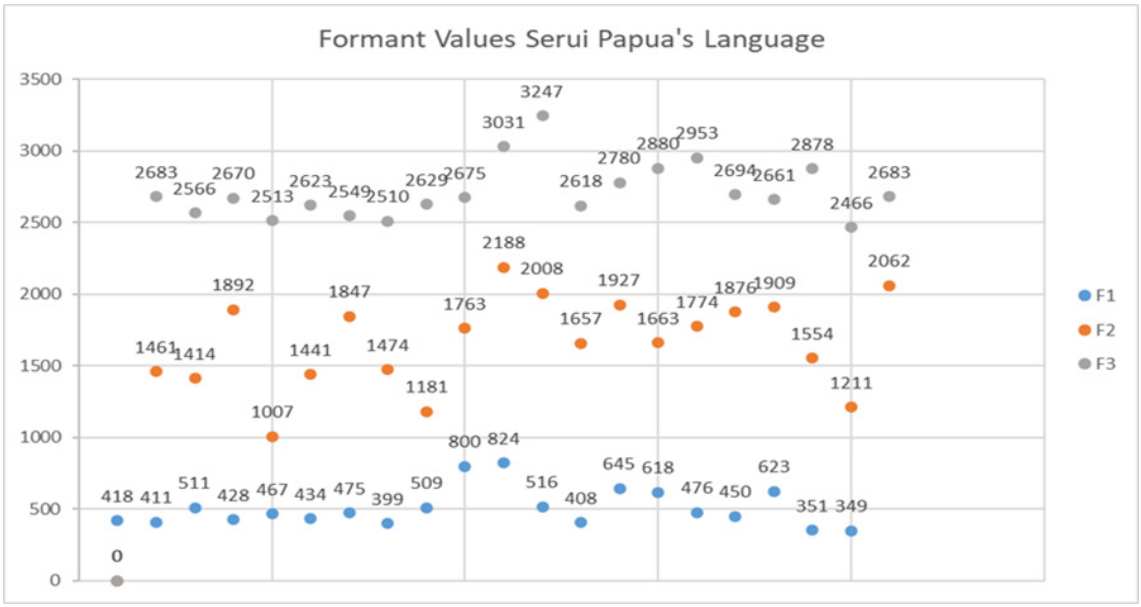

Figure 8. Chart of Formant Values of the Serui Papua Language

Table 4. Formant Values of Serui Papua Language

Value	Mamanengko				narindamu				Yanes			koyari			ja		aide		tunuge		
(Hz)	/a/	/a/	/e/	/o/	/a/	/i/	/a/	/u/	/a/	/e/	/o/	/a/	/i/	/a/	/a/	/i/	/e/	/u/	/u/	/e/
F1	418	411	511	428	467	434	475	399	509	800	824	516	408	645	618	476	450	623	351	349
F2	1461	1414	1892	1007	1441	1847	1474	1181	1763	2188	2008	1657	1927	1663	1774	1876	1909	1554	1211	2062
F3	2683	2566	2670	2513	2623	2549	2510	2629	2675	3031	3247	2618	2780	2880	2953	2694	2661	2878	2466	2683

Based on the data presented in Table 4, the highest first formant (F1) value was observed in the vowel /o/ in *koyari* at 824 Hz, while the lowest F1 was found in the vowel /e/ in *tunuge* at 349 Hz. For the second formant (F2), the highest value occurred in the vowel /e/ in *Yanes* at 2188 Hz, whereas the lowest was produced by the vowel /o/ in *Mamanengko* at 1007 Hz. Regarding the third formant (F3), the highest value was again associated with the vowel /o/ in *koyari* at 3247 Hz, while the lowest was recorded in the vowel /u* in *tunuge* at 2466 Hz. To complement these quantitative findings, the acoustic measurements are visualised in Figure 9, which presents a spectrogram image generated using the Praat application.

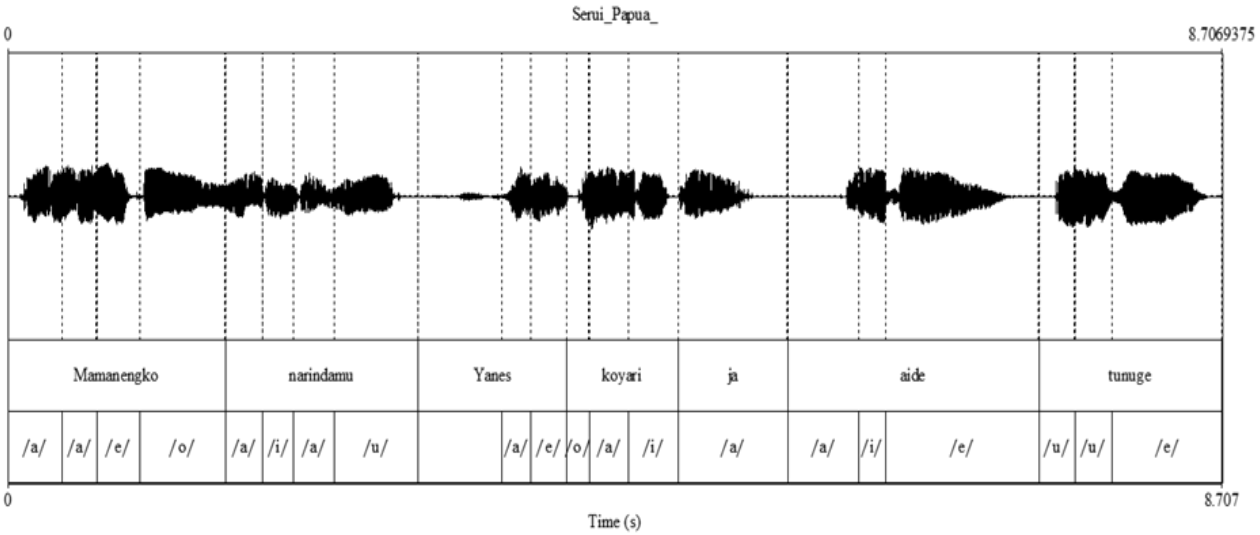

Figure 9. Praat picture of Serui Papua Language

Based on Figure 9, the twenty vowels obtained from the sample consist of eight /a/ vowels, four /e/ vowels, two /o/ vowels, three /u/ vowels, and three /i/ vowels. This distribution indicates a tendency for the open vowel /a/ to dominate in Serui Papuan speech. The highest F1 and F3 values were observed in the vowel /o/ in *koyari*, while

the highest F2 value appeared in the vowel /e/ in *Yanes*. Conversely, the lowest F1, F2, and F3 values were found in the vowel /e/ in *tunuge*, the vowel /o/ in *Mamanengko*, and again the vowel /e/ in *tunuge*, respectively. These results highlight the significant acoustic variation of the vowels /o/ and /e/ in Serui Papuan, particularly across F1, F2, and F3 values. Overall, the findings provide valuable insights into the vowel characteristics of Serui Papuan and contribute to the broader phonetic-acoustic database of Indonesian regional languages.

Sunda Language

An acoustic analysis of the Sundanese language was carried out to examine the characteristics of vowel formants based on the speech of native speakers. The research sample consisted of ten words containing twenty-three vowels: *"Wilujeng enjing, nepangkeun nami abdi Iman, abdi ti Bandung haturnuhun,"* which translates into English as *"Good morning, my name is Iman, I am from Bandung, thank you."* This sample was selected because it provides a representative distribution of vowels within the phonological structure of Sundanese.

Figure 10 presents the distribution of Sundanese vowel formant values in chart form, while Table 5 provides the numerical details of the F1, F2, and F3 frequencies for each analysed vowel.

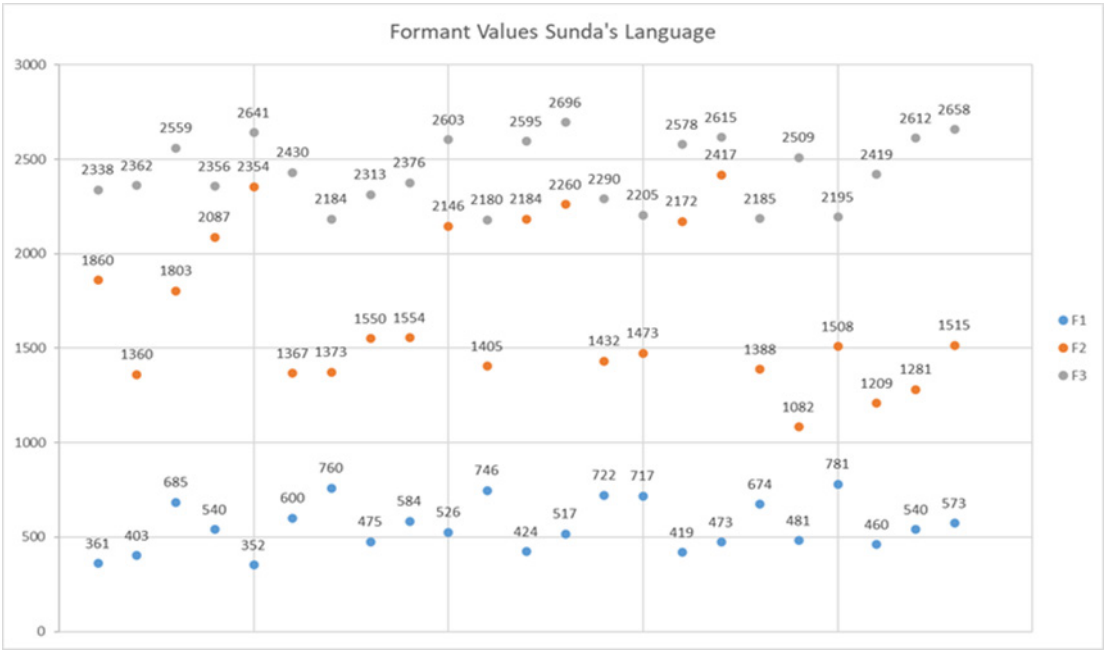

Figure 10. Chart of Formant Values of the Sundanese Language

Table 5. Formant Values of the Sundanese Language

Value (Hz)	Wilujeng			enjing		nepangkeun			nami		abdi	
	/i/	/u/	/e/	/e/	/i/	/e/	/a/	/e/	/a/	/i/	/a/	/i/
F1	361	403	685	540	352	600	760	475	584	526	746	424
F2	1860	1360	1803	2087	2354	1367	1373	1550	1554	2146	1405	2184
F3	2338	2362	2559	2356	2641	2430	2184	2313	2376	2603	2180	2595

Value (Hz)	Iman		abdi		ti	Bandung		haturnuhun			
	/i/	/a/	/a/	/i/	/i/	/a/	/u/	/a/	/u/	/u/	/u/
F1	517	722	717	419	473	674	481	781	460	540	573
F2	2260	1432	1473	2172	2417	1388	1082	1508	1209	1281	1515
F3	2696	2290	2205	2578	2615	2185	2509	2195	2419	2612	2658

Based on Table 5, the highest first formant (F1) value was found in the word *haturnuhun* with the vowel /a/ at 781 Hz, while the lowest F1 value was found in the word *Wilujeng* with the vowel /i/ at 361 Hz. For the second formant (F2), the highest value appeared in the word *ti* with the vowel /i/ at a frequency of 2417 Hz, while the lowest value was obtained from the word *Bandung* with the vowel /u/ at 1082 Hz. As for the third formant (F3), the highest value was found in the word *Iman* with the vowel /i/ at a frequency of 2696 Hz, while the lowest value was found in the word *abdi* with the vowel /a/ at 2180 Hz.

To support these quantitative findings, the results of the acoustic analysis are visualised in Figure 5 in the form of a spectrogram image generated using Praat software.

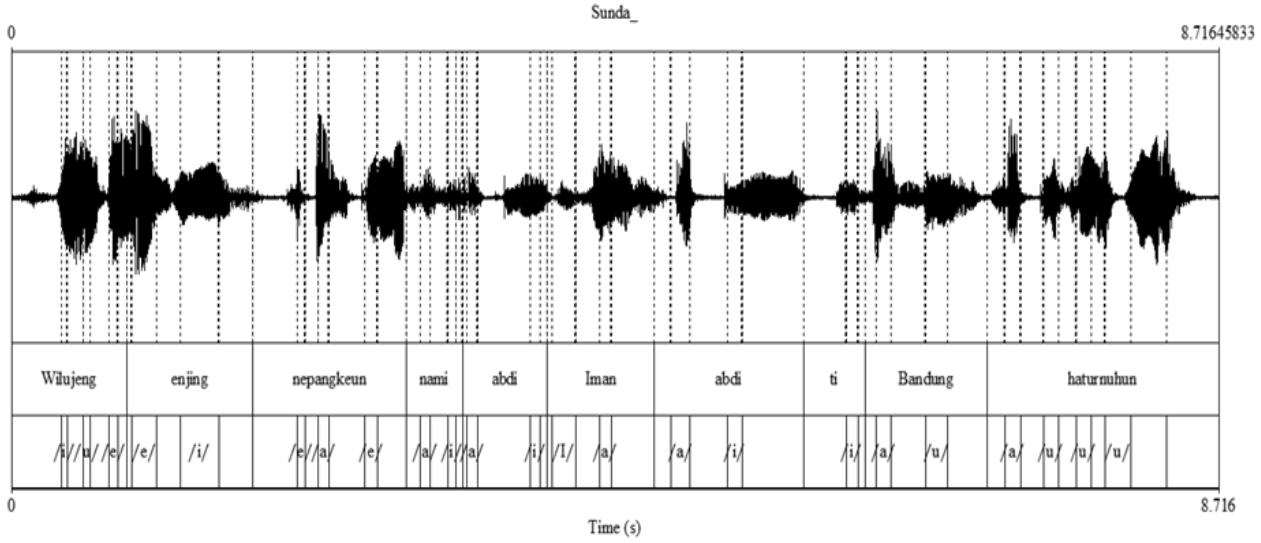

Figure 11. Praat picture of the Sundanese language

Based on Table 5, the highest first formant (F1) value was observed in the word *haturnuhun* with the vowel /a/ at 781 Hz, whereas the lowest F1 value occurred in the word *Wilujeng* with the vowel /i/ at 361 Hz. Regarding the second formant (F2), the highest value was recorded in the word *ti* with the vowel /i/ at 2417 Hz, while the lowest F2 value appeared in the word *Bandung* with the vowel /u/ at 1082 Hz. For the third formant (F3), the highest frequency was identified in the word *Iman* with the vowel /i/ at 2696 Hz, whereas the lowest F3 value was found in the word *abdi* with the vowel /a/ at 2180 Hz. To complement these quantitative findings, the results of the acoustic analysis are illustrated in Figure 5 through a spectrogram generated using *Praat* software.

Formant Comparison of Indonesian Local Languages

A comparative analysis was carried out to examine the vowel formant values across several regional languages in Indonesia. The purpose of this analysis was to identify differences in their acoustic characteristics and to determine the dominance patterns of specific formants that reflect the phonetic uniqueness of each language. The results of this comparison are systematically presented in Table 6, Table 7, and Table 8.

Table 6. The Highest Formant Values of Indonesian Local Languages

Value (Hz)	Formant Values			
	Highest	Words	Local Language	Vowels
F1	1210	Sia	Ambon	/i/
F2	2417	ti	Sunda	/i/
F3	3250	Sia	Ambon	/i/

Table 7. The Lowest Formant Values of Indonesian Local Languages

Value (Hz)	Formant Values			
	Lowest	Words	Local Language	Vowels
F1	337	GunungSitoli	Nias	/i/
F2	1007	Mamanengko	Papua	/o/
F3	2171	Hajir	Bugis	/a/

Table 8. Formant Values Comparison of Indonesian Local Languages

Value (Hz)	Nias		Ambon		Bugis		Papua		Sunda	
	High	Low	High	Low	High	Low	High	Low	High	Low
F1	791	337	1210	397	635	340	824	349	781	361
F2	2007	1115	2201	1195	2186	1012	2188	1007	2417	1082
F3	2997	2512	3250	2330	3223	2171	3247	2466	2696	2180

Based on the analysis using Praat software, notable cross-linguistic variations were observed. In the first formant (F1), the highest value was identified in the Ambon language, specifically in the word *Sia* with the vowel /i/ at a frequency of 1210 Hz, while the lowest F1 value occurred in the Nias language, in the word *Gunungsitoli* with the vowel /i/ at 337 Hz. For the second formant (F2), the highest value was recorded in the Sundanese language, in the word *ti* with the vowel /i/ at 2417 Hz, whereas the lowest F2 value was found in the Serui Papua language, in the word *Mamanengko* with the vowel /o/ at 1007 Hz. Regarding the third formant (F3), the Ambon language again showed the highest value, in the word *Sia* with the vowel /i/ at 3250 Hz, while the lowest F3 value was identified in the Bugis language, in the word *Hajir* with the vowel /a/ at 2171 Hz.

Overall, these comparative results demonstrate that the high vowel /i/ consistently produces the highest formant values across F1, F2, and F3, particularly in Ambonese and Sundanese. Conversely, the low vowel /a/ and the back vowel /o/ exhibit relatively lower formant values, especially in Bugis, Nias, and Serui Papua. These findings highlight the presence of phonetic-acoustic variations that underscore the uniqueness of regional languages in Indonesia and contribute to a broader mapping of the acoustic phonology of the archipelago.

Discussion

The findings of this study demonstrate that the acoustic characteristics of vowels in several regional languages of Indonesia reveal both universal phonetic tendencies and language-specific variations. The analysis of the first three formants (F1, F2, and F3) highlights how vowel quality is shaped by articulatory configuration, while also showing distinctive acoustic profiles across languages. These results align with previous research that views formant frequencies as reliable indicators of vowel articulation and cross-linguistic comparison (Ladefoged & Johnson, 2015; Johnson, 2012). The comparative findings emphasize the dominant role of the high vowel /i/ in producing the highest formant frequencies across F1, F2, and F3, particularly in Ambonese and Sundanese. Conversely, the low vowel /a/ and the back vowel /o/ consistently yielded lower formant values, especially in Bugis, Nias, and Serui Papua. This pattern reflects both universal tendencies in vowel acoustics and language-specific phonetic realizations. The results also provide empirical evidence that supports the mapping of vowel systems in Indonesian regional languages, contributing to broader phonetic-acoustic studies in Austronesian linguistics.

Each regional language demonstrates its own distinctive acoustic profile, reflecting unique articulatory configurations and phonological systems. Ambonese, for instance, displays the highest F1 and F3 values, while Sundanese shows the highest F2 values. By contrast, Nias presents the lowest F1 value, Serui Papua the lowest F2 value, and Bugis the lowest F3 value. This pattern indicates that vowel production across languages is not uniform but shaped by specific articulatory tendencies. The extreme values associated with particular vowels, such as the vowel /i/ in Ambonese and Sundanese, confirm the established phonetic principle that high front vowels typically yield high F2 values, while low or back vowels such as /a/ and /o/ more frequently produce higher F1 and lower F2 values (Ladefoged, 2006).

One of the key contributions of this study lies in documenting systematic differences across Indonesian regional languages. The findings highlight that vowel systems are not acoustically homogeneous but are strongly influenced by physiological and sociolinguistic factors. For example, the tendency of Ambonese vowels to produce high F1 and F3 values suggests a preference for more open and resonant vowel articulation. In contrast, the higher F2 values in Sundanese reflect a preference for more fronted vowel articulation. These observations align with phonetic theories that stress the interaction between articulatory mechanisms and acoustic outcomes (Erickson et al., 2017; Goldstein, 2019; Lee et al., 2018). The role of vocal tract length and shape is particularly important, as these factors directly affect resonance. Languages that produce more front vowels often yield higher F2 values because the posterior resonance cavity shortens. By contrast, languages such as Ambonese, which favour more back or open vowels, demonstrate higher F1 or F3 values due to increased resonance within the oral cavity.

The acoustic variations identified in this study are also consistent with findings from earlier cross-linguistic research. Korkmaz and Boyacı (2018) and Korkmaz and Boyacı (2018; Kemaloğlu et al., 2020) report that vowel formants in Turkish are influenced by their consonantal environment, underscoring the importance of phonetic context in shaping acoustic properties. Similar results have been observed in studies of English vowels produced by Indonesian speakers, where deviations from native-speaker formant patterns suggest the

transfer of articulatory habits from the first language into second-language production (Subandowo et al., 2020; Zen, 2020; Masykar et al., 2023; Redford & Oh, 2017). Studies on other Austronesian languages have also confirmed that each regional language in Indonesia maintains a unique phonetic identity (Choesin & Bella, 2019; Sakhiyya & Martin-Anatias, 2020; Smith, 2017). These studies collectively suggest that acoustic distinctions are not merely physiological but also shaped by cultural and social contexts that influence the phonological structure of each language.

The findings of this research have several implications for both academic and applied domains. From a documentation perspective, acoustic descriptions based on formant analysis can serve as valuable references for language revitalisation efforts. Many regional languages in Indonesia are at risk of extinction due to the decreasing number of younger speakers (Ministry of Education and Culture, 2022). Detailed acoustic documentation ensures that the phonetic characteristics of these languages are preserved for future generations, providing an authentic reference in language learning. From an educational perspective, the results can inform the development of phonetic and phonological teaching materials in both formal and non-formal contexts. Regional language instruction often prioritises vocabulary and grammar, while phonetics receives comparatively little attention (Couper, 2016; Chapuis & Berthele, 2024; Tench, 2017). Yet accurate sound production is essential for preserving language authenticity (Aryani et al., 2018; Hay, 2018; Nance & Moran, 2022). With systematically documented formant data, language educators and phonetic trainers can integrate these findings into teaching practices. Furthermore, in the field of speech technology, the acoustic data generated in this study can contribute to the development of speech recognition and synthesis systems for minority languages. Artificial intelligence systems require accurate acoustic databases in order to process and reproduce language sounds effectively. Thus, the significance of this research extends beyond theoretical contributions to practical applications in inclusive linguistic technology.

At the theoretical level, this study adds to our understanding of acoustic phonetics by demonstrating that Indonesian regional languages differ not only in segmental aspects but also in the systematic distribution of their acoustic patterns. This supports the view that each language develops its own "acoustic mapping," which becomes a fundamental part of its linguistic identity. The distribution of F1, F2, and F3 values shows that while universal principles linking articulation and acoustics do hold (Ladefoged, 2006; Ladefoged & Johnson, 2011), the realisation of these principles is shaped by local linguistic and cultural contexts. This supports the broader argument that universal phonetic tendencies are always mediated by specific phonological traditions (Boersma, 2011; Nakajima et al., 2017; Mann et al., 2021; Chodroff, 2024).

Although this study primarily emphasises cross-linguistic variation, it is important to note that formant values are also influenced by individual speaker characteristics. Gender, age, vocal tract length, and speaking style are known to affect vowel acoustics (Fitch, 1994). Some of the variation observed here may therefore reflect physiological differences rather than language-specific phonological patterns. However, the inclusion of multiple languages in this study helps to reduce the impact of individual bias. The consistent identification of systematic patterns, such as the dominance of the vowel /i/ at high F2 values and the vowel /a/ at high F1 values, supports the conclusion that the observed variation is more systematic than individual in nature.

In summary, this study demonstrates that Indonesia's regional languages display significant variation in vocal formant values, reflecting the diversity of their phonological and articulatory systems. Ambonese shows the highest F1 and F3 values, Sundanese shows the highest F2 values, while Nias, Serui Papua, and Bugis record the lowest values for F1, F2, and F3 respectively. These findings are consistent with universal theories of acoustic phonetics, while also highlighting the distinctive phonetic identities of each language. The results enrich the academic literature in acoustic phonetics and have direct relevance for language education, speech technology, and the preservation of regional languages. Consequently, this study provides a dual contribution: it advances theoretical understanding of cross-linguistic vowel systems and offers empirical evidence that supports the revitalisation of Indonesia's linguistic heritage.

Conclusion

Based on the analysis, this study successfully identified variations in vowel formant values (F1, F2, and F3) across five Indonesian regional languages: Nias, Ambonese, Bugis, Serui Papua, and Sundanese, using PRAAT analysis. The results indicate that Ambonese produced the highest F1 and F3 values, while Sundanese recorded

the highest F2 value. Conversely, the lowest values were observed in Nias for F1, Serui Papua for F2, and Bugis for F3. These findings are consistent with acoustic phonetic theory, which states that vowel quality is largely determined by formant frequency variation, where high front vowels such as /i/ typically yield high F2 values, while low or back vowels such as /a/ and /o/ are more closely associated with high F1 values. This study therefore achieved its main objective: to map the acoustic variation of vowels across regional languages and to confirm the existence of distinctive phonetic diversity in each system. Theoretically, the findings broaden our understanding of vowel acoustics and their contribution to cross-linguistic phonetic research. Practically, they provide useful insights for language preservation, phonetics education, speech recognition systems, and technology development for local languages. The originality of this research lies in its systematic effort to document and compare formant values in Indonesian regional languages, which remain underexplored, thereby offering a new empirical foundation for both comparative phonetics and language revitalization programs. Nevertheless, this study has certain limitations. The number of speakers was relatively small, and the analysis was limited to greetings and introductory expressions. In addition, individual speaker variation may have influenced the results. For future research, it is recommended to involve a larger number of speakers, incorporate more complex linguistic materials, and integrate articulatory analysis to provide a deeper understanding of the phonetic dynamics of Indonesian regional languages.

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Conflicts of Interest
The author declares that there are no conflicts of interest, either financial or non-financial, that could influence the conduct of the research, interpretation of data, or writing of this article. The entire research process and manuscript preparation were carried out independently, without any external influence that could cause bias in the results or conclusions of the research.

References

Aalto, D., Malinen, J., & Vainio, M. (2018). Formants. *Oxford Research Encyclopedia of Linguistics*. https://doi.org/10.1093/acrefore/9780199384655.013.419

Abalkheel, A. M. (2025). Shifts in Qassimi Arabic: A linguistic analysis of lexical and phonological changes between two generations. *Journal of Language Teaching and Research*, *16*(4), 1415–1424. https://doi.org/10.17507/jltr.1604.34

Alhammad, R. (2023). The phonology, morphology, and syntax of Sundanese. *Forum for Linguistic Studies*, *5*(3), 1945. https://doi.org/10.59400/fls.v6i1.1945

Ali, I. E., Sumita, Y., & Wakabayashi, N. (2023). Comparison of Praat and Computerized Speech Lab for formant analysis of five Japanese vowels in maxillectomy patients. *Frontiers in Neuroscience*, *17*. https://doi.org/10.3389/fnins.2023.1098197

Annamalai, R., Kalathinathan, A., & Vally, M. (2022). Pratt Software's phonological characteristics, prosodic features, and importance. *Journal of Reproducible Research*, *1*(1), 1–7. https://doi.org/10.58288/jrr.v1i1.4

Aryani, A., Conrad, M., Schmidtke, D., & Jacobs, A. (2018). Why "piss" is ruder than "pee"? The role of sound in affective meaning making. *PLoS ONE*, *13*(6), e0198430. https://doi.org/10.1371/journal.pone.0198430

Bangga, L. A., & Doran, Y. J. (2021). A systemic functional sketch of material clauses in Sundanese. *WORD*, *67*(2), 208–233. https://doi.org/10.1080/00437956.2021.1909840

Bašić, I., & Varošanec-Škarić, G. (2023). The normalization of vowel formants – a case study of Croatian and Serbian. *Fluminensia*, *35*(1), 61–81. https://doi.org/10.31820/f.35.1.6

Bissoonauth, A. (2019). Language and attitude shift of young Mauritians in secondary education. *Journal of Multilingual and Multicultural Development*, *42*(1), 64–78. https://doi.org/10.1080/01434632.2019.1677675

Boboqulovna, K. M. (2025). The linguistic levels: classification, characteristics, and interrelationships. *International Journal of Literature and Languages*, *5*(4), 26–30. https://doi.org/10.37547/ijll/volume05issue04-08

Boersma, P. (2011). Praat : doing phonetics by computer [Computer program]. *Phonetic Sciences, University of Amsterdam*. https://ci.nii.ac.jp/naid/20001461274

Bořil, T., & Skarnitzl, R. (2016). Tools RPraAt and MPraAT. In *Lecture notes in computer science* (pp. 367–374). https://doi.org/10.1007/978-3-319-45510-5_42

Caumo, D. T. M., França, M. P., & Da Silva, C. H. (2023). Phonetic transcription of spontaneous children's speech with the aid of software: a systematic review. *ABRALIN*. https://doi.org/10.25189/rabralin.v21i1.2057

Cavalcanti, J. C., Eriksson, A., & Barbosa, P. A. (2021). Acoustic analysis of vowel formant frequencies in genetically-related and non-genetically related speakers with implications for forensic speaker comparison. *PLoS ONE*, *16*(2), e0246645. https://doi.org/10.1371/journal.pone.0246645

Chan, K. Y., Hall, M. D., & Assgari, A. A. (2016). The role of vowel formant frequencies and duration in the perception of foreign accent. *Journal of Cognitive Psychology*, *29*(1), 23–34. https://doi.org/10.1080/20445911.2016.1170746

Chapuis, N. D., & Berthele, R. (2024). Teaching methods emphasizing phonological forms enhance L2 vocabulary learning. *Language Teaching Research*. https://doi.org/10.1177/13621688241270803

Chodroff, E. (2024). Phonetic Universals. *Annual Review of Linguistics*. https://doi.org/10.1146/annurev-linguistics-011724-121511

Choesin, E. M., & Bella, D. R. (2019). Pointing Gestures and Verbal Acts: Linguistic Boundaries by Puor and Lamalera people in a barter market, East Nusa Tenggara, Indonesia. *Journal of Asian Linguistic Anthropology*, *1*(4), 13–24. https://doi.org/10.47298/jala.v1-i4-a2

Conklin, J. T., Dmitrieva, O., Jung, Y., & Zhai, W. (2020). Acoustic characteristics of vowel reduction in advanced Spanish-English bilinguals. *The Journal of the Acoustical Society of America*, *148*(4_Supplement), 2656–2657. https://doi.org/10.1121/1.5147397

Couper, G. (2016). Teacher Cognition of Pronunciation Teaching: Teachers' Concerns and issues. *TESOL Quarterly*, *51*(4), 820–843. https://doi.org/10.1002/tesq.354

Demir, N. (2020). Vowel harmony in Trabzon Turkish. *Proceedings of the Workshop on Turkic and Languages*

in Contact With Turkic, *5*(1), 56. https://doi.org/10.3765/ptu.v5i1.4772

Durvasula, K., Ruthan, M. Q., Heidenreich, S., & Lin, Y. (2021). Probing syllable structure through acoustic measurements: case studies on American English and Jazani Arabic. *Phonology*, *38*(2), 173–202. https://doi.org/10.1017/s0952675721000142

Erickson, D., Honda, K., & Kawahara, S. (2017). Interaction of jaw displacement and F0 peak in syllables produced with contrastive emphasis. *Nippon Onkyo Gakkaishi/Acoustical Science and Technology/Nihon Onkyo Gakkaishi*, *38*(3), 137–146. https://doi.org/10.1250/ast.38.137

Ferrat, K., & Guerti, M. (2017). An experimental study of the gemination in Arabic language. *Archives of Acoustics*, *42*(4), 571–578. https://doi.org/10.1515/aoa-2017-0061

Fitch, W. T. S. (1994). *Vocal tract length perception and the evolution of language* (Doctoral dissertation, Brown University, Department of Cognitive and Linguistic Sciences).

Genidze, N. K. (2020). Vocalic ratio as one of the most important criteria of phonetic classification of world languages. *Discourse*, *6*(5), 87–96. https://doi.org/10.32603/2412-8562-2020-6-5-87-96

Goldstein, L. (2019). The role of temporal modulation in sensorimotor interaction. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02608

Guo, L. (2025). An Empirical study on English Phonetic teaching reform based on praat Phonetic software. *International Journal of Cognitive Informatics and Natural Intelligence*, *19*(1), 1–16. https://doi.org/10.4018/ijcini.368243

Hauser, I. (2021). Contrast implementation affects phonetic variability: A case study of Hindi and English stops. *Laboratory Phonology Journal of the Association for Laboratory Phonology*, *12*(1). https://doi.org/10.16995/labphon.6465

Hay, J. (2018). Sociophonetics: the role of words, the role of context, and the role of words in context. *Topics in Cognitive Science*, *10*(4), 696–706. https://doi.org/10.1111/tops.12326

Kaharuddin, Rahman, F., Abbas, A., Hasjim, M., & Supratman. (2024). Sound Correspondence in Buginese and Makassarese: A Comparative Linguistics. *International Journal of Religion*, *5*(10), 1635–1644. https://doi.org/10.61707/hddjk002

Kemaloğlu, Y. K., Mengü, G., Gökdoğan, Ç., & Türkcan, A. K. (2020). A method to find out perceptional sound composition of the vowels in the contemporary Turkey Turkish. *Gazi Medical Journal, 31*(3), 237–241

Kementerian Pendidikan dan Kebudayaan Republik Indonesia. (2018, Juli 17). *Badan Bahasa petakan 652 bahasa daerah di Indonesia*. https://www.kemdikbud.go.id/main/blog/2018/07/badan-bahasa-petakan-652-

Kementerian Pendidikan dan Kebudayaan Republik Indonesia. (2022, Februari 22). *Mendikbudristek luncurkan Merdeka Belajar 17: Revitalisasi bahasa daerah*. Kementerian Pendidikan dan Kebudayaan. https://www.kemdikbud.go.id

Kik, A., Adamec, M., Aikhenvald, A. Y., Bajzekova, J., Baro, N., Bowern, C., Colwell, R. K., Drozd, P., Duda, P., Ibalim, S., Jorge, L. R., Mogina, J., Ruli, B., Sam, K., Sarvasy, H., Saulei, S., Weiblen, G. D., Zrzavy, J., & Novotny, V. (2021). Language and ethnobiological skills decline precipitously in Papua New Guinea, the world's most linguistically diverse nation. *Proceedings of the National Academy of Sciences*, *118*(22). https://doi.org/10.1073/pnas.2100096118

Kim, Y. (2020). Morphology and language documentation. *Oxford Research Encyclopedia of Linguistics*. https://doi.org/10.1093/acrefore/9780199384655.013.518

Korkmaz, Y., & Boyacı, A. (2018). Adli bilişim açısından ses incelemeleri. *Science and Engineering Journal of Fırat University, 30*(1), 329–343.

Korkmaz, Y., & Boyacı, A. (2018). Examining vowels' formant frequency shifts caused by preceding consonants for Turkish language. *Journal of Engineering Technology*, *2*(2), 38–47. http://earsiv.batman.edu.tr/handle/20.500.12402/2269

Ladefoged, P. (2006). *Representing linguistic phonetic structure* [Unpublished manuscript]. http://www.linguistics.ucla.edu/people/ladefoge/PhoneticStructure.pdf

Ladefoged, P., & Johnson, K. (2011). *A course in phonetics* (6th ed.). Nelson Education Ltd.

Lee, Y., & Kreiman, J. (2020). Language effects on acoustic voice variation within and between talkers. *The Journal of the Acoustical Society of America*, *148*(4_Supplement), 2473. https://doi.org/10.1121/1.5146847

Lee, Y., Danner, S. G., Parrell, B., Lee, S., Goldstein, L., & Byrd, D. (2018). Articulatory, acoustic, and prosodic accommodation in a cooperative maze navigation task. *PLoS ONE*, *13*(8), e0201444. https://doi.

org/10.1371/journal.pone.0201444
Lobel, J. W. (2021). Vowel fronting, raising, and backing in Luzon and north-central Sulawesi. *Wacana Journal of the Humanities of Indonesia*, *22*(1), 125. https://doi.org/10.17510/wacana.v22i1.1028
Lobel, J. W., Blust, R., & Thomas, E. (2021). Three puzzles for phonological Theory in Philippine minority Languages. *Oceanic Linguistics*, *60*(2), 474–484. https://doi.org/10.1353/ol.2021.0014
Mann, D. C., Fitch, W. T., Tu, H., & Hoeschele, M. (2021). Universal principles underlying segmental structures in parrot song and human speech. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-020-80340-y
Masykar, T., Pillai, S., & Hassan, R. (2023). A comparison of English, Acehnese, and Indonesian monophthongs. *Deleted Journal*, *10*(3), 1146–1166. https://doi.org/10.24815/siele.v10i3.30477
Melo, R. M., Mota, H. B., & Berti, L. C. (2017). O contraste entre oclusivas alveolares e velares em dados típicos de fala: análises acústica e ultrassonográfica. *CoDAS*, *29*(3). https://doi.org/10.1590/2317-1782/20172016117
Mentari, S., Ganie, R., & Syarfina, T. (2024). Bunyi Forman Vokal dalam Bahasa Jawa Ngoko: Kajian Fonetik Akustik. *Jurnal Bahasa Dan Sastra*, *12*(2), 367. https://doi.org/10.24036/jbs.v12i2.129700
Mezzedimi, C., Di Francesco, M., Livi, W., Spinosi, M. C., & De Felice, C. (2016). Objective Evaluation of Presbyphonia: Spectroacoustic Study on 142 Patients with Praat. *Journal of Voice*, *31*(2), 257.e25-257.e32. https://doi.org/10.1016/j.jvoice.2016.05.022
Miles, M. B., Huberman, A. M., & Saldaña, J. (1988). *Qualitative Data Analysis: A Methods Sourcebook*. http://cds.cern.ch/record/2261864
Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). Sage Publications.
Morris, J. (2017). Sociophonetic variation in a long-term language contact situation: /l/-darkening in Welsh-English bilingual speech. *Journal of Sociolinguistics*, *21*(2), 183–207. https://doi.org/10.1111/josl.12231
Mustafayeva, S. B. G. (2020). The role of the experiment in the study of the language material. *Theory and Practice in Language Studies*, *10*(10), 1337. https://doi.org/10.17507/tpls.1010.23
Nakajima, Y., Ueda, K., Fujimaru, S., Motomura, H., & Ohsaka, Y. (2017). English phonology and an acoustic language universal. *Scientific Reports*, *7*(1). https://doi.org/10.1038/srep46049
Nance, C. L., & Moran, D. (2022). Place identity and authenticity in minority language revitalisation: Scottish Gaelic in Glasgow. *International Journal of Bilingualism*, *26*(5), 542–563. https://doi.org/10.1177/13670069221110382
Núñez-Batalla, F., Vasile, G., Cartón-Corona, N., Pedregal-Mallo, D., De Castro, M. M., García, M. G., Gómez-Martínez, J., Fernández, P. C., & Llorente-Pendás, J. L. (2018). Comparación de la producción vocal en niños con hipoacusia prelocutiva con adaptación audioprotésica e implante coclear con normooyentes. *Acta Otorrinolaringológica Española*, *70*(5), 251–257. https://doi.org/10.1016/j.otorri.2018.05.004
Oganian, Y., Bhaya-Grossman, I., Johnson, K., & Chang, E. F. (2023). Vowel and formant representation in the human auditory speech cortex. *Neuron*, *111*(13), 2105-2118.e4. https://doi.org/10.1016/j.neuron.2023.04.004
Özek, C. U. F. (2020). Türkiye Türkçesi ağızlarında fonetik çevreye bağlı O>U, U>O değişimleri. *Turkish Studies - Language and Literature*, *Volume 15 Issue 3*(Volume 15 Issue 3), 1543–1573. https://doi.org/10.47845/turkishstudies.44961
Pareniuk, A. V. (2021). Analysis of speech sounds in the Praat program. *Electronic and Acoustic Engineering*, *4*(2). https://doi.org/10.20535/2617-0965.eae.228388
Perwitasari, A. (2018). Perception of English vowels by Javanese and Sundanese speakers; A mouse-tracking study. *Wacana Journal of the Humanities of Indonesia*, *19*(1), 219. https://doi.org/10.17510/wacana.v19i1.607
Poon, M. S. F., & Ng, M. L. (2014). The role of fundamental frequency and formants in voice gender identification. *Speech Language and Hearing*, *18*(3), 161–165. https://doi.org/10.1179/2050572814y.0000000058
Praat: doing Phonetics by Computer. (n.d.). https://praat.org/
Rai, T. M. (2017). Koyee Vowels: An Acoustic Analysis. *Gipan*, *3*(2), 136–143. https://doi.org/10.3126/gipan.v3i2.48918
Redford, M. A., & Oh, G. E. (2017). The representation and execution of articulatory timing in first and second language acquisition. *Journal of Phonetics*, *63*, 127–138. https://doi.org/10.1016/j.wocn.2017.01.004

Sakhiyya, Z., & Martin-Anatias, N. (2020). Reviving the language at risk: a social semiotic analysis of the linguistic landscape of three cities in Indonesia. *International Journal of Multilingualism*, *20*(2), 290–307. https://doi.org/10.1080/14790718.2020.1850737

Seifart, F., Evans, N., Hammarström, H., & Levinson, S. C. (2018). Language documentation twenty-five years on. *Language*, *94*(4), e324–e345. https://doi.org/10.1353/lan.2018.0070

Seong, C. J. (2022). Guidance to the Praat, a software for speech and acoustic analysis. *Journal of the Korean Society of Laryngology Phoniatrics and Logopedics*, *33*(2), 64–76. https://doi.org/10.22469/jkslp.2022.33.2.64

Smith, A. D. (2017). MERAP Historical Phonology in the context of a Central Bornean Linguistic area. *Oceanic Linguistics*, *56*(1), 143–180. https://doi.org/10.1353/ol.2017.0006

Sofa, N. a. R., & Febrianti, N. A. (2025). Dialektologi Bahasa Arab: Analisis perbedaan linguistik berdasarkan kajian Pustaka. *Lencana Jurnal Inovasi Ilmu Pendidikan*, *3*(2), 76–87. https://doi.org/10.55606/lencana.v3i2.5018

Strömbergsson, S. (2016). Today's most frequently used F0 estimation methods, and their accuracy in estimating male and female pitch in clean speech. *Interspeech 2022*, 525–529. https://doi.org/10.21437/interspeech.2016-240

Subandowo, D., Faliyanti, E., & Siagiyanto, B. E. (2020). Formant measurement of Indonesian speakers in English vowels. *International Journal of Innovation, Creativity and Change: Special Edition, Safe Communities*.

Tavakoli, S., Matteo, B., Pigoli, D., Chodroff, E., Coleman, J., Gubian, M., Renwick, M. E., & Sonderegger, M. (2024). Statistics in phonetics. *Annual Review of Statistics and Its Application*. https://doi.org/10.1146/annurev-statistics-112723-034642

Tecumseh, W., & Fitch, S. (1994). Vocal Tract Length Perception and the Evolution of Language. *Ph.D. Thesis, Brown University*. https://www.ece.uvic.ca/~bctill/papers/numacoust/Fitch_1994.pdf

Tench, P. (2017). TRACEY M. DERWING & MURRAY J. MUNRO, Pronunciation fundamentals: Evidence-based perspectives for L2 teaching and research (Language Learning & Language Teaching 42). Amsterdam: John Benjamins, 2015. Pp. xiii + 208. ISBN: 978 90 272 1327 3. *Journal of the International Phonetic Association*, *50*(1), 141–144. https://doi.org/10.1017/s0025100317000160

Ulfa, M., Isda, I. D., & Purwati, P. (2018). The shift of Acehnese language: A sociolinguistic study to preserve regional languages. *Deleted Journal*, *5*(2), 161–174. https://doi.org/10.24815/siele.v5i2.8943

Ulfayanti, N., & Jelimun, M. O. (2018). Contrastive analysis of English and Indonesian vowel phoneme and its lesson plan in language teaching. *Journal of Applied Studies in Language*, *2*(2). https://doi.org/10.31940/jasl.v2i2.1030

Van Den Berg, R. (2014). JUARA SATU DAN DUA: MEMBANDINGKAN SITUASI KEBAHASAAN INDONESIA DAN PAPUA NUGINI. *Linguistik Indonesia*, *32*(2), 103–130. https://doi.org/10.26499/li.v32i2.21

Wang, X. (2024). Experimental research on using Praat software to assist English phonetic teaching. *International Journal of Mechatronics and Applied Mechanics, 18*, 113–120.

Xu, Y., & Gao, H. (2018). FormantPro as a Tool for Speech Analysis and Segmentation / FormantPro como uma ferramenta para a análise e segmentação da fala. *Revista De Estudos Da Linguagem*, *26*(4), 1435–1454. https://doi.org/10.17851/2237-2083.26.4.1435-1454

Yilmaz, A., Sarac, E. T., Aydinli, F. E., Yildizgoren, M. T., Okuyucu, E. E., & Serarslan, Y. (2018). Investigating the effect of STN-DBS stimulation and different frequency settings on the acoustic-articulatory features of vowels. *Neurological Sciences*, *39*(10), 1683–1689. https://doi.org/10.1007/s10072-018-3479-y

Yulita, I. N., Hidayat, A., Abdullah, A. S., & Awangga, R. M. (2018). Feature extraction analysis for hidden Markov models in Sundanese speech recognition. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, *16*(5), 2191. https://doi.org/10.12928/telkomnika.v16i5.7927

Zen, E. L. (2020). Role of Regional Language Background and Speech Styles on the Production of Voice Onset Time (VOT) in English among Indonesian Multilinguals. *Indonesian Journal of Applied Linguistics*, *10*(2), 359–368. https://doi.org/10.17509/ijal.v10i2.28604