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A Comparative Acoustic Study of the Vowels of Argobba Dialects

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Abstract

This paper explores the fundamental frequency and the first three formants of Shonke and Gachinne dialects of Argobba vowels. The vowels were put in within 8 consonantal contexts embedded in disyllabic nonsense words based on the data collected from 40 subjects. A repeated measures ANOVA was conducted to investigate the effects of contexts as within-subject factor, and dialects and genders as between-subject factors. The results showed that high vowels' F0, F2, and F3 values were higher than the lower ones; and F0, F2, and F3 values of front vowels were higher than back vowels. Argobba vowels between voiceless consonants had higher F0, F1, F2, and F3 values than vowels between voiced consonants. Likewise, vowels followed by geminate consonants had higher F0, F1, F2, F3 values than those followed by nongeminate ones. Comparison of dialects showed F0, F1, F2, and F3 values of the Shonke dialect were higher than those of the Gachinne dialect. This resulted in the vowel space of the Shonke dialect being bigger than that of the Gachinne dialect for both genders. Females' vowel space was larger than males' in both dialects. In the present study, the two central vowels of Argobba /ɨ/ and /ə/ and were found to occupy a lower position in the height dimension than the position they are assumed to occupy in the articulatory-based vowel space. As a result, a four-height vowel system was proposed for Argobba. The result of the discriminant analysis of Argobba vowels was very low.

Key words: /Acoustic value /Context/Formant/Fundamental frequency/Vowel space/

[1] Detail is given at the back of this manuscript.
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1. Introduction

A pioneering study of the acoustic property of vowels started with Peterson and Barney (1952) on the vowels of American English. This study was later replicated by Hillenbrand *et al*. (1995) and reported relatively similar findings to that of Peterson and Barney (1952). Acoustic studies of vowels also investigated possible dialectal differences. Consequently, vowel formant values have been found to differ due to dialectal differences in English and other languages (Hagiwara, 1996; Fox & Jacewicz, 2009; Leinonen, 2010; Grieve *et* al. 2013; Oder, Clopper, & Ferguson, 2013). In addition to vowel formants, fundamental frequency was found to be a marker of regional dialect variation (Jacewicz & Fox, 2018).

Acoustic studies on vowel formants have been conducted on very few Ethiopian languages: Amharic (Derib, 2011) and Oromo (Tujube, 2018; Feda, 2023). To date, there is no acoustic study on Argobba.

Argobba is a Transversal South Ethio-Semitic language that is grouped with Amharic (Hetzron, 1972; Hetzron & Bender, 1976). Linguistic studies on the language reported that it is "critically endangered" (Getahun, 2009; Moseley, 2010). In many places, the language has died and is totally replaced by Oromo (Leslau, 1957) and Amharic (Hussein *et al*., 2014)

Argobba has 7 vowel phonemes classified in three heights and three front-back dimensions (Leslau, 1997; Getahun, 2009; Wetter, 2010[3] ; Girma, 2014).

	Front	Central	Back
High	i	ɨ	u
Mid	e	ə	o
Low		a	

Figure 1: Vowel phonemes of Argobba (Leslau, 1997; Getahun, 2009; Girma, 2014)

Argobba is spoken in many scattered villages in the Affar and Amhara regions (Girma, 2013; Hussein, *et.al*., 2014). The dialectal classification of Argobba has been a point of difference. Studies suggested two to four dialects (Abebe, 2003; Wetter, 2006; Getahun, 2009; Lewis, 2009; Hussein *et al*., 2014). It has also been claimed that the different 'dialects' of Argobba can be considered different languages (Girma, 2014). This study was conducted based on Getahun's (2009) classification of Argobba into Shonke and Gachinne dialects.

This study focuses on the acoustics of Argobba vowels, which is a neglected area in the study of Ethiopian languages, not just the case of Argobba. The paper explored the fundamental frequency and the first three formant values of Argobba vowels based on the data from the Shonke and Gachinne dialects. Accordingly, the study tried to answer the following research questions:

[3] *Wetter (2010) proposes four heights: close, half close, half open and open.*

1. What are the fundamental frequency (hereafter F0) and the first three formants' values (hereafter F1, F2, and F3) of vowels for male and female speakers?
2. Is there any difference between the two dialects on their vowels' acoustic properties and vowel spaces in terms of F1-F2?
3. Is there any difference between acoustic representation and articulatory representation of Argobba vowel spaces?
4. What are dialect/language specific as well as universal implications of the acoustic properties of Argobba vowels?

2. Methods

2.1. Selection of Subjects

The selection of the subjects was made based on the assessment of the fluency of speakers by representative community members. This was made because it was difficult to get monolingual speakers, especially among the speakers of the Gachinne dialect due to the language shift from Argobba to Amharic and Oromo. As far as the Shonke dialect is concerned, most of the elder females and children speakers were monolinguals and the selection of speakers was not a problem.

For both dialects, a total of 40 subjects (10 females from each dialect) were recruited based on their willingness to participate in the study. All subjects, aged 20-47 years (average: Shonke subjects 28.6 years, and Gachinne subjects 32.2 years) self-reported to have no language (speech and/or listening) defects due to physiological and/or psychological disorders.

2.2. Data Collection Procedures

Each of the seven vowels (ə, u, i, a, e, ɨ , o) were written in Ethiopic script and presented on Microsoft Powerpoint. The vowels were placed in disyllabic nonsense words. Vowels were identical in both syllables of a word (e.g., /tutu/, /tata/, /bete/, /butu/…), and the first vowel was always the target vowel. The bilabial voiced stop /b/ and the alveolar voiceless stop /t/ were used to construct the disyllabic nonsense words with different contexts to see the effect of voice (voiced vs. voiceless) and gemination (geminate vs. nongeminate) consonantal environments as indicated in Table 1. Accordingly, each subject was allowed to do reading exercises before the actual recording and there was also a trial recording to familiarize the subjects with the recording.

Table 1

Different Contexts Used to Measure Acoustic Values of Vowels

Contexts	Geminate	Nongeminate
between voiced stops	bvbbv	bvbv
between a voiced stop and a voiceless stop	bvttv	bvtv
between voiceless stops	tvttv	tvtv
between a voiceless stop and a voiced stop	tvbbv	tvbv

Each of the vowels was presented in four consonantal contexts and two gemination contexts in a word list and in a carrier phrase. Five randomized repetitions were presented for each of the vowels and the three medial repetitions were analysed. A total of 13,440 vowel tokens (7 vowels * 4 consonantal contexts * 2 gemination contexts * 2 carrier contexts * 40 participants) were considered for data analysis.

Then the word lists and carrier sentences were written on a power point as follows:

Eg.* '*tubu*'** /*ɨnni k'al* ***tubu *nɜy*/ '*tubu*.' 'This word is *tubu'* (Shonke dialect),
'***tubu***' /*hud k'al* ***tubu*** *ne/* '*tubu*.' 'This word is *tubu*' (Gachinne dialect).

2.3. Data Analysis Procedures

First, the data was resampled at 11 KHz. Praat (Boersma &Weenink, 2017) version 6.0.26 was used to annotate and extract F0, F1, F2 and F3 values. The vowels' boundaries were demarked manually based on the spectrogram and wave form displays from Praat window. The beginning of each vowel was taken to be the beginning of a regular wave form where the formants start stably. But, if the beginning of a regular waveform was not the beginning of a vowel, the point where the formants start to be stable was taken as the beginning of a vowel and the end boundaries of vowels were demarked in the same way. The contexts, gender and dialect of a given vowel, were annotated in a tier within respective boundaries on the Praat window. After that, a given vowel's acoustic values were extracted from the middle of the boundaries demarked with Praat script to minimize the effect of neighbouring consonants.

For F0, the pitch range was set to 75-400 Hz and 120-400 Hz for male and female subjects respectively. When a vowel token did not produce a pitch by Praat, it was redone by minimizing the ceiling of the pitch: 70 Hz for male and 75 Hz for female subjects. If a pitch was still not produced, it was replaced by the average value of the same vowel formant value in the same context.

The F1, F2, and F3 values of vowels were determined by the Burg method in the Praat program with the formant range of 50 -5500 or 5000 Hz for female and male subjects. All of the vowel data extracted by Praat script was copied to the Microsoft Excel program for coding of variables and finally imported to SPSS for further analysis.

2.4 Statistical Analysis

Before proceeding to the statistical analysis, the mean values of vowels were taken from the three repetitions. The analysis was made using SPSS (version 21). Significant outliers were checked by Studentized residuals and replaced with mean values of the same vowel formant in identical contexts. The data was also computed to obtain normalized values for further statistical analysis.

The statistical analysis was done with repeated measures ANOVA to investigate if there are statistically significant effects between contexts as follows: four levels of voice versus voiceless consonantal contexts (bvbv, bvtv, tvtv and tvbv) and two levels of geminate versus nongeminate contexts (cvcv and cvccv) were used as within-subject factor. Similarly, two dialects (Gachinne and Shonke) and two genders (males and females) were taken as between-subject factors. Thus, the data were restructured and the mean values of each condition's acoustic values measured in hertz (Hz) were considered the result.

The variances of the differences between all combinations of related groups were evaluated by Mauchly's test of sphericity. After assessing the assumptions, the repeatedly measured acoustic values of vowels (F0, F1, F2, and F3) and all contexts were treated as within-subjects variables while gender and dialects as between-subjects factors.

When Mauchly's test of sphericity was insignificant, Multivariate Tests were used to see if the contexts had a significant effect on the within-subjects variables. On the other hand, when Mauchly's test of sphericity was statistically significant, the Greenhouse-Geisser correction method was used. Furthermore, when there was a statistically significant difference between levels, post-hoc analysis was employed to identify between which levels the difference occurred.

Lastly, the measurement of Fl against F2 was plotted to determine the vowel space of each gender and dialect as well as the overall Argobba vowel spaces. In addition, discriminant analysis was conducted to observe how much Argobba vowels could be separated from each other based on their various combinations of acoustic measurements.

2.5 Ethical Considerations

In order to collect the necessary data from the two locations where Argobba is spoken, a formal letter of cooperation was written from the Department of Linguistics, Addis Ababa University. Local officials read the letter and gave their permission to collect the data. The letter was also shown to the elders of the community and their consent was secured. The participants were informed that the recording would be used for academic purposes and their names would be anonymized in the presentation of the results. In addition, they were informed that the recorded data would be confidential. Each of the participants agreed orally to get recorded while saying the stimuli. They were informed that they could withdraw from the study at any moment should they desire to do so.

3. Results

3.1. Fundamental Frequency (F0)

Mean and standard deviation values of Argobba vowels F0 were found to differ along with vowels height. Accordingly, high vowels F0 was higher than the low vowels. Tests of within-subjects effects of vowels were calculated with the Greenhouse-Geisser degree of freedom (as Mauchly's Test of sphericity was violated), confirmed that the difference was statistically significant: $F(4,146) = 6.464$, $p < .001$, $\eta^2 = .152$. Besides, pairwise comparisons of vowels' F0 values with the adjustment of Bonferroni multiple comparisons showed that the differences in vowels' F0 values were statistically significant at $p < .001$. But, the front-back counterpart contrasts (i.e., high-front & high-back vowels, and mid-front & mid-back vowels) F0 values were statistically insignificant, $p < 1.0$. But there were no vowel*gender, vowel*dialect and vowel*gender*dialect interaction effect on F0 values: $F(4,146) = 1.322$, $p < .264$, $\eta 2 = .035$, $F(4,146) = .394$, $p < .815$, $\eta^2 = .011$ and $F(4,146) = 1.349$, $p < .254$, $\eta^2 = .036$ respectively.

Differences were observed in the F0 values due to voiced and voiceless consonantal contexts: vowels preceded by a voiceless consonant had higher F0 means. Particularly, vowels between voiceless consonants had the highest F0 (187 Hz) while vowels between voiced consonants had the lowest F0 values (182 Hz). Nevertheless, tests of within-subjects effects showed that voice had no statistically significant main effect. However, pairwise comparisons with the Bonferroni adjustment of multiple comparisons showed that the F0 values of vowels between voiced consonants (/bvbv/) were significantly different from F0 values of vowels between voiceless consonants (/tvtv/), and between voiceless and voiced consonants (/tvbv) with a p value of = .008 and .009 respectively. Thus, vowels following voiceless consonants had higher F0 values than vowels following the voiced ones. Similarly, vowels followed by geminate consonants had higher F0 values.

Tests of within-subjects effects calculated with the Greenhouse-Geisser degree of freedom showed that there was a statistically significant main effect of gemination on vowel's F0 values: $F(1, 36) = 16.27$, $p < .005$, $\eta_p^2 = .31$. There were also statistically significant interaction effects of context*gemination and context*gemination*gender on F0 values: $F(2.53, 91.17) = 4.07$, $p < .05$, $\eta_p^2 = .102$ and $F(2.53, 91.17) = 3.38$, $p < .05$, $\eta_p^2 = .086$ respectively. But there were no significant effects between gemination*gender, gemination*dialect, and gemination*gender*dialect interactions: $F(1, 36) = 3.98$, $p = .082$, $\eta_p^2 = .082$, $F(1, 36) = .611$, $p = .439$, $\eta_p^2 = .017$ and $F(1, 36) = .630$, $p = .432$, $\eta_p^2 = .017$ respectively.

Females' mean and SD values of F0 were higher than males' values. The highest and the lowest F0 values for female speakers were 224 Hz for the vowel /ɨ/ and 219 Hz for the vowels /a/ and /e/. Likewise, male speakers' highest F0 value was 150 Hz for the vowels /i/ and /o/, and the least F0 was 143 Hz for the vowel /a/. In both genders, lower and mid vowels /a/ and /ə/ scored smaller F0 and high vowels /ɨ/ and /u/ had higher F0 values.

Tests of between-subjects effects showed that there was a statistically significant main effect of gender on F0 values of vowels: $F(1,36)=106.38$, $p < .001$, $\eta^2 = .75$, but there was no significant interaction effect of gender and dialect: $F(1,36)=.378$, $p < .543$, $\eta^2 = .010$. The Shonke dialect had higher F0 values than Gachinne in both genders with a statistically significant main effect of $F(1,36)= 7.39$, $p < .05$, $\eta^2 = .17$.

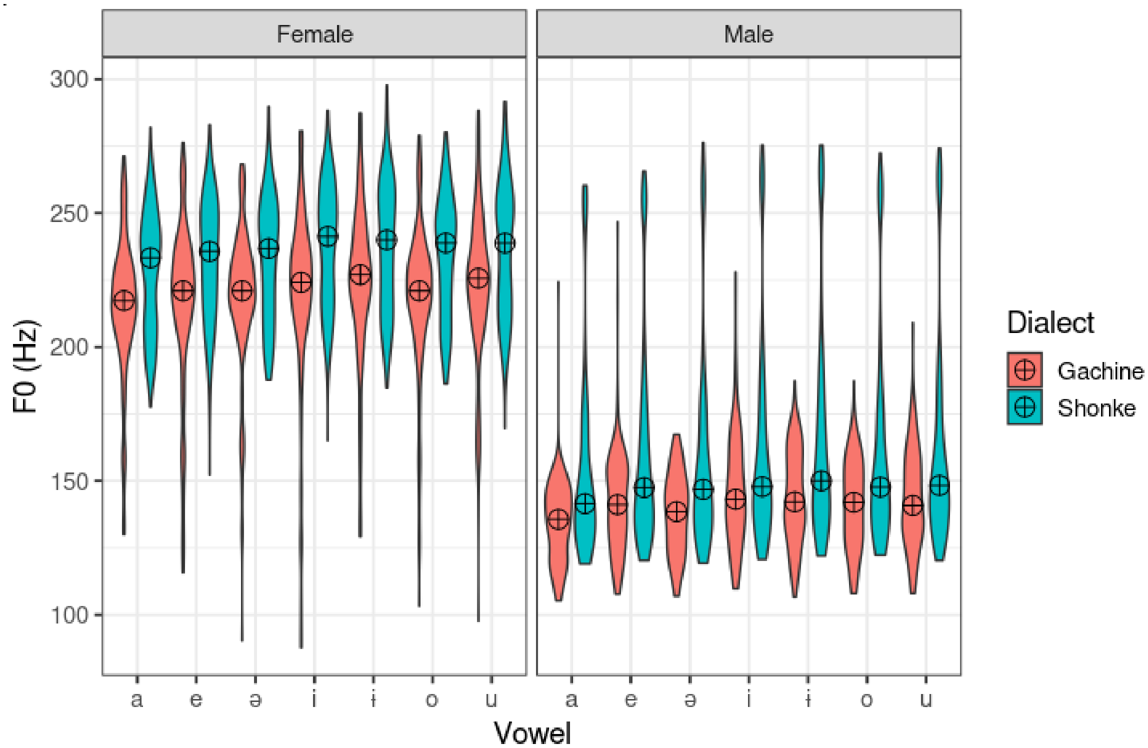


Figure 2: Mean F0 values of Argobba vowels by dialect and gender

3.2 First Formant (F1)

Low vowels had higher mean F1 values while high vowels had lower F1. Accordingly, F1 of the low vowel /a/ had the highest (673 Hz) of other vowels. The middle central vowel /ə/ was the next vowel to score the high (558 Hz) F1. The least F1 values were recorded by the high front vowel /i/ and high back vowel /u/, 388 Hz and 408 Hz respectively. These findings were true also for both genders. F1 values of high back vowels (/u/ and /o/) were higher than their front counterparts (/i/ and /e/) in both dialects as well as both genders.

A repeated measures of ANOVA were conducted on vowel factor as tests within subject and the results showed that there was a statistically significant main effect of vowels on F1 values: $F(2.46,88.61) = 422.65$, $p < .001$, $\eta^2 = .92$, but there were no significant interaction effects of vowel*gender as well as vowel*dialect interactions on F1 value: $F(2.46,88.61) = 2.21$, $p < 0.10$ and $F(2.46,88.61) = 1.68$, $p < 1.68$ respectively.

Likewise, the result of repeated measures ANOVA with tests of within-subjects effects showed that voiced and voiceless consonantal contexts had a statistically significant main effect on vowels F1 value: $F(1.9,70.22) = 15.65$, $p < .001$, $\eta^2 = .30$. Accordingly, vowels preceded by voiceless stops had higher F1 values than vowels preceded by voiced ones.

There was also significant interaction effect of context*vowel, $F(9.88, 355.72) = 6.345$, $p < .001$, $\eta_p^2 = .15$. Similarly, there was a three-way interaction effect of context*gemination*gender on the F1 value: $F(2.4,86.48) = 3.99$, $p < .05$, $\eta^2 = .1$. But there was no interaction effect of context*gender*dialect, $F(1.95, 70.22) = 0.07$, $p = .929$, $\eta_p^2 = .002$.

In the same way, vowels followed by geminate consonants had higher F1 values (481.55 Hz) than followed by nongeminate consonants (479.14). However, the difference was not statistically significant.

Hence, the result sustained that the F1 value of vowels was not affected by gemination. With regards to gender and dialect, F1 values of Shonke subjects were higher than their Gachinne counterparts in both genders.

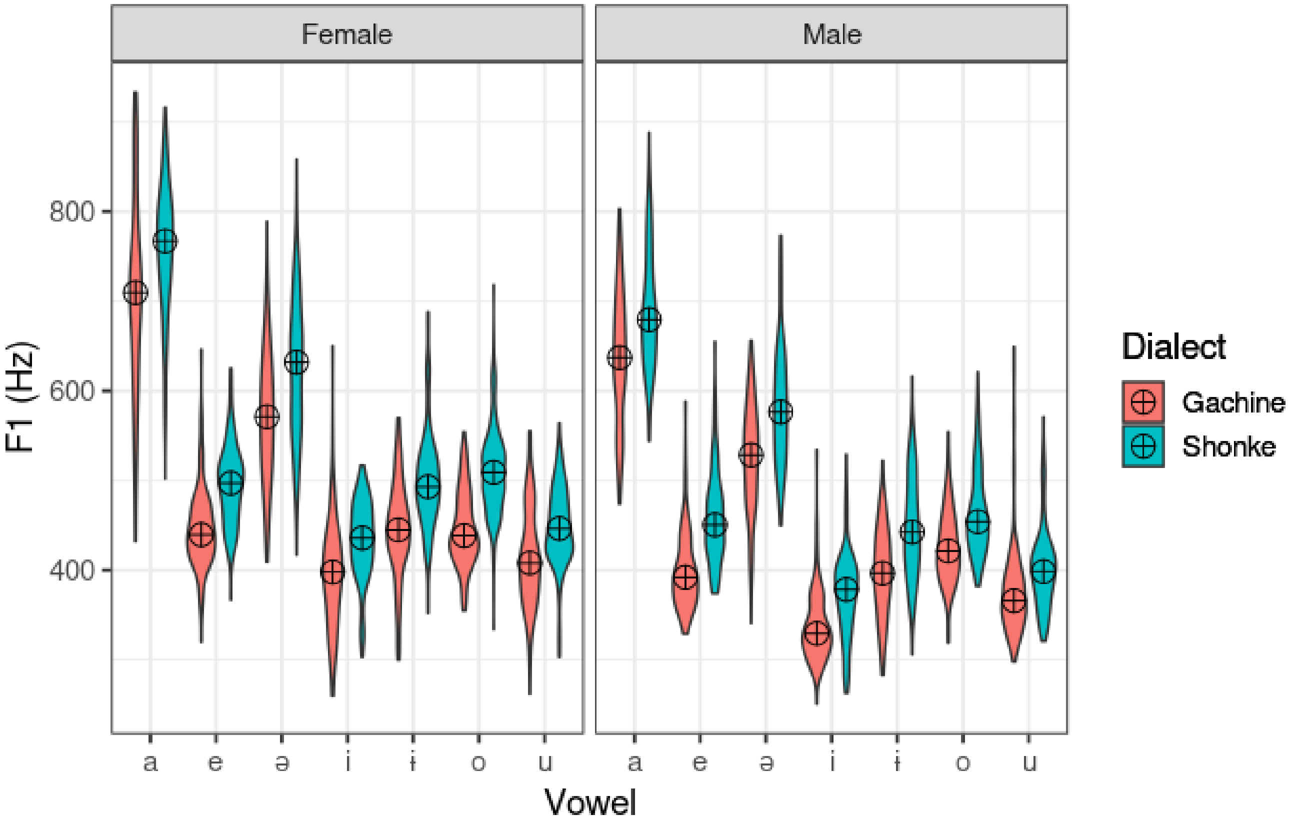


Figure 3: Mean F1 values of Argobba vowels by dialect and gender

The repeated measures ANOVA conducted to test the effect size of gender and dialect on F1 values of vowels showed that gender and dialect had a significant main effect of $F(1{:}36) = 15.654$, $p < .005$, $\eta^2 = .303$ and $F(1{:}36) = 30.41$, $p < .001$, $\eta^2 = .46$ respectively.

3.3 Second Format (F2)

Front vowels had the highest F2 values, (/i/: 2137 Hz and /e/: 2046 Hz) while back vowels' F2 values were lower than the rest vowels, (/u/: (1219 Hz) and /o/: (1167 Hz). Tests of within-subjects effects on the vowel category as within-subject factor showed that vowels' main effect on F2 values were statistically significant: $F(3.06,110.04) = 353.23$, $p < .001$, $\eta^2 = .91$. There were also vowel*gender, vowel* dialect and a three-way interaction of vowel*gender*dialect significant effect of: $F(3.06,110.04) = 7.95$, $p < .001$, $\eta^2 = .18$, $F(3.06,110.04) = 3.46$, $p = 018$, $\eta^2 = .088$, and $F(3.06,110.04) = 3.18$, $p = .026$, $\eta^2 = .081$ respectively.

F2 values of vowels followed by a voiceless consonant were higher than those followed by a voiced one. Within-subject effects test with the assumption of sphericity (being its assumption was not violated), was conducted to discover the effect size of voiced versus voiceless consonantal contexts. The result showed that voice had a statistically significant main effect on F2 values of vowels: $F(3,108) = 44.46$, $p < .001$, $\eta_p^2 = .553$. However, there were no significant interaction effects of context*gender, context*dialect and context*gender*dialect interactions on F2 values. Equally, vowels in a nongeminate context had higher F2 values than vowels in a geminate context; however, tests of within-subjects effect indicated that there was no statistically significant effect: $F(1{:}36) = 3.21$, $p < .081$, $\eta_p^2 = .082$.

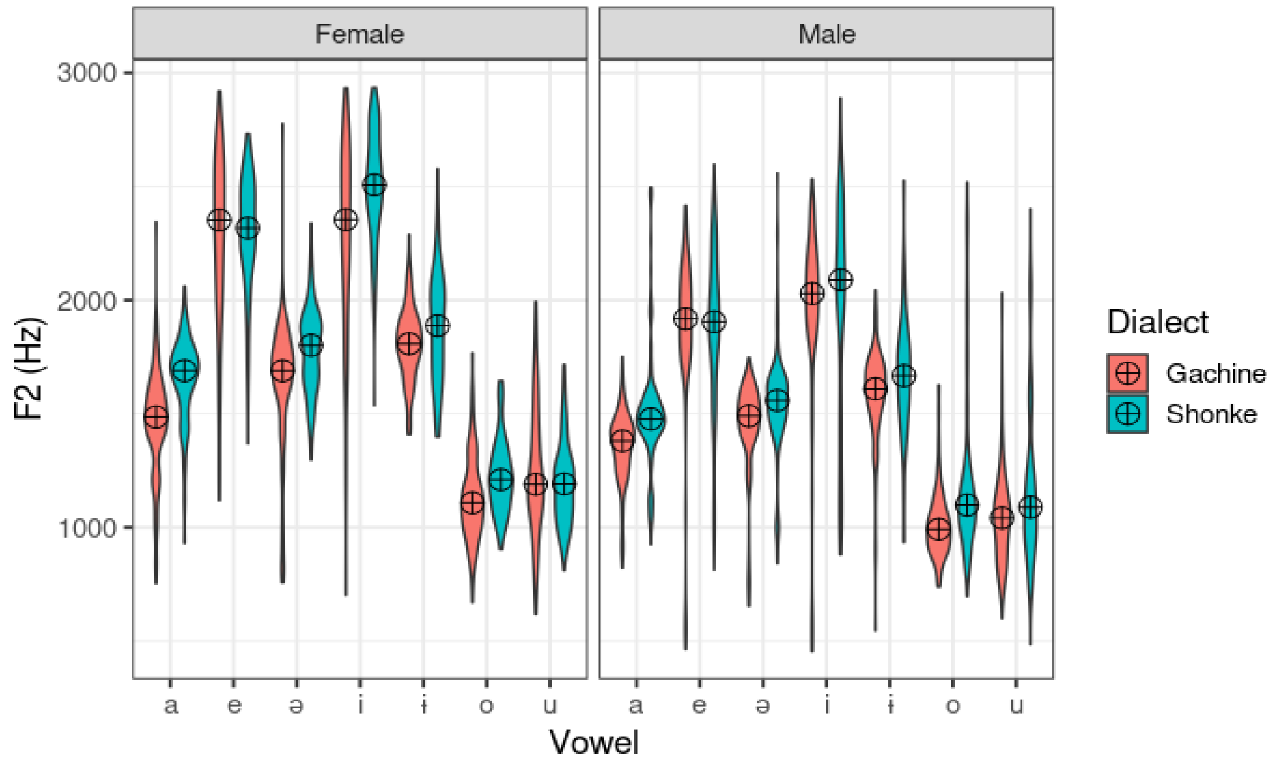


Figure 4: Mean F2 values of Argobba vowels by dialect and gender

Tests of between-subjects effects showed that there was statistically significant effect of gender on F2 values of vowels: $F(1{:}36) = 37.86$, $p < 001$, $\eta^2 = .51$. The same test also confirmed that dialect had significant effect on vowels' F2: $F(1{:}36) = 9.57$, $p < 005$, $\eta^2 = .21$. However, there was no significant interaction effect of gender and dialect.

3.4 Third Format (F3)

Among Argobba vowels, front and central high vowels (/i/, /e/ and /ɨ/) F3 values (2970 Hz, 2919 Hz and 2891 Hz respectively) were higher than the rest vowels. Back and low vowels had lower F3 (/u/ = 2814, /o/ = 2818, and /a/ = 2797). Hence, the F3 value of the lower vowel /a/ was the least of all. Tests of within-subjects effects on the vowel category as within-subject factor showed that vowels' main effect on F3 values were statistically significant: $F(2.52, 90.86) = 8.42$, $p < .001$, $\eta^2 = .19$.

As to contexts, vowels between voiceless consonants had a higher F3 value than in the context of voiced consonants. The result of tests of within-subjects' effects, adjusted to Greenhouse-Geisser, showed that context had a statistically significant main effect on vowels' F3 values: $F(2.34,84.55) = 8.41$, $p < .001$, $\eta^2 =.189$. There was also significant effect of context*dialect interaction: $F(2.34,84.55) =2.986$, $p < .05$, $\eta^2 =.077$. However, there was no significant effect of context*gender interaction as well as three-way interaction effect of context*Gender*Dialect on F3 value.

Concerning the context of gemination, vowels followed by nongeminate consonants had higher F3 value than those followed by geminate consonants with a statistically significant main effect of $F(1, 36) =5.351$, $p < .05$, $\eta^2 =.129$. Generally, F3 values of the Shonke dialect were higher than Gachinne in both genders.

Tests of between-subjects effects showed that gender had a statistically significant main effect of: $F(1,36) = 93.529$, $p < .001$, $\eta^2 = .722$ on vowels' F3 value. The same test revealed dialect had a statistically significant main effect, $F(1,36) = 8.678$, $p < .05$, $\eta_p^2 = .194$. This result indicated that dialect's effect on vowels' F3 value was a little bit lower than that of gender.

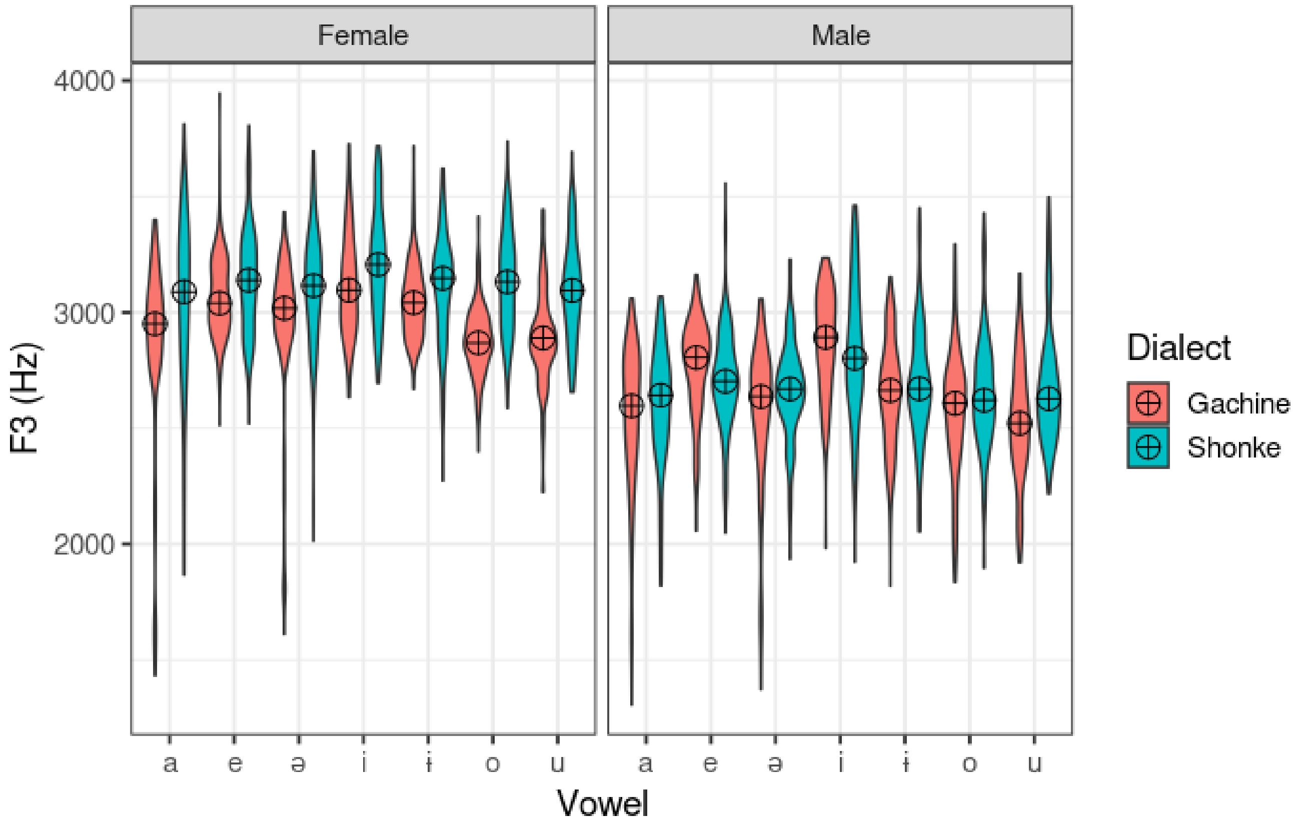


Figure 5: Mean F3 values of Argobba vowels by gender and dialect

3.5 Vowel Space

In the subsequent description, the vowel space of each dialect based on genders and the Argobba vowel space collapsed across dialects and genders will be presented with the plot of F1 against F2.

Vowel space of the Gachinne dialect. F1 value of the front-high vowel /i/ was low in males' vowels while it was higher in females' vowels, and F2 of /e/ was higher in females'. Besides, the F1 value of /a/ was higher in females' vowels than in males' vowels. As a result, females' vowel space was larger than males'. What is common for both genders in the Gachinne dialect was that the back vowel /o/ was sliding backwards more than its neighbouring upper back vowel: /u/ did.

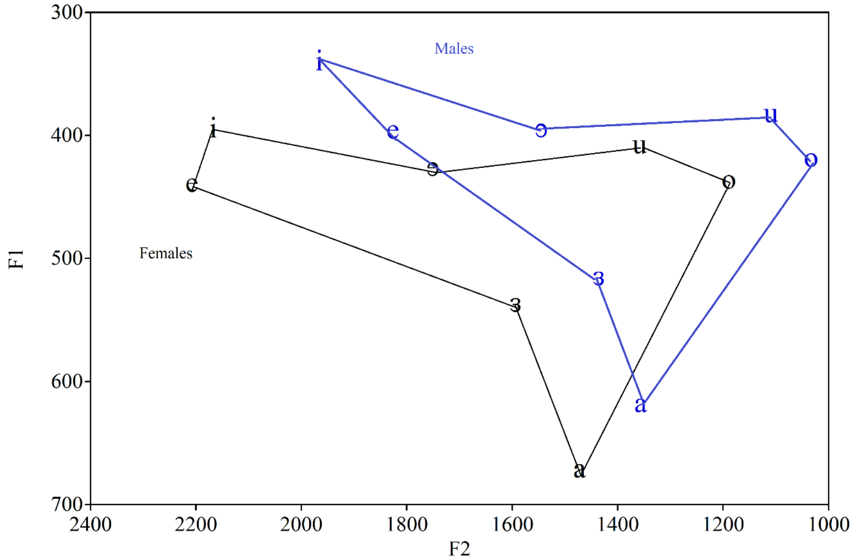


Figure 6: F1-F2 Plot of the vowels of the Gachinne dialect

Vowel space of the Shonke dialect. Here also, just like the Gachinne dialect, Shonke females' vowel space was larger than male subjects. Hence, the point vowels (i.e., /i/, /u/ and /a/) were far apart in females' vowel plot than in males' vowel plot. In the Shonke dialect, the central vowels are lowered and slid backwards in the vowel space.

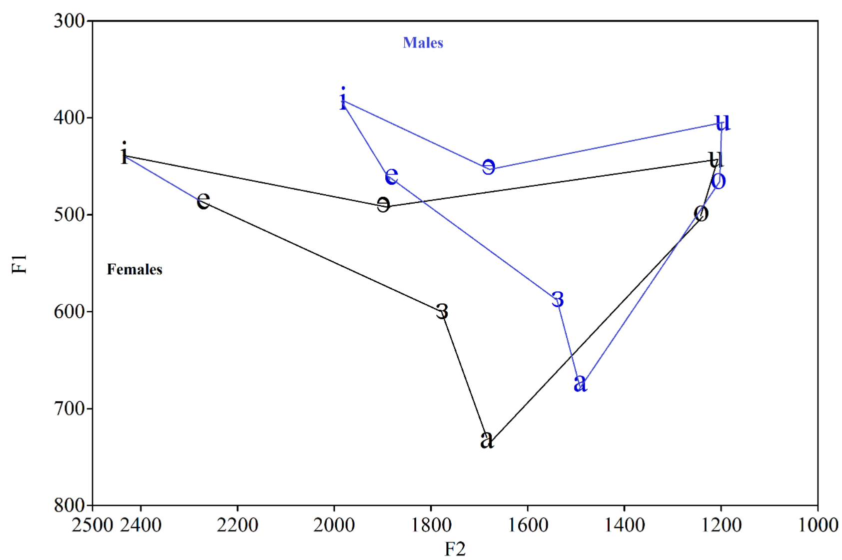


Figure 7: F1-F2 Plot of the vowels of the Shonke dialect

In Gachinne females' vowels, the F1 values of /i/, /a/ and /u/ were lower than similar vowels of the Shonke females' vowels' F1 values. In the same way, the front-back contrast of the F2 values of Gachinne females' vowels was still smaller than the F2 values of the Shonke females' vowels. Furthermore, Gachinne females' vowels' F2 value of the high back vowel /u/ was unexpectedly higher than the mid back vowel /o/, and F2 of the high front vowel /i/ was lower than the mid front vowel /e/. These F2 values caused the mid-back vowel /o/ to slide further back than its adjacent high vowel /u/, and the mid-front vowel /e/ to slide to the front than the front high vowel /i/. Consequently, the vowel space of Gachinne females became asymmetrical to the males' ones. Shonke females' vowel space was also larger than the Gachinne females' vowel space.

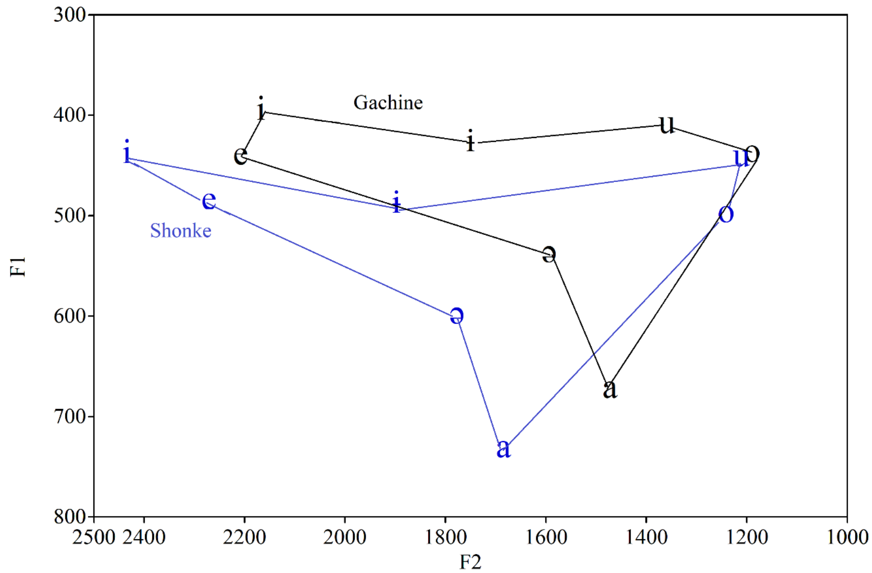


Figure 8: F1-F2 plot of females' vowels of Argobba

Similarly, all F1 and F2 values of Gachinne males' vowels were lower than the F1 and F2 values of the Shonke males' vowels. As a result, the vowel space of Gachinne males' vowels was smaller than that of Shonke males' vowels.

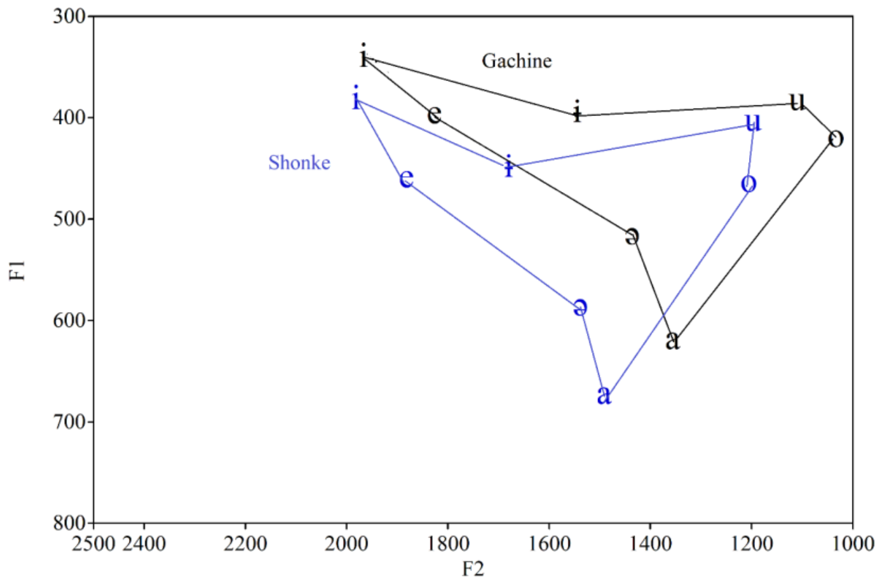


Figure 9: F1-F2 plot of Males' vowels of Argobba

In Gachinne males, the F2 value of the high-back vowel /u/ was higher than the mid-high back vowel /o/. Therefore, the mid back vowel /o/ was further back than the high vowel /u/ which affected the vowel space of the back vowels to slope asymmetrically.

To sum up, the vowel space of the Shonke dialect was larger than the vowel space of the Gachinne dialect. The high central vowel /ɨ/ and the mid-central vowel /ə/ were in a significantly lower position, and higher vowels were more concentrated than lower vowels. In addition, among central vowels, the low vowel /a/ is found further backwards than the higher ones.

In Argobba vowel space collapsed across dialects, the vowel space for females' vowels was larger than the vowel space of the males' vowels. Besides, the vowel plots of both genders showed a front-back contrast rather than a high-low contrast.

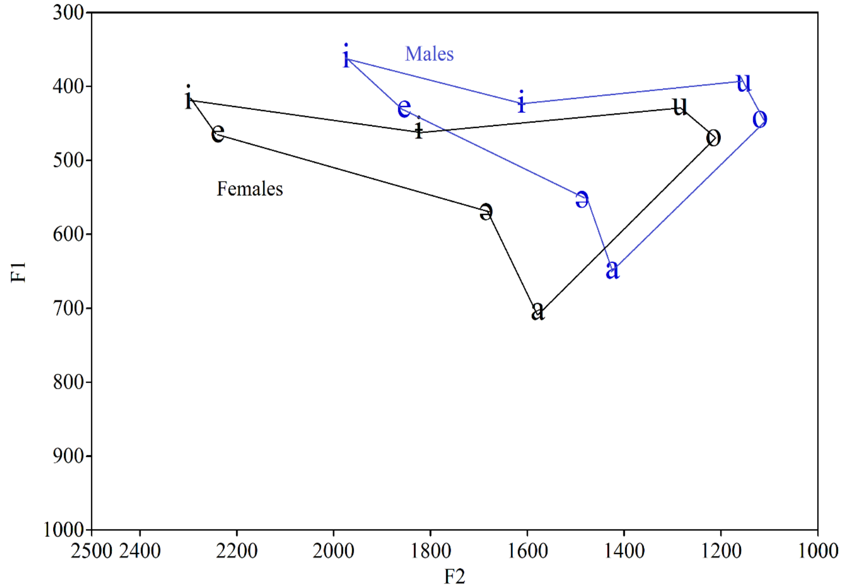


Figure 10: F1-F2 plot of Argobba vowels collapsed across dialects

As it can be seen in Figure 11, among the central vowels of Argobba, lower vowels seemed to slide backwards while the higher ones to the front position. Besides, central vowels were found to occupy a further lower position. Moreover, among these vowels, the lower vowels are found further back in the F1-F2 plot.

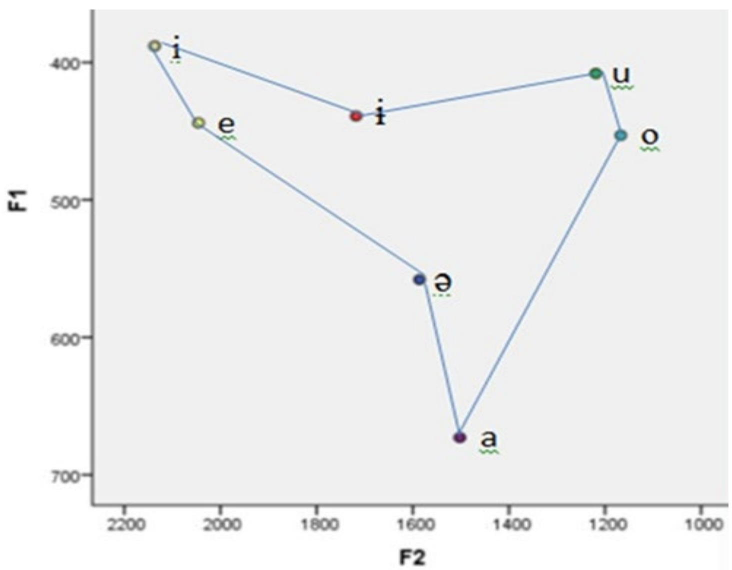


Figure 11: F1-F2 plot of Argobba Vowels Collapsed across Genders and Dialects

3.6 **Discriminant Analyses**

A linear discriminant analysis was conducted after normalizing the acoustic values of vowels to observe how combinations of different formants accurately classify Argobba vowel tokens in each dialect. The analysis was made in four different ways: classification across collapsed genders and dialects, classification across separate dialects but collapsed genders, classification across separate genders but collapsed dialects, and classification across separate genders and separate dialects.

Discriminant analysis for collapsed genders and dialects. In the first classification that was made across collapsed genders and dialects, the results of the analysis showed that F1 and F2 had higher contribution than F0 and F3. Particularly, the separation rate of F0 was very low. The combination of more formants used in the analysis had a better contribution.

The results of the discriminant analysis using F1 and F2 values showed that 59.1% of original grouped cases were correctly classified. Besides, F1 and F2 had significant contribution to the difference in variance (Wilks' Lambda < 0.001). Nevertheless, classification values of F1 were lower than F2.

Table 2

Classification Results of Argobba Vowels Using F1 and F2.

Vowel	Predicted Group Membership							Total
	ə	u	I	a	e	ɨ	o	
ə	53.9	1.6	0.2	19.4	2.3	14.1	8.6	100
u	1.7	61.1	1.3	0.2	1.3	9.8	24.7	100
i	0.2	7.3	72.2		14.5	5.6	0.2	100
a	20.3			76.4	0.2	0.8	2.3	100
e	4.1	2.3	31.4		39.7	19.5	3	100
ɨ	9.7	8	6.3	0.3	17.8	54.8	3.1	100
o	7.3	30.2	0.5	1.1	1.6	3.6	55.8	100

The low central vowel /a/ had the highest classification result (76.4%) followed by the high front vowel /i/ (72.2%) and high back vowel /u/ (61.1%). On the other hand, the mid vowels /e/ and /ə/ had lowest classification results.

In the same token, when F3 was combined with F1 and F2, classification results increased to 61.9%, but the contribution of F3 was very low. The result from this analysis showed that the low central vowel /a/ had the highest classification result (76.3%) followed by the high front vowel /i/ (69.4%), and high back vowel /u/ (64.5%). However, the mid front vowel /e/ and the mid central vowel /ə/ had the lowest classification results.

Table 3

Classification Results of Argobba Vowels Using F0, F1, F2 and F3.

Vowel	Predicted Group Membership							Total
	ə	u	I	a	e	ɨ	o	
ə	60.6	0.5	0.3	19.4	1.7	12.5	5	100
u	0.3	61.6	0.9	0.3	1.6	7.7	27.7	100
i	0.3	6.9	73.1		13.1	6.4	0.2	100
a	18.3			79.2	0.2	0.5	1.9	100
e	3.4	1.9	27.2	0.2	48.1	15.6	3.6	100
ɨ	8.8	4.7	7	0.3	12.3	62.3	4.5	100
o	6.3	28.6	0.2	0.3	2.3	2.8	59.5	100

Hence, based on the analyses conducted so far, one can conclude that the three point vowels which have a "special status in theories of vowel systems" (Escudero, Boersma, Rauber & Bion, 2009, p.5) had high classification results while the mid vowels had lower results. In addition, classification results of vowels were higher in the analysis using F0, F1 and F2 than using F1, F2 and F3.

Discriminant analysis for separate dialects but collapsed gender. In the second discriminant analysis that dealt with separate dialects but collapsed gender, using F1 and F2 values, the vowels of the Shonke dialect were better classified (61%) than the vowels of the Gachinne dialect (57.6%) based on the result of selected original grouped cases. In both dialects, the contribution of F1 and F2 were significant (Wilks' Lambda <0.001) with higher contribution of F1 than F2 in Shonke, and vice versa in Gachinne. In both dialects, the low vowel [**a**] had still the highest classification result as presented in Table 4 and Table 5.

Table 4

Classification Results of Vowels for Separated Dialect across Collapsed Gender Based on F1 and F2 Values: The Shonke Dialect

Vowel	Predicted Group Membership							Total
	ə	u	i	A	e	ɨ	o	
ə	36.9	1.3	0.6	29.2	5.6	21.3	5.2	100
u	0.2	69.6			0.4	4.6	25.2	100
i	0.2	2.5	76.3		14.8	5.8	0.4	100
a	14	0.4	0.2	80	0.2	2.9	2.3	100
e	2.5	1.7	27.3		55.2	9.6	3.8	100
ɨ	12.3	6.7	6.3	0.8	16.7	51.3	6	100
o	4.4	29.6		1.9		3.5	60.6	100

Table 5

Classification Results of Vowels for Separated Dialect across Collapsed Gender Based on F1 and F2 Values: The Gachinne Dialect

Vowel	Predicted Group Membership							Total
	ə	u	i	A	e	ɨ	o	
ə	45.2	2.9	0.4	21.9	1	17.7	10.8	100
u	2.5	43	3.1	0.4	1.7	10.6	38.5	100
i	1.3	9.2	57.3	1	19.2	8.8	3.3	100
a	15	1.5	0.8	75.2	0.2	1.5	5.8	100
e	1.3	3.5	23.3	0.8	55.2	11	4.8	100
ɨ	12.3	9.8	6.9	0.2	7.5	61.9	1.5	100
o	2.1	27	0.4		0.4	5	65.6	100

When F0 was combined with F1 and F2 values, nearly 63% and 61% of selected original grouped cases of the Shonke and Gachinne dialects' vowels were correctly classified respectively. In both dialects, the contribution of F0 is very poor and insignificant. Besides, the low vowel /a/ had highest classification result in both dialects, and /ə/ had the lowest in Shonke dialect while /u/ had the lowest result in Gachinne's.

Similarly, the analysis using F1, F2 and F3 values for separated dialect across collapsed gender showed that the Shonke and Gachinne dialects were correctly classified 62.6% and 58.9% on selected original grouped cases respectively. However, the result was lower than the result obtained from F0, F1, and F2. The contribution of F3 was very poor.

In both dialects, the low vowel /a/ had highest classification result of 80.6% in Shonke and 75.2% in Gachinne. As to the lowest value, /ə/ had the lowest result of 37.9% in Shonke and 44% in Gachinne based on selected original grouped cases.

Discriminant analysis for separate genders but collapsed dialect. The third discriminant analysis was made for separate genders but collapsed dialect. The discriminant analysis results of male and female subjects' vowels based on F1 and F2 values showed 62.8% and 57.6% of selected original grouped cases being correctly classified respectively. The contribution of both F1 and F2 were significant (Wilks' Lambda <0.001) in both genders. The front vowel [i] had the highest classification result (79.6%) in male subjects, but it was the low vowel [a] that had the highest classification result (75.2%) in females' values based on selected original grouped cases. The middle front vowel /e/ had the lowest (44.8%) classification result in males' while the back vowel /u/ had the lowest (43.1%) in female subject vowels based on selected original grouped cases.

Table 6

Classification Results of Vowels for Separated Gender across Collapsed Dialect Based on F1 and F2 Values: Male

Vowel	Predicted Group Membership							Total
	ə	u	i	A	e	ɨ	o	
ə	55.6	2.1	0.4	22.9	1	15.2	2.7	100
u	1.3	72.1	0.8	1.7	0.4	6	17.7	100
i	0.4	7.3	79.6	0.6	6.7	5	0.4	100
a	21	0.4	0.2	74.4	0.2	1.5	2.3	100
e	2.3	1.9	35	1	44.8	9.2	5.8	100
ɨ	11.7	5.4	11		19.8	48.3	3.8	100
o	3.3	26.9	0.2	0.8	0.2	4	64.6	100

Table 7

Classification results of vowels for separated gender across collapsed dialect based on F1 and F2 values: female

Vowel	Predicted Group Membership							Total
	ə	u	i	a	e	ɨ	o	
ə	45.2	2.9	0.4	21.9	1	17.7	10.8	100
u	2.5	43.1	3.1	0.4	1.7	10.6	38.5	100
i	1.3	9.2	57.3	1	19.2	8.8	3.3	100
a	15	1.5	0.8	75.2	0.2	1.5	5.8	100
e	1.3	3.5	23.3	0.8	55.2	11	4.8	100
ɨ	12.3	9.8	6.9	0.2	7.5	61.9	1.5	100
o	2.1	26.5	0.4		0.4	5	65.6	100

Discriminant analysis result of vowels based on F0, F1, and F2 values showed 63.1% of males' and 60.7% of females' vowels of selected original grouped cases were correctly classified. The contribution of F0 was significant in both genders; however, its separation rate was very low. The low vowel /a/ had the highest classification result in both genders: 76.3% in males' vowels and 73.3% for that of females' vowels. In male subjects' vowels /e/ had the lowest (46.9%) measure while the back vowel /u/ had the lowest, 43.1% value in females' vowels.

In the same way, the analysis result of vowels based on the first three formants' values showed 62.7% and 58.9% of male and female vowels of selected original grouped cases were correctly classified respectively. In both genders, the separation rate of F3 was very low, but higher than F0. For male and female subjects' vowels, the front vowel /i/ and the low vowel /a/ had the highest classification results of 78.5% and 75.2% respectively. The mid-vowel /e/ and the high-back vowel /u/ had the lowest classification results of 46.9% (for males') and 44% (for females') based on selected original grouped cases.

Discriminant analysis for separate genders and dialects. In the fourth and last discriminant analysis, the classification was made for separate genders and dialects. The classification results for separated genders and dialects using F1 and F2 values for Gachinne male speakers' vowels were the highest (62.8 %) followed by Shonke female speakers' vowels (61.4%) and Gachinne female speakers' vowels (57.6). Shonke males' vowels' classification results were the lowest of all: 56.1%. In this analysis, F2 had a slightly higher contribution than F1. Besides, the separation rate of F2 was higher for the Gachinne dialect than for the Shonke one. The contribution of F1 was higher for males than for females in both dialects.

Table 8

Classification results for separated dialect and gender based on F1 and F2

Dialect	Gender	Vowel	Predicted Group Membership							Total
			ə	U	i	a	e	ɨ	o	
Shonke	Male	ə	49.8		0.2	25.6	5.8	10.6	7.9	100
		u	1	68.1	7.3	0.2	2.7	6	14.6	100
		i		21.3	66.3		8.5	3.1	0.8	100
		a	24.4		0.2	74.8		0.2	0.4	100
		e	5.4	7.1	19.4	0.4	48.3	13.3	6	100
		ɨ	9.8	15.6	13.5	0.6	21.3	32.7	6.5	100
		o	8.5	24.8	2.5	1	7.1	3.5	52.5	100
	Female	ə	36.9	1.3	0.6	29.2	5.6	21.3	5.2	100
		u	0.2	69.6			0.4	4.6	25.2	100
		i	0.2	2.5	76.3		14.8	5.8	0.4	100
		a	14	0.4	0.2	80	0.2	2.9	2.3	100
		e	2.5	1.7	27.3		55.2	9.6	3.8	100
		ɨ	12.3	6.7	6.3	0.8	16.7	51.3	6	100
		o	4.4	29.6		1.9		3.5	60	100
Gachinne	Male	ə	55.6	2.1	0.4	22.9	1	15.2	2.7	100
		u	1.3	72.1	0.8	1.7	0.4	6	17.7	100
		i	0.4	7.3	79.6	0.6	6.7	5	0.4	100
		a	21	0.4	0.2	74.4	0.2	1.5	2.3	100
		e	2.3	1.9	35	1	44.8	9.2	5.8	100
		ɨ	11.7	5.4	11		19.8	48.3	3.8	100
		o	3.3	26.9	0.2	0.8	0.2	4	64.6	100
	Female	ə	45.2	2.9	0.4	21.9	1	17.7	10.8	100
		u	2.5	43.1	3.1	0.4	1.7	10.6	38.5	100
		i	1.3	9.2	57.3	1	19.2	8.8	3.3	100
		a	15	1.5	0.8	75.2	0.2	1.5	5.8	100
		e	1.3	3.5	23.3	0.8	55.2	11	4.8	100
		ɨ	12.3	9.8	6.9	0.2	7.5	61.9	1.5	100
		o	2.1	26.5	0.4		0.4	5	65.6	100

As to the results for each of the vowels, the low vowel /a/ had high classification result for all dialects and genders except for Shonke males' vowels. In Shonke males' vowels', it was the front vowel /i/ that had the highest classification result. There were different vowels with the lowest classification results for each dialect and gender: /ɨ/ for Shonke males', /ə/ for Shonke females', /e/ for Gachinne males', and /u/ for Gachinne females' vowels.

When the same analysis was conducted by combining F3 with F1 and F2 values, there was a little improvement in classification rate though the contribution of F3 was very low. In this analysis, the classification results for Gachinne male speakers' vowels were the highest (62.7 %) followed by Shonke female speakers' vowels (62.6%) and Gachinne female speakers' vowels (58.9). The Shonke male speakers' vowels' classification result was still the lowest of all: 56.8%.

The classification results for each of the vowels showed that the high vowel /i/ had the highest classification results for Shonke (79.6%) as well as Gachinne male speakers (78.5). The low vowel /a/ had the highest classification results in both dialects' female speakers with an identical value of 75.2%. For male speakers, the mid vowel /e/ had the lowest classification result. But for females it was the back vowel /u/ which had the lowest result.

4. Discussion

4.1 Discussion on Vowel Inventory and Vowel Space of Argobba

Results of the acoustic analysis of Argobba vowels indicate that the front-back contrasts of vowels are categorized into three groups: front, central, and back. In this regard, the present findings are in line with articulatory studies conducted on the language (Leslau, 1997; Ahmed & Girma, 2002 E.C; Getahun, 2009; Girma, 2013, 2014).

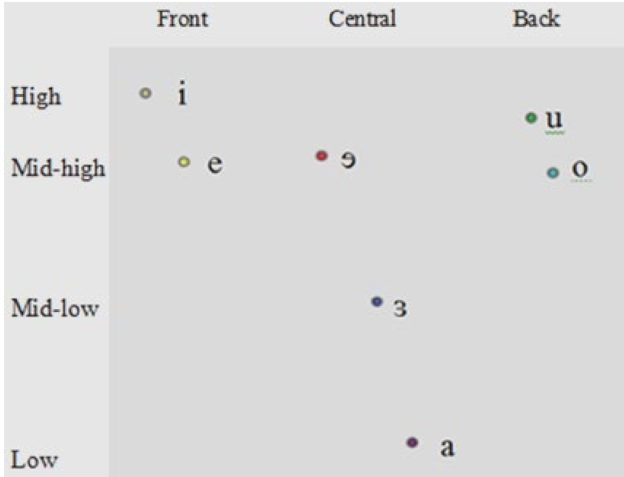
However, in terms of vowel height, the present finding is different from previous studies which categorized vowels into three heights. According to the present study, vowels are categorized into four heights: 2 high vowels (front /i/ and back /u/), 3 mid-high vowels (front /e/, central /ɨ/ and back /o/), 1 mid-low vowel (central /ə/), and 1 low vowel (central /a/). Besides, in this study, unlike the previous descriptions, the central vowels /ɨ/ and /ə/ were shifted to one step lower. Of course, phoneticians argued that articulatory descriptions are not entirely satisfactory to determine vowels' plots. They are often not in concurrence with the actual articulatory facts (Lodge, 2009; Ladefoged & Johnson, 2011). Therefore, we suggest that the acoustic measure of the present study deserves to be taken as appropriate to determine the Argobba vowel heights.

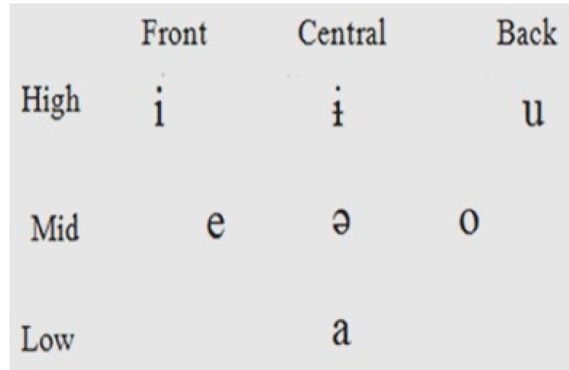
Hence, as per the results of this study, the location of the vowel /ɨ/ is a mid-high vowel. According to Lipinsky (1997), Semitic vowels (including Argobba) have no high-central vowel /ɨ/, at least in the vowel space illustration. In the same token, in both dialects of Argobba, /ə/ is a mid-low vowel, not a middle vowel (schwa). This finding is also supported by a previous study conducted on Argobba (Wetter, 2010).

Thus, the appropriate symbols suggested for the mid-high and for the mid-low vowels should be /ɘ/ and /ɜ/ respectively, as far as these symbols are proposed by the International Phonetic Association (IPA) (2015) for the same vowel heights[4]. This finding is consistent with the results on Amharic vowels (a language very similar to Argobba than any other Ethio-Semitic language), where the seven vowels are presented with four heights (Derib, 2011). Yet in articulatory explanations, Amharic vowels were described with three heights just like the previous studies done on Argobba.

Accordingly, as depicted below in *Figure 12,* a new vowel chart is proposed for Argobba.

[4] *Concerning the dispute to choose appropriate symbols for central vowels, see Derib (2011:152).*





a) b)

Figure 12. A comparison of proposed Argobba vowel chart with its articulatory a) acoustic representation (proposed chart) and b) articulatory representation

The vowel space in the articulatory demonstration assumes that the vowels are located on the sides of an equilateral triangle with equal spaces among each vowel in terms of height and backness. However, based on the acoustic values, high and mid-high vowels are not scattered apart as much as the mid-low and low vowels. There are studies which support this finding: the locations of mid-low and low vowels are far apart from each other than the dimension between high and mid-high vowels in other Semitic languages (Lipinsky, 1997; Derib, 2011).

The other feature of Argobba vowel chart is that, among central vowels, the lower ones are sliding to the back while the higher ones are sliding to the front dimension. The vowel chart of Amharic also showed similar properties (Derib, 2011). In some instances, the same has been seen in the dimension of the Oromo low vowel too (Tujube, 2017). In addition, as mentioned above, the locations of central vowels /ɨ/ and /ə/ are shifted to mid-high and mid-low spaces. Hence, it is possible to conclude that the height of the central vowels is being lowered further. But, what could be the reason for the shift?

Vowel shift, including The Great Vowel Shift occurred in English, is a common phenomenon in other languages too (Peterson and Barney, 1952, *p*.178). The cause has been a subject of debate among scholars. For example, for the Great Vowel Shift, some maintained migration of peoples in England caused a mixing of accents that forced a change in the vowels' pronunciation (Wolfe, 1972) while others argued French loanwords were considered a big player in the shift (Millward & Hayes, 2011). In the case of Argobba (possibly for Amharic and other South Ethio-Semitic languages too), we suggest two possible causes for the shift/change of vowels' location.

First of all, earlier articulatory descriptions of Argobba vowels might not depict the phenomenon accurately as linguists identify vowels mainly by hearing, which is quite subjective. The other cause might be the influence of Cushitic languages such as Oromo on Argobba. As it is stated earlier, Argobba has been replaced with Oromo in many places. Hence it is most probable that Argobba has been influenced much by Oromo.

A comparison of the two dialects' vowel spaces showed that the Shonke dialect's vowel spaces were larger than the Gachinne dialect in both genders. Besides, in Gachinne dialect, specially, in Gachinne males, the high-back vowel /u/ is not as high as its front equivalent /i/. Rather it is demarked almost in the dimension of a high-mid vowel.

In addition, the vowel space of Gachinne dialect was asymmetrical. However, as studies conducted on other languages, this kind of vowel dimension has been seen in several languages (Pätzold & Simpson, 1997, German vowels; Derib, 2011, Amharic vowels; Williams, 2013, Northern Standard Dutch; Lee & Jongman, 2016, Korean dialects). Moreover, according to Adank and Roeland (2004, p.1734), asymmetrical vowels' dimension occurs when "back vowels" are not in universal symmetry where the high vowel /u/ has higher F2 than lower /ɔ/ for both men and women, and dialects".

4.2 Discussion on F0, F1, F2, and F3 Values of Argobba Vowels

The fundamental frequency of Argobba vowels was found to be significantly different along with vowels height: high vowels F0 was higher than the low vowels, conforming to previous studies and the universal on F0 (Peterson & Barney, 1952; Most *et al*., 2000; Fox & Jacewicz, 2014; Tujube, 2017). Besides, the back vowels F0 values were relatively lower than the values for the front vowels in both dialects. The relation between F0 and vowel quality is complicated and indirect (Barreda & Nearey, 2012). So, except for vowel height, it is difficult to conclude whether the relation between Argobba vowels' quality and their F0 value is direct or not.

As to F1 measures, it is expected that high vowels score low F1 values while low vowels score high F1. Consequently, the low vowel /a/ had the highest F1 and high vowels (/i/ and /u/) scored the least F1 value, where the high front vowel /i/ scored the least of all. In addition, in all genders and dialects, high back vowels F1 values were higher than the formant values of high front vowels. These are not specific to Argobba: they are language universal acoustic properties (Hillenbrand *et al*., 1995; Lodge, 2009; Derib, 2011; Tujube, 2017). Similarly, F2 and F3 values of Argobba front vowels were higher than the F2 and F3 values of back vowels. This is also common for other languages too (Ladefoged & Maddieson, 1996; Lodge, 2009). Likewise, F3 value of Argobba low vowel /a/ was less than front vowels, just as other languages did (Derib, 2011; Williams, 2013).

Consonantal contexts of voice had statistically significant effects on vowels' F0 and formants: vowels following voiceless consonants had higher F0 and formants' (F1, F2 and F3) values than vowels following the voiced ones, which is also common in other languages (Maddieson, 1997). Similarly, vowels followed by geminate consonants had higher F0 and formants' (F1, F2 and F3) values than those followed by nongeminate consonants. Recent findings confirmed that variation in consonantal context affects vowel acoustics within and across languages (Hillenbrand & Gayvert, 1993;; Derib, 2011;Williams & Escudero, 2014; Palmer, 2015).

In the same way, the study showed that gender and dialect had a statistically significant effect on the acoustic values of Argobba vowels. Hence, in Argobba, females' F0 and formant values were higher than males' F0 and formant values. This is also universally true since the first study by Peterson and Barney (1952), who reported adult females and children exhibited much higher F0, F1, F2, and F3 frequencies than adult males, because of the difference in the vocal tract length of children, females, and males (Ladefoged, 2001; Escudero *et al*., 2009).

In terms of dialect, the Shonke dialect had higher vowel acoustic values than the Gachinne dialect. This finding is consistent with other studies (Adank & Roeland, 2004; Clopper *et.al*., 2005; Palmer, 2015; Tujube, 2017) where dialect can alter vowels' acoustics.

4.3 Discussion on the Discriminant Analyses of Argobba Vowels

Based on the discriminant analyses conducted on Argobba vowels, except few exceptions, the three-point vowels which have a "special status in theories of vowel systems" (Escudero & Boersma, 2009) had high classification results while the mid vowels had lower results.

However, discriminant analysis for Argobba vowels (based on F1 and F2) has lower classification results (59.1%) than found for American English vowels (74.9%) by Peterson and Barney (1952) and (68.2 %) by Hillenbrand *et al*. (1995); Amharic vowels (more than 84%) by Derib (2011) and Oromo (69.7%, for short vowels) by Tujube (2017). Tujube (2017) also noticed that the Wollo dialect of Oromo classification result was very poor. "This may lead us to conclude that the vowel of the Wollo dialect was greatly influenced by other languages" (Tujube, 2017, p. 99). The same might be true for Argobba, but this time the influence comes from Oromo and Amharic.

Argobba is spoken in an area where several speech communities live with similar cultures including religion. Consequently, there is higher linguistic interaction. As a result, a feature of one language could affect others. Particularly Oromo's influence on Argobba is high.

In the same token, several evidences indicate the influence of Arabic on Argobba vowels. In many instances, Argobba speakers shift the mid-vowels (/e/ and /o/) to their equivalent high vowels (/i/ and /u/), as in */hal**o**/* > */hal**u**/* 'hello', */am**e**n/* > */am**i**n/* *'let* it be'. Therefore, it bids us to conclude that Argobba vowels classification results became very poor due to the influence of adjacent languages.

5. Conclusions

According to the findings, high vowels F0, F2, and F3 values were higher than the lower ones. Besides, front-back acoustic values of vowels showed different patterns: accordingly, F0, F2 and F3 values of front vowels were higher than back vowels, and front vowels F1 was lower than the back ones.

Argobba vowels between voiceless consonants had higher acoustic values (F0, F1, F2, and F3) than vowels between voiced consonants. In addition, vowels following a voiceless consonant had higher acoustic values than vowels following a voiced one. Likewise, vowels followed by geminate consonant had higher acoustic values than those followed by nongeminate consonants.

Generally speaking, all acoustic values of the Shonke dialect were higher than the Gachinne dialect. Similarly, the vowels of female speakers have higher F0 and formant values than that of the males' vowels. As a result, the vowel space of the Shonke dialect is larger than the Gachinne dialect in both genders; and the females' vowel space is larger than males' vowel space in both dialects too.

The study pointed out that there is a significant difference between acoustic representation and articulatory representation vowel plots of Argobba. Unlike the articulatory representation of Argobba vowel space, the acoustic values of Argobba vowels showed that the vowels were divided into four heights. In addition, the central vowels of Argobba were shifting one step to the lower dimension. Thus, a new vowel chart is proposed based on the findings, as illustrated in *Figure 12*.

However, there is no difference between acoustic and articulatory vowel plots in terms of front-back vowel contrast. Accordingly, in both representations, vowels were classified in three categories.

Most of acoustic features of Argobba vowels were universal or near universal. Thus, the effects of gender, dialect, and consonantal contexts on Argobba vowels' F0 and formants were common in other languages too. In addition to this, the results showed that Argobba is in the process of vowel shift as other languages did.

There are also dialect/language specific features of Argobba. The vowel space of Gachinne dialect was asymmetrical. In addition, the result of discriminant analysis of Argobba vowels was very poor.

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Authors' contributions:

1. Yimam Mohammed: developed the proposal, collected data, analysed data, and wrote the manuscript as part of his PhD dissertation.
2. Derib Ado: is the main and sole supervisor in the PhD program. He commented on the proposal, data collection tools, the segmentation of the vowels, and the analysis and the manuscript.

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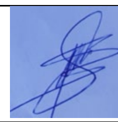
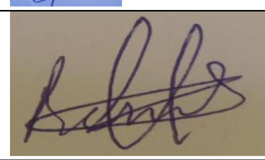
Competing of Interest

The authors declare that there is no conflict of interest.

Declarations of Corresponding author: This study is a part of the PhD dissertation, *Documentation and Acoustic Analysis of the Vowels of Argobba Dialects,* which is in preparation under the supervision of Dr. Derib Ado. The topic of this study is quite different from any other studies published (or to be published) on any other journals, but only related to them under the umbrella of the PhD dissertation.

Consent for publication

We have agreed to submit to the Journal of Social Sciences and Language Studies and approved the manuscript for submission.

Authors name in sequence	Signature of authors
Yimam Mohammed (corresponding Author)	
Dr. Derib Ado	

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