QUALITY OF JAVANESE AND SUNDANESE VOWELS

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Abstract
The vowel quality of Javanese and Sundanese is influenced by phonation types. The acoustic measurements of the differences in phonation between all Javanese and Sundanese vowels have not been instrumentally examined. Evidence suggests that F_1 lowering is a common characteristic of vowel quality correlated with the phonation after the slack-voiced stop /b/. The current study seeks to extend the possible variation in the realization of phonation by Javanese vowels /i/, /e/, /a/, /ə/, /u/ and /o/ and Sundanese vowels /i/, /a/, /ə/, /ɨ/, /e/, /u/ and /o/ after the slack-voiced /b/ and the voiceless glottal /h/. In this experiment, the authors recorded the vowel production of four Javanese and four Sundanese native speakers and measured the formant frequencies (F_1 and F_2). The results confirm that Javanese and Sundanese vowels are constantly pronounced with lower F_1 after /b/. In addition, the Javanese speakers articulate the vowel /ɘ/ rather than schwa /ə/ in the slack-voiced /b/ and voiceless glottal stop /h/, in which the vowel occupies the high-mid central position of the vowel space area. The Sundanese speakers in this study surprisingly produce the expected high vowel /ɨ/ in the high near-front of the vowel space; it is suggested to transcribe this as /ʏ/. The results of the formant frequencies of the Javanese and Sundanese vowels are consistent with the study by Hayward (1993) indicating F_1 lowering after the slack-voiced /b/.

Keywords: acoustic analysis, duration, formants, vowel quality, vowel quantity
ISO 639-3 codes: jav, sun, ind

1 Introduction

Javanese has the most first-language speakers of any Austronesian language (Ogloblin 2005; Oakes 2009). Javanese is spoken by about 65 million people and considered the thirteenth most widely spoken language in the world (Comrie 2003). Nothofer (1982) classifies Javanese as a branch of the Malayo-Polynesian subgroup, which includes Malay, Madurese, Sundanese and Lampung. Javanese is spoken primarily in the central and eastern region of Java Island (Oakes 2009). There are three dialects of Javanese, which are mutually intelligible: Solo and Yogyakarta, East Java, and West Java dialects (NVTC 2007; Cole, Hara, & Yap 2008). The Solo and Yogyakarta dialects are spoken in the center of Java Island and are considered the standard form of Javanese. The East Java dialect is spoken in Surabaya, Malang and Pasuruan, and the West Javanese dialect is spoken in Banten, Cirebon and Tegal (Gordon 2005). The present study examines the vowel quality of the Solo and Yogyakarta dialect and Bogor/ Karawang dialect.

Sundanese is spoken by approximately 34 million people in Indonesia, making it the second most widely spoken language in Indonesia after Javanese (Lewis 2009). Sundanese is spoken in the western half of the island of Java (Hardjadibrata 1985) (see Figure 1). Sundanese has four dialects: Banten, Bogor/Karawang, Priangan and Cirebon (Muslim, Haerani, Motohiko, & Hiroshi 2010). The Banten dialect is spoken in Karesidenan Banten; the Bogor/Karawang dialect is spoken in Tangerang, Bogor, Purwakarta, Krawang and Subang; the Priangan dialect is spoken in Karesidenan Priangan, and the Cirebon dialect is spoken in Karesidenan Cirebon, Brebes and Cilacap. Sundanese is distinguished into four speech levels: high *basa lemes*, neutral *basa sedeng*, everyday *basa kasar*, and low *basa tjohag* (Harjadibrata 1985; Campbell 1995). The subjects in the current study spoke the Bogor/Karawang dialect of Sundanese.

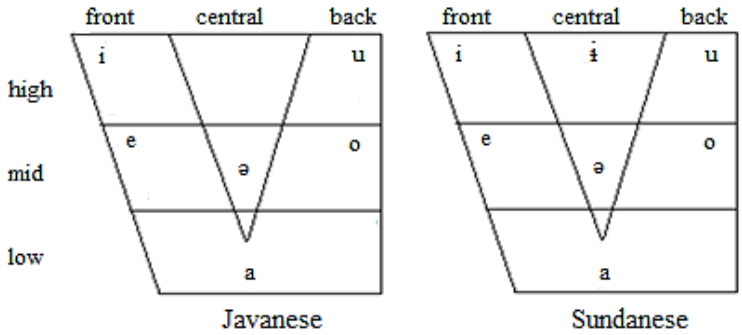
Figure 1: *Map of Traditional Languages in Java Island*

2. Javanese and Sundanese Vowels

Traditional analysis of the Javanese vowel inventory claims that Javanese has eight vowel phonemes: 6 phonemes and 2 additional pairs (Uhlenbeck 1963; Horne 1961; Clynes & Rudyanto 1995). Gordon (2006) claims that the phonemes /ɛ/ and /ɔ/ are in complementary distribution with /e/ and /o/, respectively. Other studies confirm that Javanese vowels are grouped into 6 phonemes and 4 allophonic pairs: /i/-/ɪ/, /u/-/ʊ/, /e/-/ɛ/, and /o/-/ɔ/ (Dudas 1976; Hayward 1999; Wedhawati et al. 2006; Nothofer 2009). These vowels are traditionally classified as high front /i/, high back /u/, mid front /e/-/ɛ/, mid central /ə/, mid back /o/-/ɔ/, and central low /a/. While /i/ and /u/ are realized as /ɪ/ and /ʊ/ in closed syllables, /e/ and /o/ are realized as /ɛ/ and /ɔ/ in closed syllables, in open syllables where the vowel in the following open syllable is high, and in open syllables where the vowel in the following syllable is identical (Wedhawati et al. 2006).

With respect to vowel inventories, Sundanese has seven vowels (Crothers 1978; Sudaryat et al. 2007). According to Crothers (1978) and Sudaryat et al. (2007), Sundanese vowels are classified as high front /i/, high central /ɨ/, high back /u/, mid front /e/- /ɛ/, mid central /ə/, mid back /o/-/ɔ/, and central low /a/. Conforming to the standardized orthography evidenced in Tamsyah (1996), Hardjadibrata (2003) and Danadibrata (2006), Kurniawan (2013) mentions that the vowel /ɨ/ represents a lax central unrounded vowel and is produced in a higher position than the schwa /ə/. The Javanese and Sundanese vowel inventories are illustrated in Figure 2.

Figure 2*: Traditional view of Javanese vowel inventory (left) (Dudas 1976; Hayward 1999; Wedhawati et al. 2006) and Sundanese (right) (Crothers 1978; Sudaryat et al. 2007).*



2.1 Vowel Quality in Javanese and Sundanese

Vowel quality in the Javanese and Sundanese languages is influenced by phonation differences, which are correlated with the stops in preceding vowels (Fagan 1988; Hayward 1993, 1995; Thurgood 2004). Fagan (1988) analyses acoustic differences between the slack-voiced stops /b/, /d̰/, /ḍ/, /g/ and the stiff-voiced stops /p/, /t̰/, /ṭ/, /k/ followed by vowel /a/. His study shows that that Javanese slack-voiced stops are characterized by a lower f_0 (except when followed by a velar), a lower F_1 and a higher F_2. The vowel /a/ was articulated with a significantly lower F_1 after voiced stops. Fagan (1988) claims that vowels following stiff-voiced stops are pronounced with a clear voice; while vowels following slack-voiced stops are pronounced with breathy voice.

A later investigation by Hayward (1993) yields similar results: Javanese vowels are pronounced with lower F_1 and F_0 after the slack-voiced /b/. She also observed a higher F_2 after voiced stops. Hayward (1995) extends her study by comparing the Voice Onset Time (VOT) of the stiff-voiced /p/ and the slack-voiced /b/, as well as the vowels /i/, /u/, /ɔ/ and /a/ following the stops. Her study shows that Javanese slack-voiced stop /b/ is characterized by having a lower F_0 at the vowel onset and was pronounced with longer VOT.

In her acoustic study of Javanese vowels /u/, /ɔ/ and /a/, Thurgood (2004) found that vowels after the stiff-voiced stops /p/, /k/ or the slack-voiced stops /b/, /g/ have less different formant frequencies. The vowel /a/ is the only vowel which is characterized as having a lower F_0 after the voiced stops. The vowel /ɔ/ was articulated with a lower F_0 after a velar stop, but higher F_0 after a bilabial stop. The vowel /u/ was articulated with a higher F_0 for bilabial and velar stops. The lowering of F_1 after slack-voiced stops did not occur in all vowels. The vowel /u/ was pronounced with a higher F_1 after slack-voiced stops at all places of articulation. The raising of F_2 was found after slack-voiced stops in all vowels.

A recent study by Gordon et al. (2012) reported the first formant values of Javanese vowels across two speakers and found that the first formant frequencies distinguished five vowel phonemes. The height of the Javanese mid vowels /e/ and /o/ was slightly lower than that of the schwa /ə/. Although Gordon et al. (2012) did focus on the first formant frequency, maximum intensity, acoustic energy and perceptual energy of the vowels, the study did not measure the second formant frequency, which might be useful in mapping the standardized representation of the sounds of spoken Javanese vowels. In summary, the previous studies shows the acoustic characteristics of Javanese vowel quality are typically described as slack voiced vowels. The slack-voiced vowels are shown on the vowels and characterized by a lower F1 and F_0.

With regard to Sundanese vowels specifically, Kulikov (2010) conducted an acoustical analysis which compares the phonation differences between the voiced /b/, /d/, /g/ and voiceless stops /p/, /t/, /k/ in seven Sundanese vowels /i/, /a/, /ə/, /ɨ/, /ɛ/, /u/ and /o/. Kulikov's study shows that the phonation of vowels after voiceless and voiced stops is characterized with breathy voice. The vowels /a/, /ə/, /ɛ/ /o/ are pronounced by the changing of F_1 and F_2 after voiced stops.

The current study sets to extends those of Fagan (1988), Hayward (1993, 1995) and Thurgood (2004) by investigating Javanese vowels /i/, /e/, /a/, /ə/, /u/ and /o/ (Dudas 1976; Nothofer 2009; Clynes 1995) and Sundanese vowels /i/, /a/, /ə/, /ɨ/, /e/, /u/ and /o/ (Crothers 1978; Sudaryat et al. 2007) after the slack-voiced /b/ and the voiceless glottal /h/. The word initial segment /h/ was interesting to examine since Sundanese is characterized as having only voiceless alveolar /s/ and glottal /h/ as fricatives (Robins 1953; Kulikov 2010). Thus, the authors of this study predict that the Javanese and Sundanese vowels after the slack voice /b/ are pronounced with lower F1 than the voiceless glottal /h/.

Overall, the present study is aimed at characterizing the vowel quality of Javanese and Sundanese vowels. Additionally, we investigated the role of consonantal context /b/ vs /h/ on vowel quality.

3. Materials and Methods

3.1 Participants

The authors collected speech data from 4 L1 Javanese speakers (2 male, 2 female, M_{age} = 34.75, SD = 6.9) and 4 L1 Sundanese speakers (2 male, 2 female, M_{age} = 35, SD = 4.7). The participants use the Javanese or the Sundanese language for daily interactions. The Javanese participants speak the Solo and Yogyakarta dialect while the Sundanese participants speak the Priangan dialect. All the participants demonstrated normal speech and hearing abilities.

3.2 Stimuli

In the data collection, the participants produced six Javanese vowels /i/, /e/, /a/, /ə/, /u/ and /o/ and seven Sundanese vowels /i/, /a/, /ə/, /ɨ/, /e/, /u/ and /o/ were inserted in /bVC/ and /hVC/ syllables. The target vowels and the syllables were prefaced by a carrier phrase, /*kula ngendika* _____*malih*/ "I say _____ again" for Javanese speakers, and /*abdi nyarios* _____ *deui*/ "I say _____ again" for Sundanese speakers. The participants read the lists (Table 1) three times in random order. In total, the Javanese dataset comprises 3 repetitions x 6 vowels x 4 speakers = 72 items, and the Sundanese dataset comprises 3 repetitions x 7 vowels x 4 speakers = 84 items.

***Table 1**: Javanese and Sundanese vowels in /bVC/ and /hVC/ contexts.*

Javanese vowel	Context	Target word	Transcription	English gloss	Sundanese vowel	Context	Target word	Transcription	English gloss
/a/	/bVC/	***ba** dhe*	/**ba**'dhe/	will (be)	/a/	/bVC/	***ba** tur*	/**ba**'tur/	colleague
/ə/		***be** cik*	/**bɔ**'cɪʔ/	main	/ə/		***be** legbeg*	/**bə**'ləgbəg/	murky
/i/		***bi** narung*	/**bi**'naruŋ/	in a row	/i/		***bi** tu*	/**bi**'tu/	explode
/o/		***bo** dho*	/**bo**'do/	stupid	/o/		***bo** lotot*	/**bo**'lotot/	goggle
/u/		***bu** deg*	/**bu**'dəg/	deaf	/u/		***bu** ni*	/**bu**'ni/	sealed
/e/		***be** lekan*	/**be**'leʔan/	sore eyes	/e/		***be** ntes*	/**be**'ntes/	clear
					/ɨ/		***beu** reum*	/**bi**'rɨm/	red
/a/	/hVC/	***ha** kekat*	/**ha**ke'kat/	truth	/a/	/hVC/	***ha** ndap*	/**ha**n'dap/	under
/ə/		***he** mpas*	/**hə**m'pas/	smash	/ə/		***he** nteu*	/**hə**n'tɨ/	no
/i/		*wa**hi**ng*	/wa'**hi**ŋ/	sneeze	/i/		***hi** deung*	/**hi**'diŋ/	black
/o/		***ho** bi*	/**ho**'bi/	hobby	/o/		***ho** ream*	/**ho**'ream/	lazy
/u/		*dhu**hu**r*	/du'**hu**r/	high	/u/		***hu** rung*	/**hu**'ruŋ/	sparkle
/e/		***he** bat*	/**he**'bat/	great	/e/		***he** rang*	/**he**'raŋ/	shine
					/ɨ/		***heu** rin*	/**hi**'rin/	narrow

3.3 Procedure

All participants were audio recorded one by one in a sound-attenuated room. Before the recording started, the participants filled in a demographic questionnaire and signed a consent form. Participants were then familiarized with the equipment, stimulus and procedures for the production experiment. The stimulus in the carrier phrase was shown on the computer screen in a random order. Immediately after a sentence appeared, participants read the lists in a natural tone. Recordings were made using a digital audio recorder (H4N Zoom) and an adjustable microphone headset (Sennheiser PC 141) at a 44.1kHz/16 bit rate. The microphone was hung 3 cm in front of the participants' mouths in order to create a constant sound recording for the entire session of every subject.

3.4 Analysis

Formant frequency (F_1 and F_2) values were manually extracted and in Praat (Boersma & Weenink 2013). Using Praat, the measurements were made by identifying the formant peak of the chosen time point and were measured at the midpoint of the steady state of the selected vowel. To plot in a vowel quadrilateral, the formant frequency measurements were converted to the Bark scale using the following formula: Zi = 26.81/(1+1960/Fi) - 0.53 (Traunmuller 1988).

Statistical analysis was carried out with the general linear model. Four separated repeated measures ANOVAs were conducted with F_1 and F_2 as dependent variables, and JavaVOWEL /i/, /e/, /a/, /ə/, /u/, /o/ or SundaVOWEL /i/, /a/, /ə/, /ɨ/, /e/, /u/, /o/ and SYLLABLE /bVC/, /hVC/ as independent variables. Pairwise comparison using a Bonferroni correction was used to control for Type 1 errors. The data were analyzed using SPSS Version 22.0 (IBM, 2013).

4. F_1 and F_2 formants of Javanese and Sundanese Vowels

Vowel quality was normalized across speakers for each target word. The following are the results of both languages.

4.1 Javanese

The separated repeated measures ANOVAs were conducted with the F_1 and F_2 values as dependent variables. The results showed a significant main effect of VOWEL on F_1 [$F(2.059, 6.177) = 15.344$, $p < .05$], but there was no VOWEL effect on F2 [$F(1.359, 4.077) = 3.836$, $p = .119$]. There was SYLLABLE effect on F_1 [$F(1, 3) = 30.363$, $p < .05$] but there was no SYLLABLE effect on F_2 [$F(1, 3) = .374$, $p = .584$]. There was no significant VOWEL * SYLLABLE interaction on F_1 [$F(1.159, 3.478) = 0.716$, $p = .621$] or on F_2 [$F(1.198, 3.593) = 2.011$, $p = .244$].

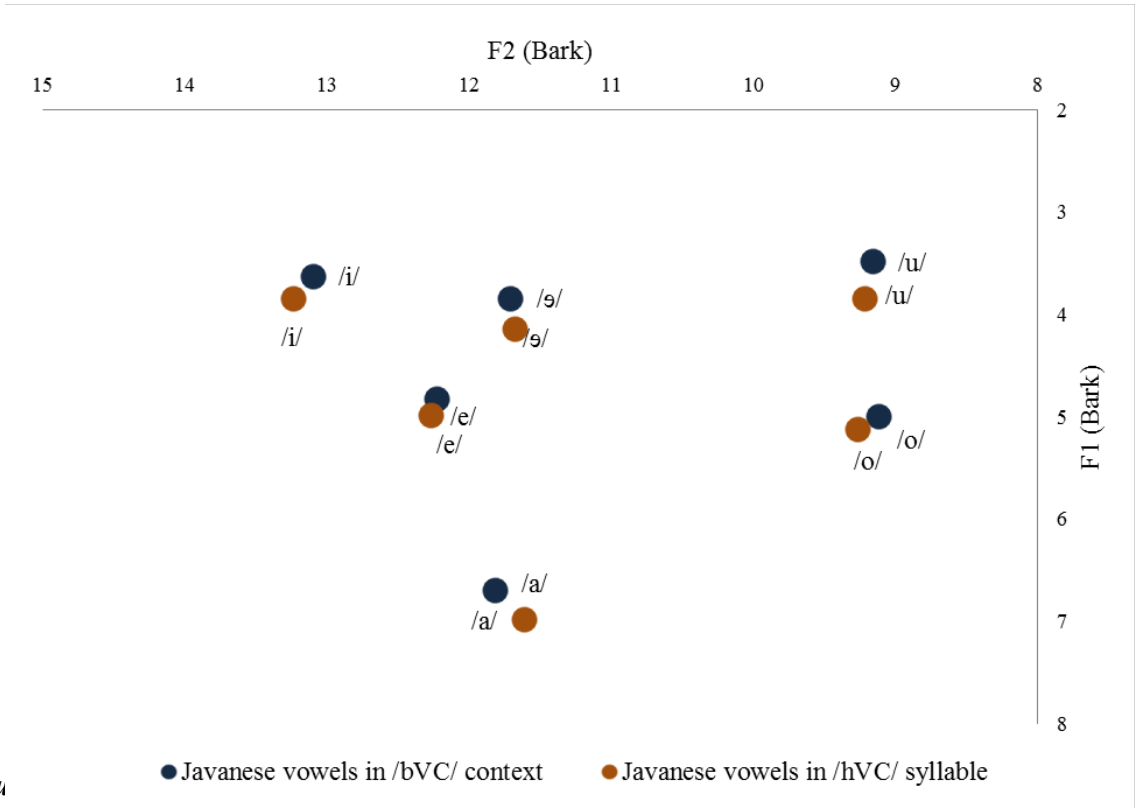
Table 2 further presents the summary of the mean F_1 and F_2 values of each of the six Javanese vowels uttered by four speakers of the Javanese language.

***Table 2**: F_1 and F_2 mean of the formant frequency values of each Javanese vowel.*

	F_1 /bVC/		F_1 /hVC/	
Javanese Vowels	**M**	**SD**	**M**	**SD**
/a/	621	127.6	778	115.7
/ə/	399	51.4	472	253.3
/i/	376	62.1	450	38.2
/o/	408	56.2	544	55.9
/u/	360	48.6	461	50.9
/e/	510	98.1	528	105.6
	F_2 /bVC/		F_2 /hVC/	
Javanese Vowels	**M**	**SD**	**M**	**SD**
/a/	1731	195.4	1596	133.5
/ə/	1885	198.4	1612	503.7
/i/	1551	1034.9	2044	337.8
/o/	1099	93.77	1153	151.1
/u/	1105	134.6	1116	271.2
/e/	1749	235.8	1894	399.1

The mean normalized plot of each of the six Javanese vowels produced by the four native speakers is displayed in Figure 3. It can be seen that the Javanese language has one high front vowel /i/, one mid near-front vowel /e/, one low near-front vowel /a/, one mid central vowel /ə/, one high back vowel /u/ and one mid back vowel /o/. Given its height occupying the high-mid central area of the vowel space (see Figure 3), a more accurate transcription of the Javanese schwa would be /ɘ/.

***Figure 3**: The quadrilateral vowel chart for Javanese vowels in /bVC/ and /hVC/ syllables.*



4.2 Su

The repeated measures ANOVAs were conducted with F_1 and F_2 as the dependent variables. The results showed a significant main effect of VOWEL on F_1 [F (1.768, 5.303) = 28.320, $p < .05$], and on F_2 [F (2.486, 7.457) = 33.387, $p < .001$]. There was SYLLABLE effect on F_1 [F (1, 3) = 10.696, $p < .05$] but not on F_2 [F

(1, 3) = 6.670, p = .082]. There was significant VOWEL * SYLLABLE interaction on F_1 [F (1.658, 4.973) = 8.477, p < .027], but there was no significant interaction on F_2 [F (1.320, 3.959) = 0.397, p = .619]. T-test with Bonferroni correction was conducted to see which Sundanese vowels have an effect of syllable. We adjusted the alpha level of .007 (.05/7 vowels).

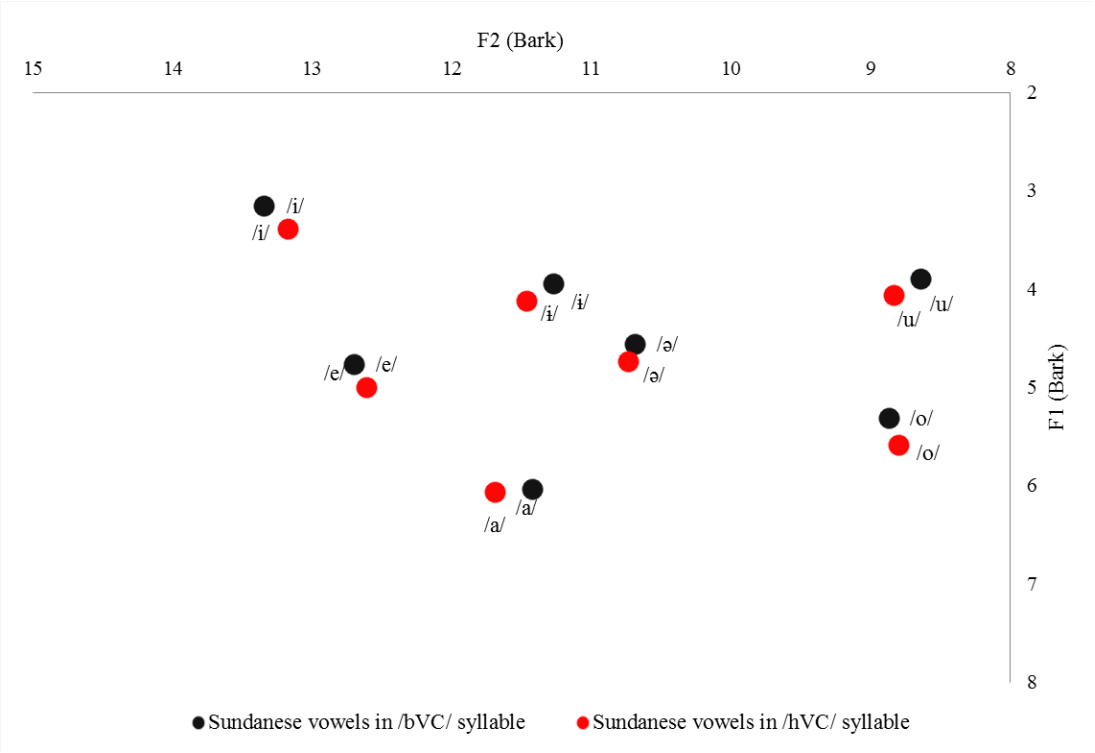
Table 3 further presents the summary of the mean F_1 and F_2 values and t-test results of each of the six Sundanese vowels, produced by the four Sundanese speakers.

***Table 3**: F_1 and F_2 means of the formant frequency values of each Sundanese vowel, * = p < .007.*

Sundanese Vowels	**F_1 /bVC/**		**F_1 /hVC/**			
	M	**SD**	**M**	**SD**	***t***	***p***
/a/	656	119.9	812	193.9	-4.098	0.026
/ə/	480	44.4	382	171.4	1.421	0.250
/i/	324	65.2	375	60.7	-10.961	0.002*
/o/	548	33.7	653	90.3	-3.16	0.051
/u/	406	68.8	443	48.1	-2.094	0.127
/e/	503	69.9	665	95.7	-10.757	0.002*
/ɨ/	411	75.1	456	105.5	-2.013	0.138
Sundanese Vowels	**F_2 /bVC/**		**F_2 /hVC/**			
	M	**SD**	**M**	**SD**	***t***	***p***
/a/	1500	182.9	1613	190.5	-1.484	0.234
/ə/	1390	200.9	1673	347.9	-1.646	0.198
/i/	2075	362.8	2229	272.7	-0.497	0.653
/o/	1057	125.8	1207	128.7	-9.476	0.002*
/u/	1020	93.9	1106	106.7	-10.274	0.002*
/e/	1878	272.9	1853	218.7	0.336	0.759
/ɨ/	1515	161.2	1619	222.9	-1.323	0.278

Figure 4 displays a normalized plot for every vowel among the Sundanese speakers. There are seven predominant vowels: a front vowel /i/, one mid near-front vowels /e/, one low near-front vowel /a/, a high near-front vowel /ɨ/, one mid central vowel /ə/, a high back vowel /u/ and one mid back vowel o/. Since vowel /ɨ/ occupies the high near-front area of the vowel space, a more accurate transcription would be /ʏ/.

***Figure 4**: The quadrilateral vowel chart for Sundanese vowels in /bVC/ and /hVC/ syllables.*



5. Discussion

Earlier studies on Javanese and Sundanese vowels have found that the vowel quality of these languages is influenced by different phonation types (Fagan 1988; Hayward 1993, 1995; Thurgood 2004). In the current study, the authors found that the F_1 values are lower for Javanese and Sundanese vowels production in the /bVd/ context than the /hVd/ context. The current study found F_1 lowering in the phonation of Javanese /i/, /e/, /a/, /ə/, /u/ and /o/ vowels and Sundanese /i/, /a/, /ə/, /ɨ/, /ɛ/, /u/ and /o/ vowels following the slack-voiced stop /b/. Altogether, the results are consistent with the study done by Hayward (1993), which mentioned that Javanese vowels are produced with lower F_1 after the slack-voiced /b/.

Visual inspection of the mean normalized plot has empirically shown that the Javanese language has a high front vowel /i/, a mid near-front vowel /e/, a low near-front vowel /a/, a mid central vowel /ə/, a high back vowel /u/ and a mid-back vowel /o/. Similar but not identical results of vowel inventory findings were obtained by Wedhawati et al. (2006). The current study shows that the Javanese speakers produce the vowel /ə/ rather than schwa /ə/ in both slack-voiced /b/ and voiceless glottal stop /h/ environments since the vowel occupies the high-mid central position of the vowel space area. In addition, the vowel /a/ was produced as a low near-front rather than a central low vowel.

The Sundanese speakers produced seven vowels: a front vowel /i/, a mid near-front vowel /e/, a low near-front vowel /a/, a high near-front vowel /ɨ/, a mid central vowel /ə/, a high back vowel /u/ and a mid-back vowel o/. Previous Sundanese vowel inventory studies claim that Sundanese has a high central vowel /ɨ/ (Crothers 1978; Sudaryat et al. 2007). It is somewhat surprising that high central /ɨ/ was not found in the acoustic measurements of the current study. This study demonstrates that the expected high vowel /ɨ/ is produced in the high near-front of the vowel space. Thus, we suggest that the vowel /ɨ/ should be transcribed as /ʏ/.

6. Conclusion

Previous research has presented the influence of phonation types on the vowel quality for Javanese and Sundanese. Therefore, the current study aims at extending the possible variation in the realization of the slack-voiced stop. This study provides evidence on the difference of phonation between the slack-voiced stop and the voiceless glottal stop by looking at formant frequency values. The lowering of F_1 in vowels after the voiced stop was found in Javanese and Sundanese vowel production.

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