CHAMLING BASIC VOWELS: ACOUSTIC ANALYSIS

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This study analyzes Chamling vowels acoustically. Fundamental and formant frequency values of the vowels have been measured for both the male and female speakers and their individual values have been calculated for the comparison. Then, the average values have been computed for the specification of the vowels through the acoustic measurement. Acoustic properties have been observed in terms of gender, age, conditioning environment and intrinsic values. All this has clearly been presented in tables and figures. The study covers an overall acoustic description of the Chamling vowels on the basis of sound spectrogram using the up-to-date Pratt software. On the whole, it is concerned with phonetic study of the Chamling vowels in terms of acoustic properties and articulatory strategies.

Keywords: Chamling, basic vowels, acoustic analysis, fundamental frequency, formant frequency

1. Background

As the previous studies are not associated with acoustic analysis of the Chamling vowels, the articulatory description made by Ebert (1997) and Rai (2012) has been taken as a background for the study. In fact, the articulatory description has been considered to form the basis for the observation of the acoustic description and its comparison.

Ebert (1997) studied the Chamling vowels in terms of opposition between five cardinal vowels that can be demonstrated with verbs, e.g. *i* in *khima* 'quarrel', *u* in *khuma* 'steal, hide', *e* in *khema* (SE) 'break', *o* in *khoma* 'cut' and *a* in *khama* 'be satisfied'. All vowels combine with *i* to form a diphthong. Nasalization is restricted to *o* and *a* in open syllables (*cãyu* 'net', *tõ* 'head') and to the diphthong. There is a great deal of free variation between nasalized and non-nasalized forms but the examples show that nasalization can be phonemic, e.g. *phūima (phund-)* 'jump', *phuima (phuid-)* 'pluck'.

Rai (2012) described the Chamling vowels in terms of height (high, mid and low), position (front, central and back) and lip rounding (rounded and unrounded). Chamling contains six pure vowels or monophthongs. The Chamling diphthongs have either /i/ or /u/ as their second element.

Pokharel (1989) studied the sound system of Nepali language. His study, in the case of vowels, shows that the area of the statistical experimentation includes the location of the vowels in the vowel quadrilateral comparable to the cardinal vowel in the formant chart, development of the vowel length, the length of a vowel before consonants with the same place of articulation but with different manners like voicing, aspiration etc.

Gautam (2011) carried out an acoustic analysis of the Balami phonemes. The Balami vowels have been observed based on oscillogram, FFT spectra, spectrogram and LPC spectra. The fundamental frequencies (F0s) and average formant frequencies of the vowels have been measured in terms of gender, age, conditioning environment and intrinsic properties.

Stevens (1998) has had an examination of the various acoustic properties that can result when the vocal tract is in a relatively open configuration. He has focused primarily on the sounds produced for modes of vibration for which the average airflow is not large enough to cause this pressure drop at the constriction.

Reetz and Jongman (2009) have discussed the primary acoustic characteristics of a variety of speech sounds and illustrated them by means of spectrogram and spectra. The primary acoustic characteristic of vowels is the location of the formant frequencies, especially the first three formants (F1-F3).

2. Methodology

This section is concerned with the measurement and specification of the Chamling vowels. All the vowels are measured acoustically in word level and measurements of the fundamental and formant frequency are observed in different environments, i.e. p-p, t-t, b-b, d-d, k-k, and g-g. The section 2.1 presents average frequency values of the Chamling basic vowels.

3. The Basic vowels

In Chamling, there are six vowels, i.e. /i/, /e/, /a/, /ə/, /o/, and /u/, in terms of articulatory parameters. These vowels need to be analyzed and presented again in terms of fundamental and formant frequency values as it is more scientific based on an instrumental technique of investigation. For this, using the sound spectrogram through the Pratt software, the vowels, /i/, /e/, /a/, /ə/, /o/, and /u/, for both the male and female speakers, have been measured, computed and presented on the ground of average frequency in the following tables.

The vowel /i/

Table 1: Fundamental and formant frequency values of the vowel /i/ produced by the male and female speakers in terms of places of articulation and voicing

			Bilabial		Alveolar		Velar	
			p-p	b-b	t-t	d-d	k-k	g-g
/i/	Male (average)	F0	127	155	160	151	157	157
		F1	277	301	293	305	296	278
		F2	2199	2219	2290	2228	2289	2320
		F3	2898	3093	3128	3009	3204	3273
	Female (average)	F0	218	231	232	235	236	228
		F1	348	346	354	347	320	317
		F2	2299	2352	2499	2349	2514	2563
		F3	2973	2896	3054	2793	2964	3144

The vowel /e/

Table 2: Fundamental and formant frequency values of the vowel /e/ produced by the male and female speakers in terms of places of articulation and voicing

			Bilabial		Alveolar		Velar	
			P-p	b-b	t-t	d-d	k-k	g-g
/e/	Male (average)	F0	132	142	157	138	149	148
		F1	343	346	346	359	327	334
		F2	2141	2090	2174	2075	2221	2217
		F3	2763	2656	2674	2691	2835	2782
	Female (average)	F0	225	219	223	242	235	231
		F1	456	442	440	481	436	393
		F2	2243	2173	2221	1998	2302	2331
		F3	2971	2926	2791	2778	2774	3006

The vowel /a/

Table 3: Fundamental and formant frequency values of the vowel /a/ produced by the male and female speakers in terms of places of articulation and voicing

			Bilabial		Alveolar		Velar	
			p-p	b-b	t-t	d-d	k-k	g-g
/a/	Male (average)	F0	139	132	129	134	147	137
		F1	683	646	628	546	625	623
		F2	1467	1439	1512	1593	1524	1496
		F3	2430	2506	2421	2458	2521	2455
	Female (average)	F0	204	217	205	222	215	226
		F1	806	742	764	740	639	643
		F2	1687	1672	1738	1719	1853	1759
		F3	2233	2558	2276	2314	2571	2565

The vowel /ə/

Table 4: Fundamental and formant frequency values of the vowel /ə/ produced by the male and female speakers in terms of places of articulation and voicing

			Bilabial		Alveolar		Velar	
			p-p	b-b	t-t	d-d	k-k	g-g
/ə/	Male (average)	F0	139	141	145	140	146	136
		F1	547	524	504	515	509	499
		F2	995	987	1264	1192	1040	1082
		F3	2621	2392	2437	2308	2499	2412
	Female (average)	F0	222	216	195	222	223	227
		F1	622	591	638	626	594	546
		F2	1087	1176	1465	1563	1178	1280
		F3	2798	635	2274	2631	2582	2733

The vowel /o/

Table 5: Fundamental and formant frequency values of the vowel /o/ produced by the male and female speakers in terms of places of articulation and voicing

			Bilabial		Alveolar		Velar	
			p-p	b-b	t-t	d-d	k-k	g-g
/o/	Male (average)	F0	149	144	156	151	159	148
		F1	381	371	372	377	364	359
		F2	832	855	1102	1042	846	889
		F3	2522	2485	2447	2404	2532	2404
	Female (average)	F0	221	218	226	223	237	227
		F1	447	449	458	457	440	452
		F2	931	1098	1263	1269	997	1053
		F3	2846	2818	2644	2535	2702	2795

The vowel /u/

Table 6: Fundamental and formant frequency values of the vowel /u/ produced by the male and female speakers in terms of places of articulation and voicing

			Bilabial		Alveolar		Velar	
			p-p	b-b	t-t	d-d	k-k	g-g
/u/	Male (average)	F0	130	158	168	159	169	156
		F1	327	339	300	319	328	323
		F2	883	897	1350	1192	868	943
		F3	2441	2374	2369	2376	2250	2361
	Female (average)	F0	222	223	229	232	236	229
		F1	419	432	361	391	374	360
		F2	908	954	1541	1506	912	1006
		F3	2919	2945	2607	2745	2762	2689

4. Formant frequency

In this section, we discuss the analysis of formant frequency values of the Chamling vowels. The vowel specification is studied on the basis of the average frequency values, using the sound spectrogram and spectra of the spoken vowels. The average values of the vowels are analyzed and compared with each other in formant tables and charts.

The Chamling vowels have separately been measured for the formant frequency values. The average formant frequencies have been computed for both the male and the female speakers. In Table 1, the first formant (F1) increases for the high vowels on account of the decrease in the height of the tongue. Contrary to this, the first formant (F1) decreases for the back vowels due to the increase in the tongue height. Therefore, the first formant (F1) has an inverse relationship with the height of the tongue. The second formant (F2) decreases continually from the front to back vowels, i.e. the vowel [i] has the high value and the vowel [o] has the low value. As a result, the second formant (F2) has a direct relationship with the parameters of back vowels. As for the third formant (F3), it has the high value for the vowel [i] and the low value for the vowel [u]. That is to say it does not change the vowel quality as it is not changeable as the first formant (F1) and the second formant (F2). It shows that the quality of the vowels depends on the locations of the first and the second formant frequency values.

Table 7: Average formant frequency values of six pure vowels of the Chamling language for the male speakers.

		Vowels					
	Formant Freq. (in Hz)	[i]	[e]	[a]	[ə]	[o]	[u]
Male	F1	292	343	625	516	371	323
	F2	2258	2153	1505	1093	928	1022
	F3	3101	2734	2465	2445	2466	2362

The average formant frequency values in Table 7 have been given in Figure 1.

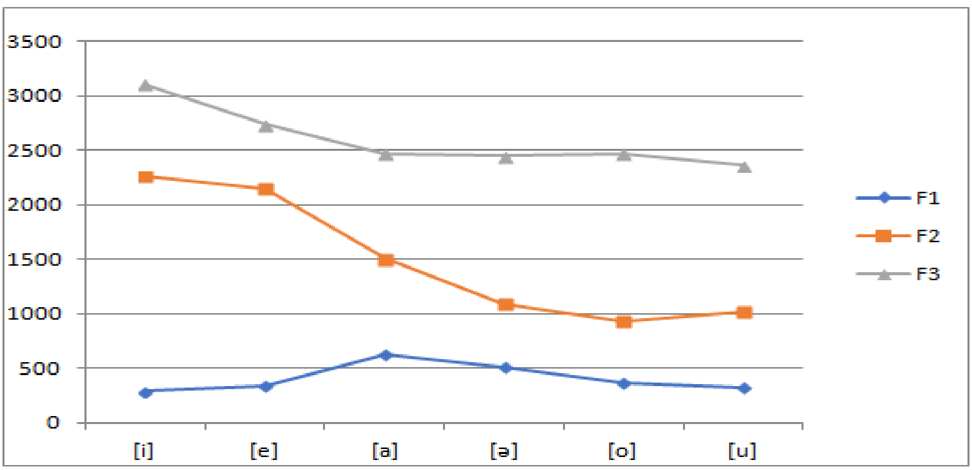

Figure 1: Average and stylized formant frequencies F1, F2, and F3 of the pure vowels of the Chamling language produced by the male speakers

In Figure 1, the tongue height decreases, so the F1 goes up for production of the front vowel. The vowel [a] has the highest formant frequency values compared to the values of other vowels as the tongue body is in the lowest position. On the other hand, the vocal tract is also open enough for the sound. As for the back vowels, the tongue height increases and the F1 gets lowered but the F2, without any change, goes from the front to back. It is slightly higher for the back vowel /u/. The figure also shows that the F3 does not show any change as the F1 and the F2 do, so it does not play an important role to specify the vowels. It has the highest value for the front vowel /i/.

The first formant (F1) and the second formant (F2) are the determinant of changing the qualities of the vowel. The former is directly related to the articulatory parameter of the tongue height whereas the latter is related to the articulatory parameter of the backness of the tongue body. The formant frequencies of the vowels can be plotted and observed in the F1 versus F2 plane. The figure with the F1 in the vertical axis and the F2 in the horizontal axis is similar to the traditional vowel quadrilateral based on articulatory and auditory vowel space.

The formant frequencies of the Chamling vowels have also been computed for the female speakers. Average formant frequencies for the oral vowels produced by the female speakers have been given in Table 8 below.

Table 8: Average formant frequency values of six pure vowels of the Chamling language for the female speakers

		Vowels					
	Formant Freq. (in Hz)	[i]	[e]	[a]	[ə]	[o]	[u]
Fem-ale	F1	339	441	722	603	451	390
	F2	2429	2211	1738	1292	1102	1138
	F3	2971	2874	2420	2609	2723	2778

These frequency values have been shown in the stylized Figure 2.

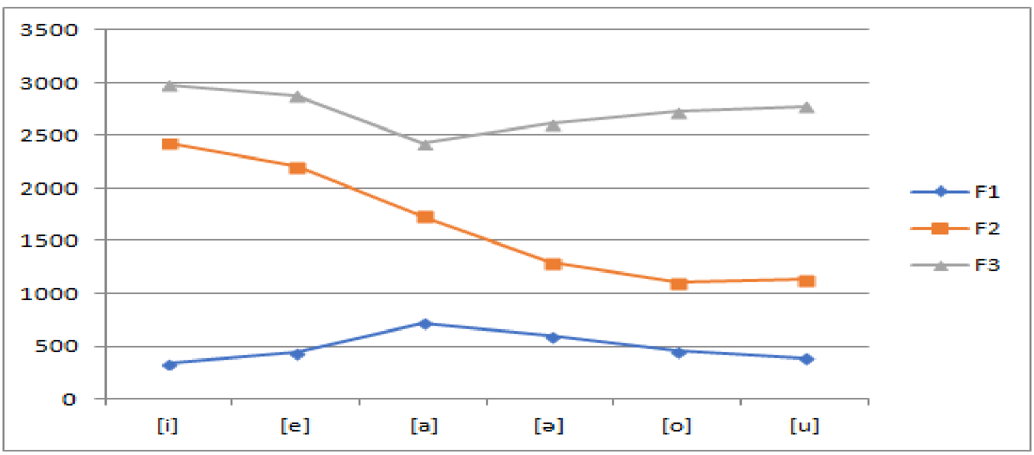

Figure 2: Average and stylized formant frequencies of the F1, F2 and F3 of the oral vowels of the Chamling language produced by the female speakers

In Table 7 and 8, the average formant frequency values can be compared with each other in many ways. The formant frequency values have changed from one vowel to another but they can be compatible to all the formant frequency values. The F1 of [i] sound for the female speaker is higher than that for the male speaker by 47 Hz. Similarly, the values of other vowels are also higher for the female than that for the male. In the case of the F2, the correspondence is found for the female and male speakers. That is to say, the higher F2 of [i] sound for the female speaker is accompanied by all other vowels.

This comparison shows that the vocal tract shapes determine the locations of the formant frequency values. The value differences for the male and the female speakers are accompanied by the differences of the vocal tract shape. Bordon and Harris (1980) has said that a female has a different vocal shape with the female vocal tract shape shorter by about 2 cm in the pharynx whereas 1.25 cm shorter in the oral cavity. However, the ratio difference of the values between the male and female speakers is similar. That is to say, the difference between the formant frequency values of the vowel [i] and that of [e] is one hundred two hertz (102 Hz) for the female whereas it is fifty-one hertz (51 Hz) for the male. It is the ratio difference of frequency values of formants rather than the exact frequency values.

In effect, both the Figure 1 and the Figure 2 can be observed in terms of the relationship between the vocal tract shape and formant frequency values. The tongue height is decreased and the first formant (F1) is higher for the front vowel whereas it is increased and the first formant is lower for the back vowels. But as for the second formant (F2), it is continually decreased for the vowels from the front to the back. The third formant (F3) is constant except it is associated with the high front vowel [i].

5. Fundamental frequency

Fundamental frequencies are the representations of the rate of the vocal fold vibration. The complex signals of the vowels are the result of the multiple frequencies of the vibration. However, one period gets repeated and becomes a complex one. This period frequency of the complex signals is called the fundamental frequency (Reetz and Jongman 2009). The frequency components of the complex signals are the harmonics. In other words, the fundamental frequency is defined as the greatest common denominator (GCD) of all the harmonics and the duration of a period of the fundamental frequency is the lowest common multiple (LCM) of the durations of the periods of the harmonics.

The fundamental frequency has a direct relationship with tension whereas it has an inverse relationship with thickness and length of an object. In human, the periodic nature of the vocal fold vibration yields the articulatory correlate of the fundamental frequency. Fundamental frequency is highly affected by gender, for male speakers' vocal folds are heavier and larger than females'.

The fundamental frequencies of the Chamling vowels in k-k context have been measured for the six speakers (three males and three females). Their measurements have been given below in Table 9.

Table 9: Fundamental frequency (F0) of the Chamling pure vowels for three male and three female speakers in k-k context

	Vowels							
F0 (in Hz)			[i]	[e]	[a]	[ə]	[o]	[u]
	Male	Narendra	132	137	127	132	135	137
		Khadga	178	152	165	156	180	208
		Tilak	160	157	149	149	163	161
		Average	157	149	147	146	159	169
	Female	Rajmaya	227	237	215	221	237	224
		Sarmila	258	250	220	245	252	257
		Nirmala	222	219	210	204	221	227
		Average	236	235	215	223	237	236

The fundamental frequency (F0) for each of the six vowels has been measured acoustically in k-k contexts for all the six speakers. There are the average computations of fundamental frequency for both the male and female speakers. The fact is that the fundamental frequency values produced by the female speakers are higher than that produced by the male speakers. Also, the F0s of the vowels across the individuals vary depending on the variations of the vocal folds. The normal F0 range is between 224 Hz and 251 Hz for the vowels produced by the female speakers whereas it is between 155 Hz and 196 Hz for the vowels produced by the male speakers. There is a difference of nearly seventy hertz between the female and male speakers.

The age factor has played an important role to show the difference between the fundamental frequencies. For instance, Tilak Chamling, who is 36, has higher F0s in all the vowels than Khadga Chamling and Narendra Chamling, who are 46 and 50 respectively. It shows that fundamental frequencies of the vowels differ in terms of gender and age. The F0s also differ within the same gender on account of the variations of the vocal folds.

The average fundamental frequency for six vowels of Chamling language for male and female speakers in Table 9 is presented in Figure 3.

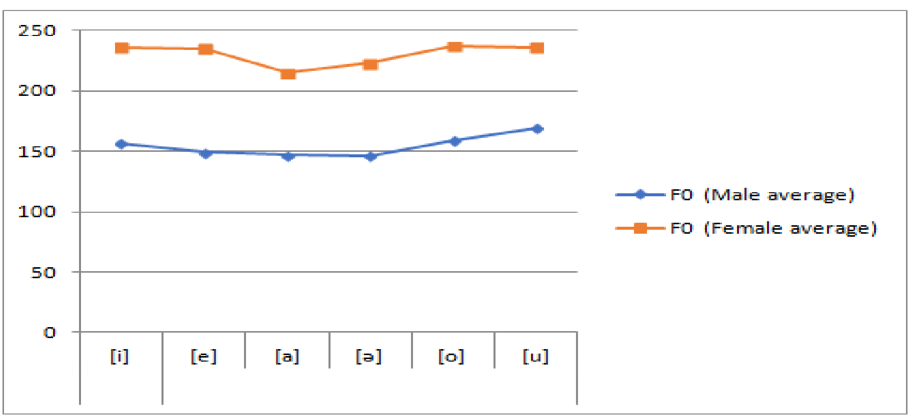

Figure 3: Average fundamental frequencies of six vowels of the Chamling language for the male and female speakers in k-k context.

Table 9 and Figure 3 show that the average fundamental frequencies (F0s) of the vowels differ from each other for the male and female speakers.

Apart from this, an intrinsic value is one of the factors that show differences of the frequencies, i.e. F0s. According to the tongue-pull theory (Lehiste 1970), the adjustment of the tongue rise also causes the larynx to rise at the same time. Then, it adds to the tension of the vocal folds for the production of high vowels with the increased fundamental frequencies.

When the vowels are preceded by a voiceless obstruent, the Fundamental frequencies (F0s) are higher than the situations in which they are preceded by a voiced obstruent. The measurements of the frequencies (F0s) have been given in the following Table 10. Both the individual and average frequencies have been shown in the following table.

Table 10: Fundamental frequency (F0) of the Chamling pure vowels for three male and three female speakers in g-g contexts

	Vowels							
	`		[i]	[e]	[a]	[ə]	[o]	[u]
F0 (in Hz)	Male	Narendra	129	127	124	125	129	129
		Khadga	181	165	147	142	167	185
		Tilak	160	151	140	142	149	153
		Average	157	148	137	136	148	156
	Female	Rajmaya	225	229	225	219	226	225
		Sarmila	240	254	249	249	246	241
		Nirmala	220	210	203	213	210	221
		Average	228	231	226	227	228	229

The comparison of the F0s of the oral values in k-k and g-g contexts have been presented in Table 11.

Table 11: Average fundamental frequencies (F0s) of the Chamling pure vowels in k-k and g-g contexts

		F0					
		[i]	[e]	[a]	[ə]	[o]	[u]
Male	k-k context	157	149	147	146	159	169
	g-g context	157	148	137	136	148	156
Female	k-k context	236	235	215	223	237	236
	g-g context	228	231	226	227	228	229

In Table 11, the comparison of the F0s of the vowels shows that the F0s are higher as the vowels are preceded by a voiceless obstruent and the values of the F0s are lower when they are preceded by a voiced obstruent. In the case of the female, the F0s of the vowels /a/ and /ə/ in k-k are lower than that in g-g contexts. This comparison has been shown in Figure 4.

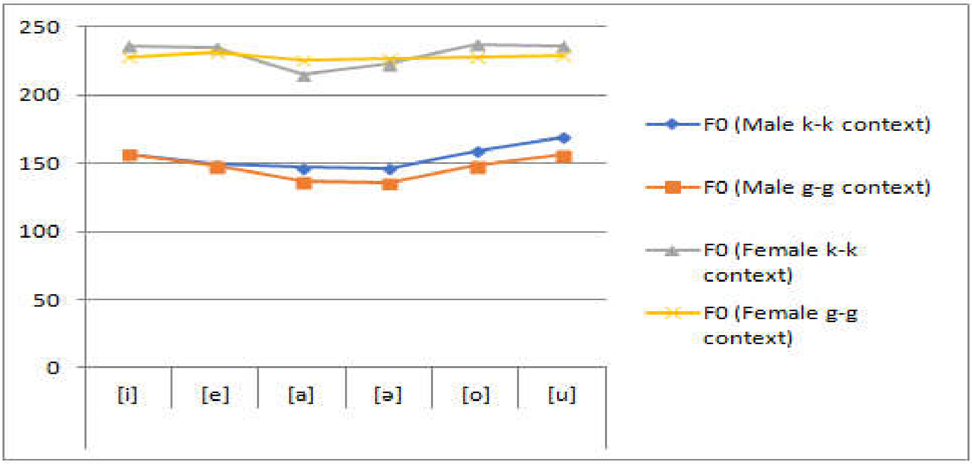

Figure 4 Average fundamental frequencies (F0s) of the Chamling vowels measured in k-k and g-g contexts

To sum up, the measurements of the vowels show that the fundamental frequency values differ from each other on the ground of different parameters. First, the gender affects the fundamental frequency significantly. The F0s of the vowels for the female speakers are higher than that of the vowels for the male speakers. Second, age factor plays an important role to show the differences of the F0s of the vowels. Younger speakers have the higher frequency values than the older ones. Third, the fundamental frequency differences depend on different contexts or conditioning environments. The F0s of the vowels with the voiceless is greater than that of the vowels with the voiced. Fourth, the vowels also vary in terms of their intrinsic fundamental frequency values. That is to say, the high vowels have higher Fundamental frequencies and the low vowels lower fundamental frequencies. Thus, the fundamental frequencies of the vowels vary on the basis of gender, age, context and intrinsic cues or properties.

6. Findings

The findings are as follows.

a. Fundamental frequency (F0) values vary in terms of gender. That is to say, the F0 of the vowels for the female speakers is higher than for the male speakers.

b. The values with a voiced plosive, i.e. b-b environment are higher than that with a voiceless plosive, i.e. p-p environment.

c. They differ in terms of age (the younger speaker has higher frequency values compared to the older ones).

d. Their variances occur on the ground of conditioning environment, i.e. the F0 measured in voiceless plosive or obstruent is higher than that in the voiced plosive or obstruent contexts.

e. The values are also different depending on the intrinsic properties of the vowels. It means the F0 is higher for high vowels and lower for the low vowels as a result of the intrinsic properties of vowels.

f. The acoustic vowels space for the female speaker is relatively larger than that for the male speakers.

g. The duration of the front unrounded and back rounded vowel is relatively longer than that of the low central short and long vowels.

h. The front vowels are more fronted than the oral vowels and the central and the back vowels are more backed than their respective counterparts.

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