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Experimental Phonetic Research on Fengke Dialect of Naxi Language

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Abstract: Up to now, numerous representative vernacular dialects of Naxi language have been described. However, there is a lack of experimental phonetic research on the Fengke dialect mentioned in previous literature. Therefore, this paper explores the phonetic characteristics of the Fengke dialect from the perspective of experimental phonetics. Methods from experimental phonetics and phonological pattern theory were employed to observe and analyze the phonetics of the Fengke dialect. Speech analysis software Praat was used to organize and process the data collected from field surveys, presenting the specific features of phonetics in graphical form. This research on the phonetics of the Fengke dialect can provide valuable reference material for the study of Naxi group languages

1. Introduction

So far, there exists abundant literature on the description and research of Naxi dialects. From previous studies, it is known that the general characteristics of Naxi dialects include being monosyllabic languages[1]. Consonants exhibit a contrast between plain-voiced and aspirated-nasal types or a three-way contrast among plain-voiced, aspirated, and aspirated-nasal types. Vowels predominantly consist of monophthongs with few diphthongs, and in some regions, nasalized vowels are present (e.g., Yongningba: ĩ, ə̃r̃; Beiquba: õ[2]; Yanyuan Duoshe dialect: ĩ, æ̃, ʊ̃, õ, uæ̃). Tone systems generally comprise 3 to 4 tones, with a few dialects having 5 to 6 tones (e.g., Shuitian dialect's disyllabic nouns[3]; Yongning dialect).In recent years, scholars have begun to use new descriptive methods to analyze new linguistic features, such as applying the level tone analysis method to the tone system of the Pending Naxi dialect, and discovering that in addition to four basic tone contours, some marginal tone positions are generated by the lexicalization of compounded tones, such as the low-mid rising tone (LM) and the high-low low mid rising tone (HL)[4]; even the description of previously studied features has been revisited, leading to the discovery of new characteristics, for example, in the phonetic system of the Lunbuluo dialect spoken in Culture Village, the phonemic opposition between /ɻ/ and /h/ has been identified[5]; compared to the Moso language spoken in Shekua Village[6], the Moso dialect spoken in Duoshe Village, Yongning, has three nasalized vowels (æ̃, ʊ̃, uæ̃) and the nasal phoneme ŋ̩[7].In terms of tone, Michaud's study[8] revolutionized the traditional description of Naxi tones by categorizing six tonal contours in Yongning dialect: L, M, H, LH, LM, and HM. Despite the diversity of contours, all derive from three

level tones. This intricate tone system contrasts starkly with Mandarin's standard four-level system of high-level, mid-level, low-level, and low-rising tones.In domestic and international studies on Naxi dialects, the phonetic system of Lijiangba Naxi has been summarized. It includes 39 consonants and 23 vowels, with 12 monophthong vowels: i, y, e, a, ɑ, ø, o, u, v, ɯ, ə, ɚ. There are four tones: high-level, mid-level, low-falling, and low-rising[9]. Jiang Zhuyi described the phonetic system of Fengkehengke dialect with 43 consonants, including retroflex consonants, 15 vowels, and four tones: 55, 33, 31, 13[10]. The Málímǎsà dialect features 44 consonants (including null consonants), both single and complex consonants, 25 vowels primarily monophthongs, and a distinction between non-nasalized and nasalized vowels. It has four tones: 33, 55, 21, 24[11]. Research on the Cien Ding Village Naxi dialect found that its main characteristics are largely consistent with Western dialects, including a relatively complete coronal consonant system and corresponding vowels and tones[12].

In summary, extensive research has been conducted on the Naxi language by scholars both domestically and internationally. However, previous studies on the Fengke dialect lack systematic experimental investigations. Therefore, this study focuses on the phonetics and phonology of the Fengke dialect in Wacun, Fengke Town, employing experimental methods to observe and analyze its phonological characteristics. This research aims to summarize the distinctive features of the Fengke dialect's phonetic and tonal system, thereby providing additional case descriptions and reference materials for future studies on Naxi dialects.

2. Initial

2.1 Consonants of the Fengke dialect

In the Fengke dialect of Naxi, there are 37 consonants in total (as shown in table 1). Among them are five nasalized voiced stops: /nd/, /mb/, /ŋg/, /ɲʝ/, and the nasalized voiced affricate /ndz/. Additionally, there are plain voiced plosive /b/, /d/, /g/ and plain voiced affricate /dz/. These consonants exhibit a three-way contrast pattern involving voiceless, voiced, and nasalized voiced categories.

Table 1: Consonants of the Fengke dialect.

Pronunciation method / Pronunciation site	Bilabial	Labiodental	Dental	Retroflex	Palatal	Velar
Plosive	p		t		c	k
	pʰ		tʰ		cʰ	kʰ
	b		d		ʝ	g
	mb		nd			
Affricate			ts	tʂ		
			tsʰ	tʂʰ		
			dz			
			ndz			
Nasal	m		n		ɲ	ŋ
					ɲʝ	ŋg
Lateral approximant			l			
Fricative		f	s	ʂ	ɕ	x
			z	ʐ	ʑ	ɣ
Approximant	w					

Consonant description:

(1)Bilabial consonants /p/, /pʰ/, /b/, and /mb/ exhibit slight lip trembling when preceding the vowel

/ʋ/; the labial approximant /w/ only occurs before the monophthong /o/.

(2)Labiodental consonants/f/ is the only labiodental consonant; there is no corresponding voiced fricative /v/, except in Chinese loanwords.

(3)Dental consonant /l/ has two allophones: [l] and [ɾ]. [l] occurs only before the monophthongs /y/, /e/, /ɑ/, /ə/, /o/ and the diphthong /jə/; [ɾ] occurs only before the monophthongs /ə˞/, /i/, /u/, /æ/, /ɯ/ and the diphthong /jæ/. When the alveolar nasal /nd/ precedes the vowels /æ/, /ə/, /ə˞/, /u/, and /wæ/, it is pronounced as a retroflex sound [ɳɖ], e.g., ndæ^{55} [ɳɖæ^{55}] “short”.

(4)Retroflex consonants do not precede the vowels /i/, /y/, /e/, /ø/, /jə/, /jɑ/.

(5)Palatal consonants only precede the vowels /i/, /y/, /æ/, /ɑ/, /ə/, /u/, /o/, /wæ/, /jə/, /jɑ/. The palatal nasal /ɲɻ/ appears only before the monophthong /i/, /y/, /ə/, e.g., ɲɻy^{11} “to be born”.

(6)Velar consonants /x/ has two allophones: [x] and [h]. [h] is nasalized when preceding the monophthongs /i/, /y/, /e/, /ø/, /ə˞/, pronounced as [hĩ^{11}] “person”, [hỹ^{11}] “red”, [hẽ^{55}] “stop”, [hø̃^{33}] “able”, [hə̃˞^{55}] “fur”. The velar nasal /ŋg/ appears only before monophthongs, e.g., ŋgo^{55} “jar”.

2.2 Consonant Spectrogram of Fengke Dialect

Acoustic properties of plosives are primarily characterized by their transient, straight-line nature[13], as shown in Figure 1:

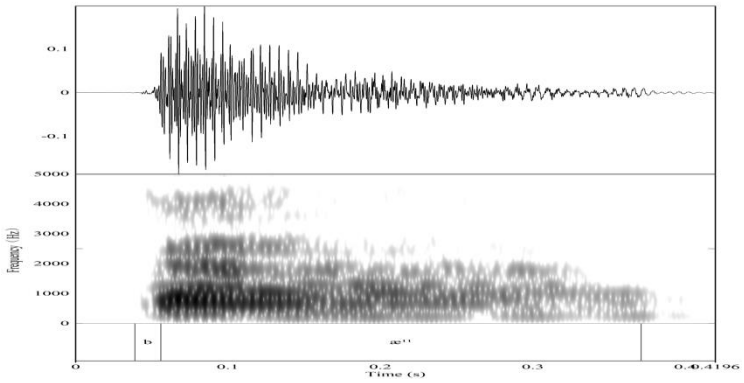

Figure 1: The spectrogram of the consonant /bæ/ in the Fengke dialect.

From the figure, it can be observed that during the burst of plosives, acoustically, there is a strong energy from low to high frequencies, commonly referred to as "transient straight lines." It is noticeable that certain frequency bands exhibit stronger energy while others are weaker, primarily due to variations in articulation where the oral cavity modulates the burst of the single-pulse sound source. From the spectrogram of the Ernashi dialect consonant /bæ/, the onset of the syllable shows the transient straight line of /b/, followed by the spectrum of the vowel /æ/.

In acoustic terms, fricatives are primarily characterized by "turbulence," as shown in Figure 2. From a spectrographic perspective, the acoustic properties of turbulence indicate a noise source. Observing the energy of the noise, different fricatives exhibit varied distributions. Typically, the articulation and properties of fricatives are determined based on the lower frequency limit, center frequency, and intensity bands of the turbulence. From the spectrogram of the Fengke dialect consonant /hĩ/, it can be observed that the fricative /h/ exhibits noticeable turbulence in the high-frequency region.

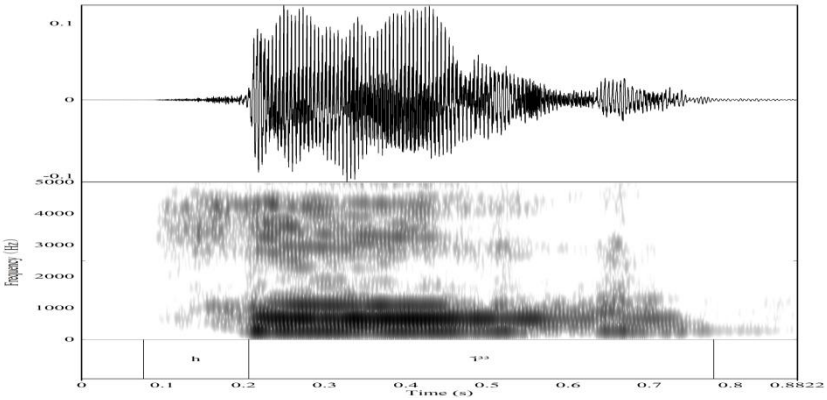

Figure 2: The spectrogram of the consonant /hĩ/ in the Fengke dialect.

The affricate is a phonetic combination unique to the Sino-Xizang language family. Acoustically, affricate manifest as "transient straight lines + turbulent noise + aspiration noise." Figure 3 illustrates the spectrogram of the Fengke dialect affricate initial /tsɑ/, where the onset of the /ts/ consonant segment begins with a transient straight line. The turbulence appears as high-frequency noise with relatively weak intensity, followed by aspiration noise. Compared to turbulent noise, aspiration noise exhibits even weaker intensity. At the juncture with aspiration noise, strong intensity bands are observed near the resonance peaks. These peaks are caused by resonance effects in the oral cavity, representing characteristics of resonance in a noise source. Once vocal cords vibrate, these peaks become evident.

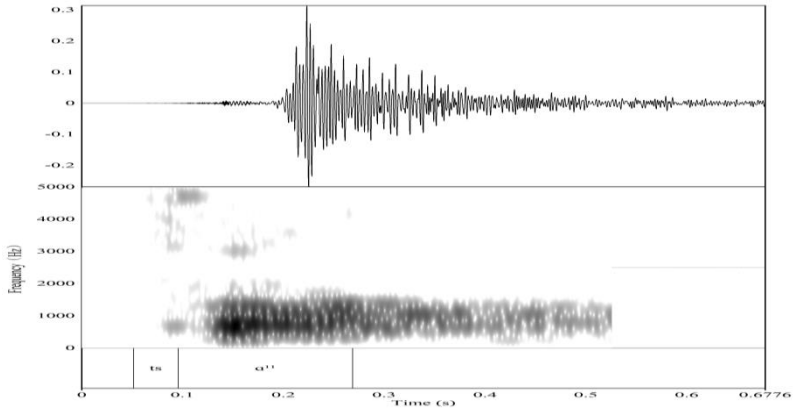

Figure 3: The spectrogram of the consonant /tsɑ/ in the Fengke dialect.

In the Fengke dialect, prenasalized sound are generally realized under voiced conditions, presenting as voiced nasal plosive and voiced nasal affricate. As depicted in Figure 4, we can clearly observe that prior to the closure of the affricate, there is a segment of nasal sound present. During the closure and hold phases, nasal sound persists; however, upon release, the oral cavity undergoes a burst, producing a voiced stop at the same place of affricate. Additionally, in the waveform, the amplitude of the initial consonant segment is relatively large. Apart from observing in the wideband spectrogram that the nasal glide preceding the plosive maintains its voiced diacritic, it also retains its own resonance peak pattern.

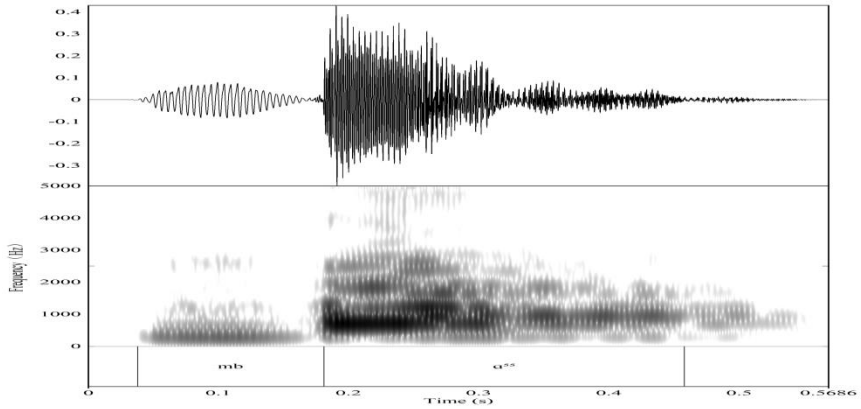

Figure 4: The spectrogram of the consonant /mbɑ/ in the Fengke dialect.

3. Final

In the Fengke dialect, there are 23 vowels (see Table 2 below), among which monophthongs are predominant (12 in total). There are 7 diphthongs classified into two types: those with the glide /j/ and those with the glide /w/. Additionally, there is one diphthong /ɑw/ that only appears in Chinese loanwords. Nasalized vowels number 4 and occur exclusively following the palatal fricative /h/. Furthermore, there is one close vowel, with diphthongs being less frequent in usage compared to monophthongs within the Fengke dialect.

Table 2: Table of vowels

Tongue vowels(10)	i,u,y,ɯ,e,ø,o,ə,æ,ɑ
Rhotacization vowels(1)	ɚ
Nasalized vowels(4)	ĩ,ỹ,ẽ,ɚ̃
Diphthongs(7)	we,wɑ,wæ,jə,jɑ,jæ,ɑw
Approximant(1)	ʋ̩

Vowel description:

(1)Monophthongal Vowel /ɯ/ has three allophones: [ɿ], [ʅ], and [ɯ].When paired with alveolar consonants (ts, ts^{h}, dz, s, z), it is pronounced as [ɿ].When paired with retroflex consonants (tʂ, tʂ^{h}, dʐ, ʂ, ʐ), it is pronounced as [ʅ].With other consonants, it is pronounced as [ɯ].

(2)Rhotacized Vowel /ɚ/ has three allophones: [ɻ̩], [ɚ], and [u˞].When paired with alveolar consonants (ts, ts^{h}, dz, s, z), it is pronounced as [ɻ̩].With other consonants, it is pronounced as [ɚ].When paired with labial consonants (p, p^{h}, mb), it is pronounced as [u˞].

(3)Monophthongal vowels i, y, e, ɚ with glottal consonant h.They are pronounced as nasalized vowels ĩ, ỹ, ẽ, ɚ̃ respectively.For example: [hĩ^{33}] “people”, [hỹ^{11}] “red”,[hẽ^{55}] “bag”,[hɚ̃^{55}] “hair”.

(4)Approximant /ʋ̩/ only occurs with labial, labiodental, alveolar, palatal, and velar consonants, with slight labial friction.For example: [kʋ̩^{13}] “can”, [gʋ̩^{55}] “believe”, [mbʋ̩^{55}] “burn”.

3.1 Monophthongs Spectrogram

The vowel is the most crucial component of speech sounds in any language, acoustically characterized primarily by formant peaks. See Figure 5 for illustration:

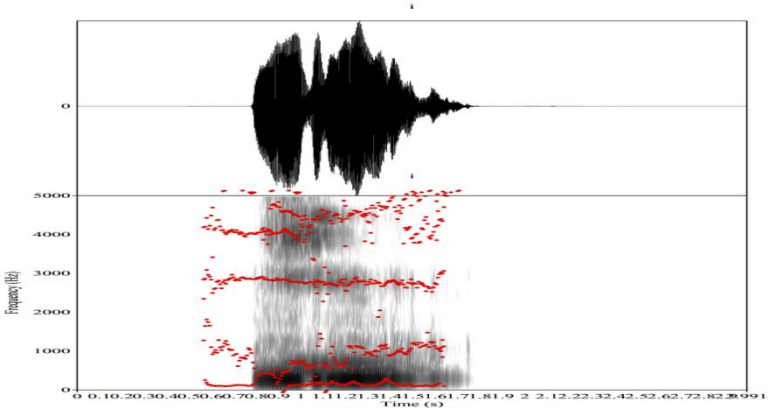

Figure 5: vowel/i/Spectrogram.

The vowel /i/ spectrogram reveals five distinct formant peaks from top to bottom. Their characteristics are as follows: F1 is relatively low, approximately at 300Hz; F2 is close to F1, around 1000Hz; F3 is distant from F2, approximately at 3000Hz; F4 and F5 are closer together, with F4 around 4000Hz and F5 around 4500Hz.

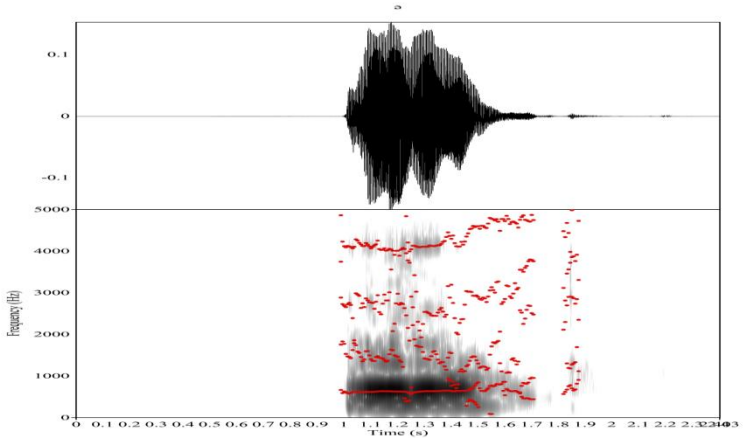

Figure 6: vowel/ə/Spectrogram.

As shown in Figure 6 the spectrogram of the vowel /ə/ shows five distinct formant peaks from top to bottom. The characteristics of these formants are as follows: F1 is approximately at 700Hz; F2 is relatively distant from F1, around 1700Hz; F3 is farther from F2, approximately at 2700Hz; and F4 is quite distant from F3, around 4000Hz.

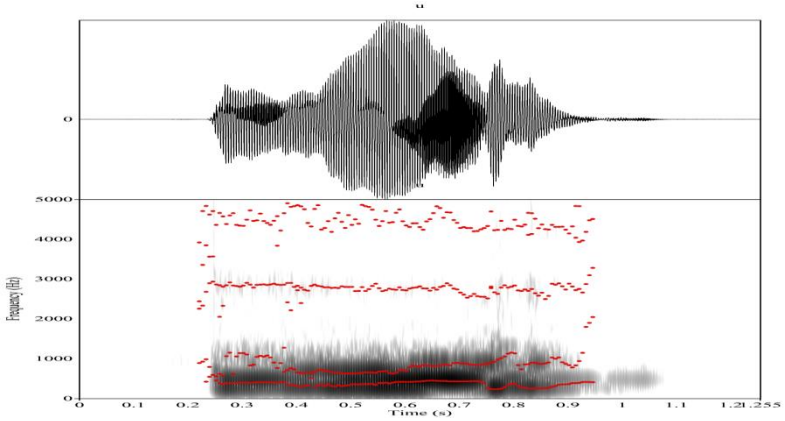

Figure 7: vowel/u/Spectrogram.

As shown in Figure 7 the spectrogram of the vowel /u/ reveals five distinct formant peaks from top to bottom. The characteristics of these formants are as follows: F1 is approximately at 400Hz; F2 is relatively close to F1, around 700Hz; F3 is distant from F2, approximately at 2800Hz; F4 is quite distant from F3, around 4600Hz; and F5 is approximately at 4800Hz.

3.2 Experimental results on tongue vowel patterns

During vowel pronunciation, the vocal tract remains unobstructed, and acoustic properties are primarily defined by formant peaks[14]. In China, vowel studies predominantly utilize the vowel pattern method proposed by Shi Feng. Vowel patterns are a concentrated manifestation of vowel systematicity. Analysis of phonetic patterns integrates phonetic and phonological advantages to describe vowel characteristics, manifestations of content changes, and overall distribution relationships[15]. This paper employs phonetic experimental methods and applies vowel pattern theory to analyze and describe aspects such as the distribution range and pattern characteristics of 10 tongue-root vowels in Fengke dialect.

3.3 Experimental data and speaker information

Based on the phonological organization, the vowels in Fengke dialect can be classified into two types: monophthongs and diphthongs. Among them, there are 10 tongue vowels, namely: i, u, y, ɯ, e, ø, o, ə, æ, ɑ. Tongue vowels are produced by raising a specific part of the tongue during pronunciation and are relatively common vowels. When selecting samples from the "Fengke dialect Vocabulary Survey Form", the Fengke dialect phonology is mainly used as a reference. Each of the 10 tongue vowels has 10 examples as pronunciation samples, recorded by 1 speaker who reads each vowel 10 times, resulting in a total of 100 sample pronunciations.

Speaker information: Hexx, M, 70, Shangwa Village, Group 1 Fengke Town Lijiang City Yunnan Province, High school, Village secretary; Shu xx, F, 45, Shangwa Village, Group 2 Fengke Town Lijiang City Yunnan Province, Junior high school, Farmer.

3.4 Experimental methods

This study's vowel pattern experiment employed Praat software to conduct acoustic experiments on all experimental samples[16], extracting resonance peak frequencies of tongue-surface vowels (F1, F2 values). Using the frequency of the first resonance peak (F1) on the vertical axis (y-axis) and the frequency of the second resonance peak (F2) on the horizontal axis (x-axis), the vowel distribution plots based on F1 and F2 values are known as acoustic vowel diagrams. This diagram illustrates the phonetic distribution of different tongue-surface vowels and variations of the same vowel. The relative positions of different tongue-surface vowels in the acoustic vowel diagram roughly correspond to physiological tongue position maps of vowels. In acoustic vowel diagrams, F1 values correlate with tongue height; higher F1 values correspond to lower tongue positions. The position of the tongue relative to the front and back correlates closely with F2; a more fronted tongue position results in a higher F2, while a more backed tongue position results in a lower F2.

3.5 The phonetic map of tongue vowels articulations in Fengke dialect

To visually highlight the distinctions among the tongue-surface vowels in the Fengke Nashi dialect, this study primarily employs F1 and F2 data to plot vowel ellipses in the drawing window of Praat software. Figure 8 below clearly shows that there are 10 distinct tongue-surface vowels in the Fengke dialect and illustrates their differences.

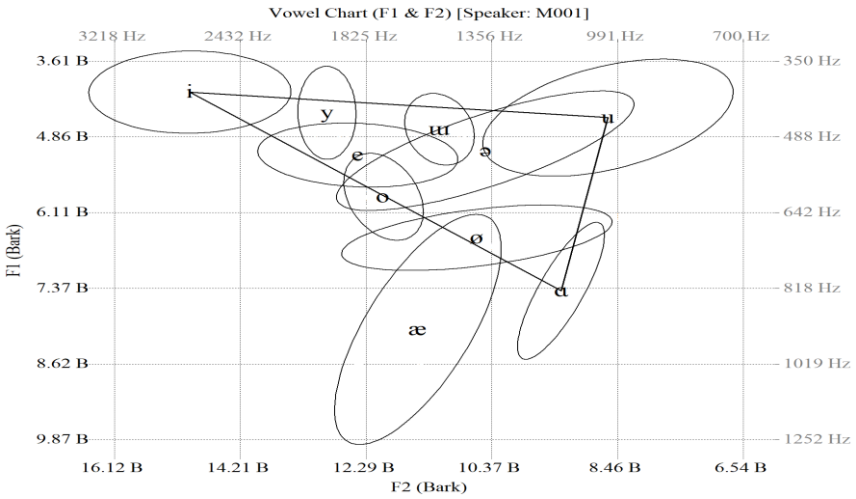

Figure 8: The tongue position vowel diagram.

Figure 8 analyzes the vowel articulatory positions of the 10 vowels in Fengke dialect through phonetic experimental methods and phonetic pattern analysis. The dialect features four front vowels: /i/, /y/, /e/, and /æ/. /i/ and /y/ are rounded high vowels and do not overlap, with /i/ being relatively stable. /e/ is an unrounded mid-high vowel, overlapping with /ə/, /o/, /ɯ/, and /y/. /æ/ is a low front vowel positioned centrally, overlapping with /ø/. /ə/ is a central vowel, less stable, and overlaps with /u/, /o/, /ɯ/, and /e/. The high rounded back vowel /u/ occupies one extreme point, overlapping with /ə/. /o/ is centrally positioned, overlapping with /e/, /ə/, and /ø/. /ɑ/ occupies another extreme point and is relatively stable, overlapping only with /ø/. Overall, the diagram illustrates the general characteristics of tongue-surface vowels in Fengke dialect, with /u/ and /ɑ/ being relatively stable in position, while /i/ shows more variability but consistently occupies an extreme point. Generally, most vowels are positioned centrally.

4. Tone

4.1 Basic articulatory positions

The Fengke dialect features three level tones: high level tone (H), mid-level tone (M), and low level tone (L), as well as a low mid rising tone (LM) with pitch values of 55, 33, 11, and 13 respectively (as shown in table 3). Among the commonly used 2500 words in Fengke dialect, these three level tones account for 50.12%, 59.72%, and 43.08% of occurrences, indicating relatively high frequencies. In contrast, the low mid rising tone (13) has a lower occurrence rate, representing 22.6% of the total.

Table 3: Tone table

Tone Number	Description	Approximate Tone Value	Example Word	Word Meaning	Example Word	Word Meaning
1	High Level Tone	55	mi^{55}	fire	se^{55}	go
2	Mid Level Tone	33	mi ^{33}	scar	se ^{33}	dry
3	Low Level Tone	11	mi ^{11}	down	se ^{11}	mole
4	Low Mid Rising Tone	13	mi ^{13}	mature	se ^{13}	finish

4.2 Single word tones fundamental frequency analyze

Every language (or dialect) has a specific tone pattern formed by all its lexical tones. This pattern serves as the foundational form of various tonal changes and the synchronic initial state of its tone system, thereby becoming the starting point of tone research.This section adopts experimental phonetic methods to place the average pitch contour of individual tones in Fengke dialect within the same tonal domain based on T-values. Since each tone occupies a linear acoustic space, this section employs the method by Shi Feng[17] to derive acoustic space diagrams for each tone category using mean T-values plus or minus standard deviations. It observes the trends in each tone category's variation, aiming to analyze the acoustic characteristics of tones in Fengke dialect.

4.3 Experimental process

This section's tone pattern experiment utilized Praat software to conduct acoustic analyses on all experimental samples. Initially processed audio files were imported into Praat, where the 'Analyse periodicity—To pitch' function was employed. In the resulting pitch settings dialogue, the upper limit of fundamental frequency (F0) was set to 600.0 Hz and the lower limit to 75.0 Hz. Subsequently, clicking 'OK' generated pitch files, which were then converted to PitchTier files. Due to the influence of speaker conditions and noise, F0 points in the audio files sometimes exhibited anomalies. To address this, both the audio files and corresponding PitchTier files were selected and edited using 'View & Edit,' manually adjusting anomalous F0 points to ensure each syllable's F0 points formed a continuous and smooth curve. Processed audio files, corresponding TextGrid files, and PitchTier files were systematically saved in pairs to the computer's C drive under the 'Temp' folder. Opening Praat's homepage, a new Praat script was created by selecting 'Praat—New Praat Script,' where a script program for extracting pitch data was entered into the script editing window. Eleven samples were specified for extraction, and upon confirming accuracy, the script was executed by clicking Run. Subsequently, for ease of data processing and analysis, extracted data was imported into Excel software and saved. Normalization of pitch data for Fengke dialect tones was conducted to provide a standardized quantitative description of tone perception, maximizing retention of common features while mitigating disturbances arising from pronunciation styles and minimizing inter-speaker differences. This article employs Professor Shifeng's T-value method to normalize pitch data and generate mean fundamental frequency curves for the Fengke dialect. The horizontal axis represents time, while the vertical axis represents T-values.

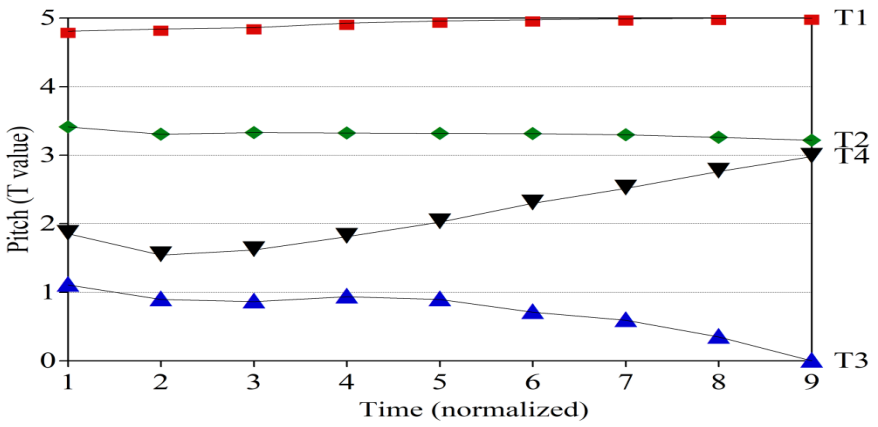

Figure 9: Mean Fundamental Frequency Curve of Fengke Dialect.

The analysis of the tone pattern of monosyllabic tones is a static analysis that serves as the

fundamental form of tone study and lays the foundation for examining various tone changes.

Combining Figure 9, we analyze the curvature and tonal trends of the mean fundamental frequency curves for single-syllable tones in Fengke dialect. The maximum mean fundamental frequency value is 128 Hz, and the minimum mean fundamental frequency value is 86 Hz. The analysis results are as follows:

T1 fundamental frequency curve is stable, covering the uppermost range of the pitch scale, positioned at the top of the 5th pitch range. Its starting and ending points remain within the same interval, indicating it is a high-level tone.

T2 fundamental frequency curve is stable, positioned between the 3rd and 4th pitch ranges. From start to finish, it remains within the same interval, closer to the 3rd range, thus classified as a mid-level tone.

T3 fundamental frequency curve is stable, covering the lowest portion of the pitch scale, situated within the 1st pitch range. Its starting and ending points remain within the same interval, indicating it is a low-level tone.

T4 fundamental frequency curve shows a downward trend at the beginning and an upward trend towards the end, positioned between the 2nd and 3rd pitch ranges, classified as a low-rising tone.

Upon comparison, it is found that the experimental pitch values obtained align generally with the descriptive perceptions of tone. The experimental pitch values for the high level tone and the low level tone are 55 and 11, respectively, which are consistent with the descriptive perceptions. However, for the mid-level tone and the low-rising tone, the experimental pitch values obtained are 44 and 23, respectively, which differ slightly from the perceived pitch values of 33 and 13. This indicates a certain degree of discrepancy. Such discrepancies may be due to the influence of factors such as the speaker's age, education level, and other variables on the fundamental frequency analysis. These individual differences can lead to minor discrepancies between the experimental results and perceptual assessments.

5. Conclusion

From a synchronic perspective, Fengke dialect features 37 initial consonants, 23 vowels, and 4 tones. The main characteristics of the initial consonants include the presence of voiceless stops, affricates, and fricatives, each having both voiced and voiceless counterparts with a complete and distinct contrast. Voiced consonants do not exhibit aspiration, forming a three-way contrast of voiceless, pure voiced, and nasal glides. There are 23 vowels, dominated by 12 monophthongs and 7 diphthongs categorized into two types: those with a medial [j] and those with a medial [w]. The vowel [ɑw] appears exclusively in Chinese loanwords. Additionally, there are 4 nasalized vowels [ĩ, ỹ, ẽ, ə̃], which only occur following glottal consonant [h]. In terms of tones, most Naxi dialects exhibit level tones, while the Fengke dialect includes 3 level tones: high level (55), mid-level (33), low level (11), and 1 rising tone (13), which appears in both Chinese loanwords and native Fengke vocabulary.

From an experimental perspective, this study provides an in-depth investigation of the phonological characteristics of the Fengke dialect, revealing its notable features in both segmental and prosodic domains. Using Praat software, the study visualized the spectrograms of consonants and vowels in Fengke, which facilitates a clear and intuitive representation of their phonetic properties. Additionally, acoustic vowel plots were constructed based on formant frequency values to visually represent the distribution characteristics of tongue body vowels in Fengke. Overall, the positions of the extreme vowels u and ɑ are relatively stable, whereas the position of i shows considerable variation but remains within the high vowel region. Most vowels tend to be centrally positioned.Furthermore, the study analyzed the fundamental frequency contours and tonal patterns of single-syllable words in Fengke. Comparative analysis reveals that the experimentally obtained pitch

values are generally consistent with perceptual impressions: the high-level tone and low-level tone are represented by 55 and 11, respectively, while the mid-level tone and low-rising tone have experimental values of 44 and 23, which differ slightly from the perceptual values of 33 and 13.In summary, through these data and visualizations, the study offers an objective and comprehensive depiction of the phonemic characteristics, internal variations, and overall distribution of the phonological system in the Fengke dialect, further illustrating the distinctive features of its phonetic system.

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