INSTRUMENTAL ANALYSIS OF MONOPHTHONGS OF HADRAMI ARABIC

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INSTRUMENTAL ANALYSIS OF MONOPHTHONGS OF HADRAMI ARABIC

ABSTRACT

Hadrami Arabic is the dialect spoken by Hadrami people in Hadramawt, the southern part of Yemen. This study aims to instrumentally analyze the acoustic properties of the eight monophthong vowels of Hadrami Arabic, three short vowels (/i/, /a/, /u/) and five long vowels (/iː/, /aː/, /uː/, /eː/ and /ɔː/). The targeted vowels are placed in between CVC and CCVC syllables, to be inserted in natural sentences. All sentences are read naturally by Hadrami Arabic speakers, who were born and live in the city of Seiyun in Hadramawt. They are aged between 36 – 60 years old. Acoustic and auditory analysis is used to investigate quality and duration of the monophthongs in Hadrami Arabic. Both the first and second formants are analyzed as well as vowel duration in milliseconds based on gender variation. The findings of vowel quality show HA vowels' classification in the acoustic vowel space. The HA /i/ and /iː/ are high front vowels. The HA /u/ is a high central vowel while the HA /uː/ is a high back vowel. The HA /a/ is a mid-low front vowel while the HA /aː/ is a low front vowel. The HA /eː/ is a mid-high front vowel whereas the HA /ɔː/ is a low back vowel. The findings of vowel quantity indicate that vowel duration is maintained between all vowel pairs. The duration of long HA vowels is more than double the duration of the short ones. Findings also indicate gender differences in pronouncing vowels for both vowel quality and quantity. While male speakers pronounce higher and more retracted HA vowels, female speakers pronounce longer HA vowels. A comparison between HA vocalic system and other Arabic vocalic system shows that all HA vowels have a slight tendency to be lower and more fronted than all other Arabic vowels and the HA long and short vowels pairs maintain a moderate range of length distinction compared to other vowels of other Arabic dialects.

Keywords: Hadrami Arabic, Arabic Dialect, Vowels, Acoustic Analysis

ANALISIS INSTRUMENTAL MONOFTONG BAHASA ARAB HADRAMI

ABSTRAK

Bahasa Arab Hadrami merupakan dialek yang ditutur oleh orang Hadrami dari Hadramout yang terletak di kawasan selatan negara Yemen. Kajian ini bertujuan untuk menjalankan analisis instrumental terhadap ciri-ciri akustik yang terdapat pada lapan vokal monoftong bahasa Arab Hadrami: tiga vokal pendek (/i/, /a/, /u/) dan lima vokal panjang (/i:/, /a:/, /u:/, /e:/ and /ɔ:/). Vokal sasaran terletak di antara suku kata jenis CVC dan CCVC dan dimasukkan ke dalam ayat sejadi. Kesemua ayat tersebut akan dibaca secara biasa oleh sepuluh orang penutur bahasa Arab Hadrami yand terdiri daripada empat lelaki dan enam perempuan. Semua peserta kajian dilahirkan dan bermastautin di kota Seiyun, Hadramout. Mereka berumur dalam lingkungan 36 - 60 tahun, dan purata umur peserta kajian adalah 44 tahun. Data yang dikumpul dianotasikan dan dianalisis menggunakan pengkodan ramalan linear (LPC) melalui versi Praat 6.0.37 (Boersma & Weenik, 2018). Analisis akustik dan auditori digunakan untuk menyelidik kualiti dan jangka masa monofton yang wujud dalam bahasa Arab Hadhrami. Selain daripada forman pertama dan forman keduanya, jangka masa yang akan diukur dalam unit milisaat juga dianalisis mengikut perbezaaan antara jantina. Dapatan kajian dari segi kualiti vokal bahasa Arab Hadhrami telah ditunjukkan dalam ruang vokal akustik. Vokal /i/ dan /i:/ dalam bahasa Arab Hadrami merupakan vokal depan tinggi. Vokal /u/ dalam bahasa Arab Hadhrami ialah vokal tengah tinggi manakala vokal /u:/ ialah vokal belakang tinggi. Vokal /a/ ialah vokal depan separuh rendah dan vokal /a:/ ialah vokal depan rendah. Vokal /e:/ ialah vokal depan separuh tinggi dan vokal /ɔ:/ ialah vokal belakang rendah. Dapatan kajian dari segi kuantiti vokal telah menunjukkan bahawa jangka masa vokal panjang bahasa Arab Hadhrami adalah dua kali lebih panjang berbanding dengan jangka masa vokal pendeknya. Kajian ini juga telah menunjukkan perbezaan antara jantina dalam sebutan vokal dari segi kualiti dan kuantiti vokal. Penutur lelaki mempunyai sebutan vokal yang lebih depan dan tinggi manakala penutur perempuan akan mempunyai sebutan vokal yang lebih panjang. Perbandingan antara sistem vokalik Arab Hadrami dan sistem vokalik Arab lain menunjukkan bahawa semua vokal Arab Hadrami mempunyai kecenderungan ringan untuk menjadi lebih rendah dan lebih maju daripada semua vokal Arab lain dan pasangan vokal panjang dan pendek Arab Hadrami memelihara julat perbezaan panjang yang sederhana berbanding dengan vokal lain dari dialek Arab lain.

Kata kunci: Arab Hadrami, Dialek Arab, Vokal, Analisis Akustik

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LIST OF ABBREVIATIONS

CA: Classical Arabic

MSA: Modern Standard Arabic

HA: Hadrami Arabic

F1: First formant frequency

F2: Second formant frequency

Hz: Hertz

Ms: Milliseconds

SD: Standard deviation

Avg: Average

df: Degrees of freedom

Chapter 1

Introduction

1.1. Introduction

The main motive of this study is to conduct an instrumental description of the eight Hadrami Arabic monophthongs; three short vowels /i/, /a/, /u/ and five long vowels /i:/, /a:/, /u:/, /e:/ and /ɔ:/, at the aim of preservation and documentation. The study describes the quality and quantity of HA vowels through an acoustic approach. This chapter gives an introductory account of the study. It includes the introduction of the study, the statement of the problem, the research objectives, the research questions, and the significance of the study in addition to the limitation and organization of the study.

1.2. Background of the Study

The origin of the name 'Hadramawt' comes from two parts; 'hadr' which means urban, 'wt' which means "a place or settlement" and 'm' is a definite article, (AI-Dharari, 1994; cited in Alssagf, 1999). Hence, the name Hadramawt (also written as "Hadhramaut" and "Hadhramout") means the place of the urban people. Historically, Hadramawt was the route of trade of many goods brought from the eastern part of the world to the Middle East and Europe including the famous trade of incense in the ancient world. Frankincense was planted and brought from the land of Hadramawt until today. The history of Hadramawt and Hadrami societies is a history of an early form of globalization, based on politics, trade, education, and religion. It is a story of cultural and economic cooperation and positive integration in societies with different races and ethnicities (Jacobsen, 2009). In ancient times 'Wadi Hadramawt' was a virtual Garden of Aden with its elaborated irrigation channels and dams. The channels flooded twice a year resulting in prosperous life in the valley and the luxuriant groves of incense trees that Hadramawt was famous for (Lewcock, 1986).

An astonishing sign of this ancient civilization that settled in the valley until the present day is the old walled city of Shibam or as Nicknamed by many the 'the Manhattan of the desert'. The city is located in the ancient route of trade of spice and incense. It is the first skyscrapers ever built in History and a registered world heritage center by UNESCO in 1982 to preserve the cultural heritage of the valley of Hadramawt. Another sign is the wide number of Hadrami societies of Hadrami descendants spread in countries in the far South and the far East of the world in Africa and Asia.

The inhabitants of Hadramawt are called 'Hadramis'. It is said that they are among the most civilized and bravest people of the southern part of the Arabian Peninsula" (Al-Khalidi 1986, p.135). According to the Central Statistical Organization of Yemen, more than 1651000 people live in Hadramawt. They speak Hadrami Arabic (Henceforth HA) as their mother tongue. Not to mention the Hadrami Immigrants scattered in different parts of the world including more than 5 million in Indonesia alone, a consequential dense population of Hadrami diaspora (Alaagaf,1999). However, the rate of constant change of the dialect has increased recently due to many internal and external factors. One may quote (Watson,1993, p.1) comment on Yemeni dialects:

"The rate of linguistic change has now further increased partly due to an overall improvement in communication and education, and partly due to unification of North and South Yemen in May 1990, and the forced return of almost one million emigrant workers from Saudi Arabia and the Gulf after the Gulf War in early 1991".

Even though the dialect is in constant change, very rare linguistic attempts were conducted to document the dialect.

1.3. Background of Yemen

Yemen is an Arab country in which MSA is the official language. It is the second largest country in the Arabian Peninsula. Historically, Yemen had ancient civilizations that age as early as 5000 BCE (McLaughlin, 2008). It settled in a strategic location in crossroads of trade and culture along a broad sea road in the southern part of the Arabian Peninsula. It is inhabited by 25 million citizens (Mufleh & Alquhali, 2018).

Modern Yemen is divided into twenty-two governorates, including Sanaa, Taiz, Aden, Abyan, Al Byada, Al Hudaydah, Al Jawf, ‘Amran, Dhamar, Ibb, Ma’rib, Sa’da, Shabwah, and Hadramawt, etc.

1.4. Background of Yemeni dialects

There is a wide range of dialects spoken in Yemen such as Sanani, Tazi, Adeni, Hadrami, etc. They are distinctive in their vocabulary, phonology, morphology, and syntax. They are geographically distributed in the Yemeni governorates as Sanaa, Taiz, Aden, Dhamar and Hadramawt, etc. However, Aldubai (2015) classified Yemeni Dialect into four main dialects the San'ani dialect (SD) spoken in the northern part of Yemen from Sa'dah to Dhamar, the Ta'izi dialect (TD) spoken in the region of Ta'iz, Ibb, and Aden, the Tihami dialect (THD) spoken in the western areas beginning from Hajja until Mocha, and the Hadrami dialect (HD) spoken in the region of Mareb, Shabwa, Hadramawt, and Al-Mahra. Versteegh (2009) in contrast distributed the Yemeni dialects into 16 dialectal zones, see figure 1.1.

1.5. Background of Hadramawt

Hadramawt is located in South Arabian Peninsula between Alamhara province and Shabwah and Aljawf. It has a coastal line averaging 1,370 m along the Gulf of Aden and the Arabian Sea. It is spreading in Yemen from the Ramlat as-Sabat‘ayn and the inner desert to the eastern border area of Mahra (Schiettecatte, 2007). A.F.L. Beeston (1971, p. 53) defined Hadramawt as the deep valley spreading on the southern coast of the Arabian Peninsula from 48 E to 50 E. Archaeological researches in Hadramawt revealed that the first model of settlement in Hadramawt dates to the Palaeolithic and Neolithic periods (Schiettecatte, 2007). During the British colonization of Aden (1839-1967), Hadramawt was a land of two sultanates, al-Qu‘aiti and al-Kathiri. After that in 1967 Hadramawt became one of the governorates in South Yemen then part of the Republic of Yemen after unity in 1990 (Bahumaid, 2015). When there is a mention of Hadramawt, one always recalls Hadrami diaspora to countries in Eastern Africa as Kenya, Somalia, and Tanzania and South and Southeast Asian countries as Indonesia, Malaysia, Singapore, Brunei, and India. The fascinating story of the Hadrami diaspora was a subject of many scholarly studies (Le Guennec-Coppens,1989; Alattas, 1997; Manger, 2010; Miran, 2012; Khader,2017; Walker, 2021). It is classified as both ‘trade diaspora’ and ‘religious diaspora’ involving missions of economic trading and religious spreading of Islam (Manger, 2010). It led to the diasporic prosperous Hadrami communities of commerce, religion, and politics and a great influence in the migrated countries (Miran, 2012).

1.6. Background of Arabic Language

The Arabic language is the official language in Middle East countries. It is the sixth most spoken language world widely (Newman, 2002, p.1). More than 400 million people around the globe speak Arabic language as their mother tongue (Guellil, et al., 2021). It is the language of the Holy book of Islam ‘Quran’. The language is of great importance not only to Muslims but to the whole modern world. Political and International affairs are also factoring the growing number of learners of Arabic language, (Salameh & Abu-Melhim, 2014).

Arabic language is classified into three varieties: Classical Arabic (CA), Modern Standard Arabic (MSA) and the spoken dialects or colloquial Arabic.

Classical Arabic is accounted as the most prestigious variety of Arabic in the sense that writers have to follow the syntactic and the grammatical norms set by early Arab grammarians. During pre-Islamic and post-Islamic periods, Classical Arabic was the only means of communication (Al-Saidat & Al-Momani, 2010). Some founded inscriptions of Classical Arabic dated to 5^{th} Cen. A.D. i.e. ZABAD (512 A.D.), HARRAN (568 A.D.), UMMUL JIMAL (568 A.D.).

Nevertheless, classical Arabic is no longer a native language of an Arabic speaker. The main source of Classical Arabic nowadays is the Holy Quran and Arabic literature (Aljumah, 2008). Scholars like Al-Faraheedi and Sibawaih are among the pioneering early Arab grammarians who wrote their observations about CA i.e. *Al-Kitab.*

The variety that is considered the official language in the Arab countries is Modern Standard Arabic (MSA). It is the official variety of media, documentation, and education. It stems from classical Arabic (Al Smadi et al, 2016). It is learnt formally through a child's education. MSA is indifferent to CA that the former has a larger set of vocabs and simpler grammar forms (Huthaily 2003, p. 1-2). CA and MSA are also phonologically indifferent but they are phonetically identical (Gadoua,2000). The basic morphology and syntactic structures remain the same (Fischer 1997, p.189). Colloquial Arabic is the spoken dialects in Arab countries. Native speakers learn it as their mother tongue prior to any formal education (Holes, C., 2004). It varies and differs among different regions as it has different linguistic properties (Ziadeh & Winder, 2003).

1.7. Background of Hadrami Arabic

Hadrami Arabic is classified as a colloquial Arabic variety. It is an Arabic dialect spoken by the people living in the governorate of Hadramawt in the Republic of Yemen. Hadrami Arabic is also spoken by the people who left Hadramawt seeking trade during Hadrami Diaspora to Southeast Asia, East Africa, the Indian continent, and to Arabian Gulf Countries in recent years (Bahumaid, 2015). Geographic factors have a crucial influence on dialectal variation (Wieling, et al., 2011). Geographically distributed, Hadrami Arabic has two main varieties, the Hadrami Arabic of the valley resides in the cities of the valley of Hadramawt, such as Seiyun, Tareem, Do'n, and Al-Qten. The Hadrami Arabic of the coast resides in the coastal cities such as the city of Mukalla and Ash Shihr. In this study, Hadrami Arabic is restricted to Hadrami Arabic of the valley spoken in the city of Seiyun. There were some rare early studies giving a dialectological description of the dialect. One may illustrate Landberg's (1901) descriptive account of the dialect, and a more comprehensive description done by Van den Berg (1886).

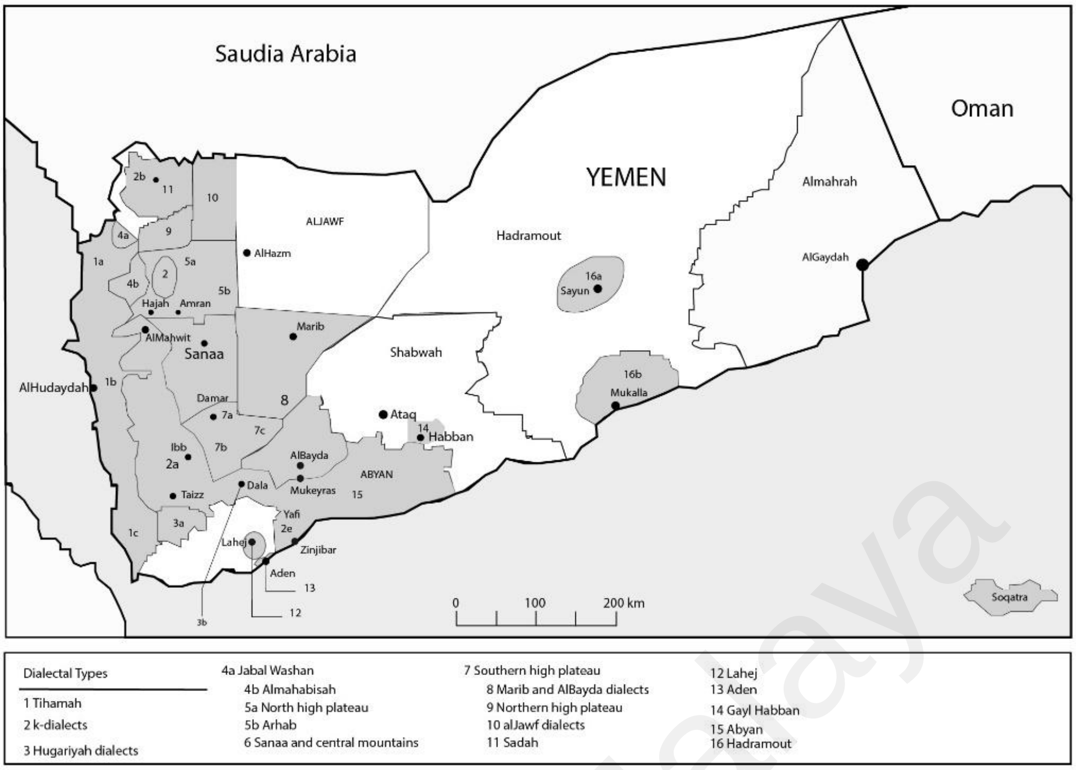


Figure 1.1: Map of dialectal zones in Yemen (Versteegh, 2009, p.2)

1.8. Statement of The Problem

When it comes to Hadrami dialect, linguistic scholars' attention was grabbed to study the dialect due to Hadrami diaspora to Africa, India, South East Asia, and other parts of the Arabian Peninsula and its economic and religious influence on these regions (Alattas, 1997). Reflecting upon this 'diaspora', one may recall Sir Richard

Burton's quote: 'It is generally said that the sun does not rise upon a land that does not contain a man from Hadramawt' (Burton, 1966, p. 58). Making Hadrami culture and dialect rich of diversity and integration. Linguistic phenomena as Hadrami Loanwords and borrowings were a consequence of this integration. Scholars such as Al-Saqqaf, A. H. (2006) and Bahumaid, S. (2015) studied this phenomenon. Descriptive studies were conducted on the dialect by foreign scholars as Landberg (1901) and local scholars as

Al-Saqqaf, A. H. (1999). Al-Saqqaf, A. H. (1999), in his study a descriptive study of the spoken Arabic of the valley of Hadramawt, stated that the dialect is in constant change due to different social factors, internal and external ones. Several factors led to the increase of this linguistic change of Hadrami Arabic such as improvements in communication and education. Furthermore, the unification of north and south of Yemen and the return of immigrants from Gulf due to political and economic circumstances. Therefore, there is an urgent need for documenting Hadrami Arabic. According to Pulgram (1966), spectrographic analysis of sounds provides an objective analysis of the sounds of a language. Barry (1996) stated that acoustic analysis is very fundamental in studying a sound inventory. The need to study sounds acoustically has intensified. Especially, after 1970 when William Labov and his team at University of Pennsylvania started utilizing acoustic analysis to study vowels production. Despite the lack of instrumental analysis of the dialect, Basalamah (1980) was the only scholar who conducted a spectrographic analysis of the dialect. These experimental investigations were done only on the consonants of Hadarmi Arabic. Hence, no acoustic studies were conducted on the HA vowels until then. Since Al-Saqqaf, A. H. (1999) made the most comprehensive attempt to study HA variety spoken in the city of Sieyun, this study complements it with an acoustic description of HA vowels of the variety spoken in the same city. Vowels are best described in terms of their vowel quality (Maddieson, 2013; Ladefoged, 2006) and vowel quantity (Ferguson and Kewley-port, 2007; Mok, 2011). This study puts these two acoustic parameters under examination, puting into consideration gender variation and its major effect on vowel quality and quantity. As vocal tract length which is associated with gender has a mjor effect on formant frequencies (Yang, 1996). Moreover, female speakers are more prone to dialect change than male speakers due to their tendency to use more incoming forms than male speakers

(Labov, 1990). This study particularly studies vowel quality and quantity of Hadrami Arabic monophthongs in terms of the first two formant frequencies and vowel duration in spectrograms in milliseconds (ms) for Hadrami male and female speakers. and since HA is one of the colloquial Arabic varieties and this study significantly adds to the Arabic literature, this study examines to what extent HA vocalic system is variant to other Arabic vocalic systems in terms of vowel quality and duration.

1.9. Research Objectives

The present study aims to give a comprehensive description of HA vocalic system through describing both the vowel quality and quantity of HA vowels of HA of the valley. It aims to extend the previous impressionistic work done by Alssagaf (1999) that describes the phonetics of the Hadrami Arabic sounds to an acoustic approach. The acoustic properties that correlate with vowel quality and vowel quantity are investigated through an acoustic analytical framwork, from the perspective of the theoretical framework of source filter concepts of (Fant, 1960). The research also aims to contribute to the literature of Arabic dialects, through describing HA vowel system by acoustic means as one representative of colloquial Arabic varieties.

There are two main research objectives of this study:

1. To describe the vowel quality of the monophthongs of Hadrami Arabic as produced by male and female speakers.

2. To investigate the duration of short and long vowels of Hadrami Arabic as produced by male and female speakers.

1.10. Research Questions

According to the research objectives, the researcher intends to answer the following questions:

1. What are the acoustic properties of monophthongs of Hadrami Arabic based on their formant values of male and female speakers?
2. To what extent is the distinction of short and long vowels in Hadrami Arabic based on the vowel duration of male and female speakers?

1.11. Scope and Limitations

This research is restricted to monophthong vowels of Hadrami Arabic dialect spoken in the city of Seiyun, Yemen. There are other Hadrami Arabic varieties that it is highly recommended to be further investigated in future research. Diphthongs are not included in this research as they require different method and approach. Emphatic versions of vowels are not included as well due to time limitations. The average age of the participants ranges from 36-60, hence, the findings do not reflect all age groups. The method could include other reading contexts, such as spontaneous speech and conversational speech to have a richer dataset in a more native-like speech.

1.12. Significance of the Study

The findings of this research mainly contribute to the documentation and perseverance of HA as an Arabic dialect vulnerable to dialect change. It also fills the gap of acoustic analysis of the vowel system of HA that has never been acoustically analyzed, neither any other vowel system of a Yemeni dialect. Because every Arabic syllable must contain a vowel and 60% - 70% of Arabic speech consists of vowels, it is very important to give a reliable and objective description of Arabic vowels. This research relies on primary acoustic parameters of vowels quality and quantity. Hence, it gives the most reliable and objective description of Hadrami Arabic vowel system. In addition, this study contributes to the literature of Arabic vowel systems.

1.13. Organization of the Thesis

This thesis includes five chapters. Chapter one briefs an introductory account of the study. It sets the statement of the problem, the research objectives, the research questions, the significance of the study, and the limitations. Chapter two reviews the most related studies to the Arabic varieties' vocalic systems, the Yemeni varieties, and the Hadrami ones. It also gives fundamental background on the main parameters investigated in this study, vowel quality and quantity, as well as the theoretical framework of the study. Chapter three illustrates the acoustic analytical framework followed to analyse HA vowel quality and quantity. It includes the methodological steps followed; data collection, reading materials, participants, and data analysis. Chapter four explains the findings of the eight Hadrami Arabic vowels acoustic data in terms of the first two formant frequencies and vowel duration. It also contains a comparison between this thesis findings and earlier related Arabic studies' findings. Chapter five discusses and concludes the findings of the thesis.

1.14. Summary

This chapter illustrates the introductory and basic aspects of the study. It gives background information about Yemen in general and Hadramawt in particular. Moreover, an overview of Yemeni dialects and Hadrami dialect is introduced as varieties of Arabic language. The statement of the problem, the research question, and the objectives elaborated. The scholarly aspects that this research is limited to and the main contribution it adds to are discussed. Further, the organization of the coming chapters is set clear.

Chapter 2

Literature Review

2.1. Introduction

Acoustic phonetics provides the theoretical and analytical framework for implementing studies in fields such as sociophonetics, dialect geography, sociolinguistics, phonetics, and historical linguistics. It is the science describes the different kinds of acoustic signals that are produced as the vocal organs move causing patterns of air disturbance. These waves propagate outwards in all directions reflecting different speaking conditions and speaking styles, (Harrington, 2010).

The very beginning of speech signal processing was when the spectrograph was invented in the 1940s (Koenig, Dunn, and Lacy, 1946). Then In the 1950s, there were more advancements in vocal tract modelling and speech synthesis (Dunn, 1950; Lawrence,1953; Fant,1959) and a series of innovative laboratorial experiments using synthesis from hand-drown spectrograms done at Haskins Laboratories (Cooper, Liberman, & Borst, 1951). All of these attempts provided the fundamental technology for more investigation to be carried out, including the widely cited study by Peterson and Barney (1952) by which their recordings and measurements were used as a database by other researchers afterwards. Among the pioneering studies that boosted the field with methodological development through more advanced computational approaches to analyse sociolinguistic data are the series of Labovian studies done in the 1970s in acoustic phonetics. William Labov and his team at University of Pennsylvania followed a more systematic approach in utilizing acoustic analysis to study vowels production (Labov et al., 1972). Labov was motivated by the idea that dialects are in constant change. Hence, dialect documentation is very essential. This change is driven by many economic, political, and socio-geographical factors (David, 1993). Labove in 1994 has studied the progress of change in dialect geography in urban settings in English-speaking countries such as the United States, Australia, and Canada. He reported this change in his book principles in linguistic change as the following:

"It is . . . commonly reported by dialectologists that local dialects are disappearing and that we have entered a new period of linguistic convergence instead of divergence. But research in urban areas shows the opposite. Since 1972, I and others have been reporting evidence of continued sound change in the dialects of the major English speaking cities. In every large speech community studied in the United States, Canada, and Australia, we observe the vigorous development of the local vernacular . . ." (Labov, 1994, p. 22–23).

In this study, the variety of Arabic; Hadrami Arabic, spoken in the region of Hadramawt in the southern part of Yemen is investigated. As all dialects have different dialectal properties at all linguistic levels: phonology, segmental, prosody, morphology, semantics, lexicon, and syntax. Hadrami Arabic is investigated from a phonological perspective. Particularly, the vocalic system of Hadrami Arabic spoken in the city of Seiyun is objectively described within an acoustic phonetic theoretical framework.

This chapter illustrates the most related studies to acoustic analysis of Arabic vowels, the studies related to Yemeni dialects phonology as well as Hadrami Arabic. Moreover, it illustrates a brief account of the two main acoustic parameters investigated, which are vowel quality and vowel quantity and the theoretical framework on which these two parameters are perceived, which is source filter theory.

2.2. Early Arabic Phoneticians' Description of Vowels

Vowels are a very essential component of languages and very fundamental speech units that play a main role in speech production and understanding. Vowels are the most remarkable and centred sound of a syllable (Al-Eisa, 2003). Early Arab grammarians as Sibawayh and Ibn Jinni have the earliest attempts to define vowels in the late 8th and 10th century. They described vowels as 'sounds produced in the empty space in the throat and mouth' termed as 'huruuf al-jawf". Before that in the 7th century Al- Khalil Ibn Ahmed Al- Farahidi has called them "*Saoait*" sounds "الصوائت' because they are constructed without any obstruction of the tongue unlike the consonants (Al-Ani, 1993). In the 10th century, Ibn Jinni in his definition of vowels reported that they are similar to the tunes of a flute stating that vowels are "These sounds that originated from the throat and mouth and later being shaped differently from each other, based on the available space for airflow, as the tune coming out of a flute" (Alotaibi, 2018, p.17). Makki in the 10th century gave another definition to vowels stating that "they are letters that are articulated starting from the chest, where the air is, and later shaped in the throat and mouth" (Muhammad, 2005). He also stated that vowels production is in a close relation with the nature of the consonants before and after a vowel which is closely related to what recent researchers reported about coarticulatory effect on vowels; sounds have a major effect on neighbouring sounds when they are grouped together in one utterance (Liberman et al, 1967; Massaro, 1992). Later on, in the same century, Ibn Sinna presented his work *Asbab Hduth Alhuruf;* the reasons behind the sounds, which is a detailed book of six chapters discussing various aspects of sounds production such as the articulation of sounds, the anatomy of the tongue and larynx, production and perception of Arabic and non-Arabic sounds (Al-Ani, 1993; Semaan, 1963). The main motive for Arab Grammarians to provide these discreptions and discussions about vowels is to set linguistic rules for

Quranic reciters to read Quran which is a form of classical Arabic accurately. And though these descriptions might seem primitive at our era, they were very advanced at that time and provided the very first foundation for phoneticians later on. Figure 2.1. illustrates a diagram of the points of articulation system by Alsakaki from 13th century as cited in *Current issues in the phonetics sciences* by Bakalla (1977).

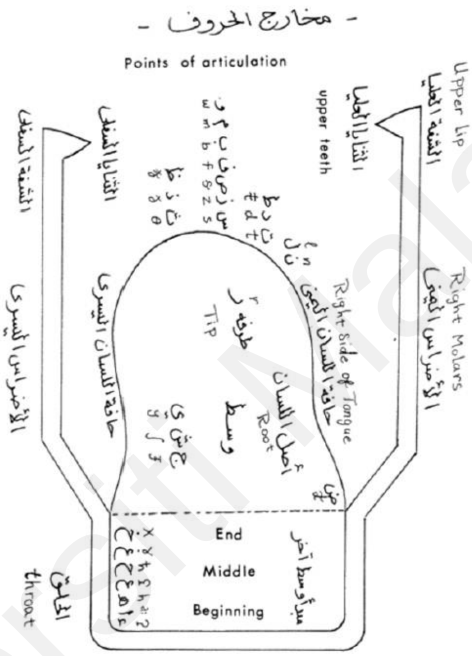


Figure 2.1: Points of articulation system by Alsakaki from 13th century

2.3. An Overview of Vowels

On the contrary, researchers of our era defined vowels as sounds produced when articulators do not come close together and involves no obstruction of the airstream (Ladefoged and Johnson, 2011). They are also defined as speech units produced with an open vocal tract, vibrating vocal folds and non-impeded air stream resulting in a very loud acoustic signal (Fucci and Lass, 1999). Regarding loudness, Vel and Aji (2015) stated that vowels require maximum energy to be produced, hence they are produced with the largest amplitude among all phonemes. Pike's definition of vowels in (1943) was among the early attempts to define vowels. He classified sounds into vocoids and contoids. As vocoids are defined as central oral resonant, he defined vowels as a syllabic vocoid. Chomsky & Halle (1968) featured vowels as (+syllabic, -consonantal), defining (-consonantal) as segments that don't have a main obstruction of the oral tract. Ladefoged (1982) defined 'syllabic' as "necessary units in the organization and production of utterances". The general definition that most scholars agreed about is that vowels are phonetic segments that are articulated with no major strictures in the vocal tract that vary in description across different vocalic systems. These vowels are characterized according to the place of the tongue, the rounding of the lips, and the vowel length (Ladefoged, 2006). The position of the tongue inside the vocal tract is closely related to the vowel quality and the vowel length is closely related to vowel quantity.

The source filter theory which provides the theoretical framework for describing vowels and the two main parameters; vowels quality and vowel duration, concerned in the description of vowels are discussed in the following sections:

2.4. Source Filter Theory

The acoustic characteristics of speech sound, as vowel quality and vowel length, are determined mainly by the complex configuration of the speech production process. The explanation of this complex process is symbolized through a source filter model. The Source filter theory of speech production was firstly introduced and theorized by Fant (1960). It involves a mapping between the vocal tract gestures and the acoustic signals. The source filter theory has been studied widely over decades by (Chiba & Kajiyama, 1941; Stevens & House, 1955,1961; Fant, 1960; Flanagan, 1972; Stevens, 1998).

The main concept of the source filter theory is that speech sounds as vowels can be analyzed in response to acoustic energy 'the source' and a frequency dependent transmission system 'the filter'. Sound production is described according to these source and filter configurations (Maddieson, 1984). In the simple model of source filter production of vowels, the source is the acoustic energy generated by the voicing signal of the vibrating vocal cords in the glottis. When there is a high air pressure as air comes from the lungs, the vocal folds get blown apart. When the air pressure produced between the vocal folds of the air coming from the lungs decreases as channelled in the narrow opening between the vocal folds, the vocal folds close. This cycle of closing and opening causes periodic audible voiced waveforms and acoustical energy of fundamental frequency (F0) (Harrington & Cassidy, 1999). The fundamental frequency (F0) of vowels equals the repetition rate of vocal fold vibration; the vocal fold makes (220 Hz) fundamental frequency in a second (Ladefoged, 2006). This mechanism of vocal cords vibration is explained by the aerodynamic-myoelastic theory of vocal fold vibration proposed by (van den Berg, 1958).

After the production of the audible source energy, the vocal tract filters these waveforms as transmitted to the lips opening resulting in formants frequencies determined by the shape and size of the vocal tract. The vocal tract length and varying cross sectional areas across the vocal tract from the glottis and to the opened lips are the result of different resonances of the sounds. The longer the vocal tract, the lower the resonances of the sounds (Kent,1993). As the air stream propagates across these sectional areas, systemic variations of formants frequencies are produced along the constriction of these areas in the vocal tract. Hence, the constriction and movements of the areas along the vocal tract are the source of formant frequencies, abbreviated as Fn where n is the formant number. Examples of these sectional areas along the tube are the chamber in the back of the vocal tract from the larynx to the top of the throat corresponding to the first formant frequency (F1), and the chamber from the top of the throat to the lips generating the second formant frequency (F2) (Ahmed, 2008). These systematic variations of the formants' frequencies correlate with the vowel quality, hence the filter determines the vowels produced. A concept that vowel formants are sufficient for vowel identification is a result of this theory (Kent, 1993).

2.5. Vowel Quality

From an articulatory point of view, vowels are characterized by the position of the tongue inside the vocal tract[1]. As far as vowel quality is concerned, vowels can be described from three comparative articulatory dimensions; tongue height (low-high dimension), tongue advancement (front-back dimension), and lip rounding. Tongue height is defined as how open the jaw needs to be to produce the vowel. The front-back dimension is defined as whether the tongue needs to be pushed forward or backward to produce the vowel (Maddieson, 2013). Ladefoged (2006) stated that there are three categories for describing the vowel advancement and retraction; front, back and central. When vowels are produced with the highest point of the tongue in the front of the mouth, they are called front vowels. When it is in a retracted position, they are called back vowels. Vowels can also occur between these two extremes as central vowels. In terms of the tongue height, when the vowel is produced while the tongue is up to the roof of the mouth, they are called high vowels. Vowels are called low vowels when they are produced with an open jaw and the tongue downward. When vowels occur between these two extremes they are called mid-

[1] There is an exception for nasal vowels linked to the nasal cavity which are not included in this research. Nasal cavity represents an extra source of formants (Laver 1994).

high and mid-low vowels. In addition to vowel height and front-back dimension, vowels can be described also in terms of lip rounding and classified as rounded and unrounded vowels (Ladefoged, 2001, p. 40). Scholars such as Chomsky & Halle (1968) suggest that there are three possible comparative levels of vowel height and advancement. However, the International Phonetic Association (1989) indicates that there are more than seven possible heights. Ladefoged and Maddieson (1996) state that there are more than three possible levels of height and advancement. According to Schwartz et al,)1997(, there are 37 possible vowels in the languages of the world (Figure 2.2.).

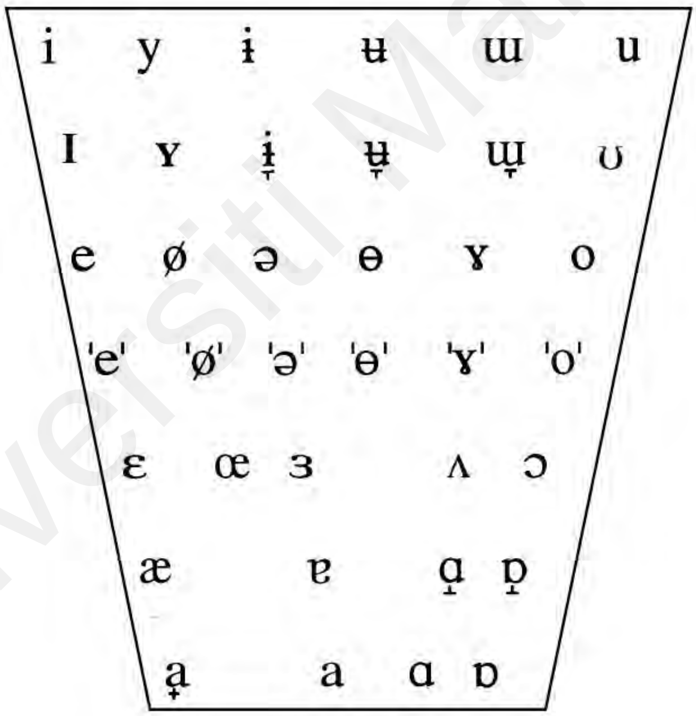


Figure 2.2: The 37 possible vowels of the languages of the world (Schwartz et al, 1997(

The vowel chart of cardinal vowels first set by Daniel Jones (1934) and utilized by the International Phonetic Association represents the extreme points of a set of eight vowels that have known quality; figure 2.4. He implies that there are four possible levels for vowel height and two for vowel advancement and retraction. Jones (1934, p. 28) defined the cardinal vowels as “a set of fixed vowel sounds having known acoustic qualities and known tongue and lip positions”. The quadrilateral of these known vowels represents the area in the mouth by which no vowels can be produced beyond; see figure 2.3. The concept of cardinal vowels is based on the idea that vowels of any language have a tongue position within a limited vowel space (Catford, 1988, p.130). The vertical axis in the chart represents the vowel height which correlates with the tongue height. Whereas the horizontal axis represents the front-back dimension which correlates with tongue advancement (Laver,1994).

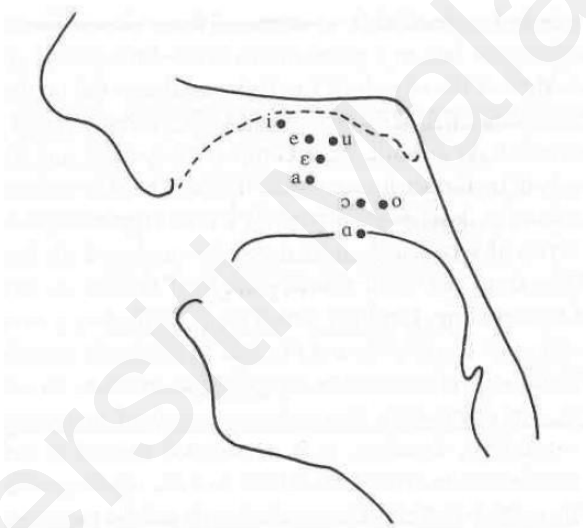


Figure 2.3: The extreme points of the tongue of cardinal vowels Ladefoged (2006:215)

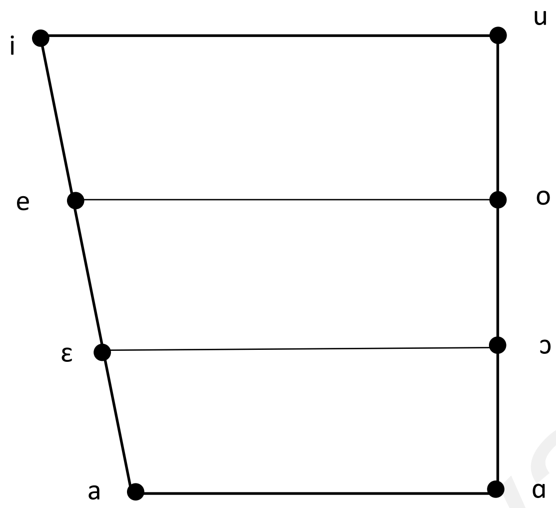


Figure 2.4: Quadrilateral of cardinal vowels set by Daniel Jones (1934)

In this chart, the /i/ vowel is considered a high front vowel, whereas the /u/ is considered a high back vowel. The /a/ is described as a low front vowel. For lip rounding, the cardinal vowel /i/ is described as an unrounded vowel whereas the cardinal vowel /u/ is considered a rounded one.

This classification is an articulatory one. From an acoustic perspective, vowel quality can be always determined in terms of formant frequencies. Since the study by Peterson & Barney (1952) formant frequencies measurements have been a norm by researchers later on to measure vowel quality. Formant frequency is defined as 'a vocal tract resonance' which is displayed on a spectrogram as a relatively broad band of energy (< 300 Hz.) (Shahin, 1997, p. 588). They are also defined as "The spectral peaks of the sound spectrum" (Fant, 1960). In the dictionaries of phonetics, they are defined as a concentration of acoustic energy representing the way the air from the lungs vibrates; it can be represented by a dark thick band in the spectrogram (Crystal, 2008, p.196; Trask, 1996, p.148). In the most basic definition, they are the resonance resulting in the oral cavity during vowels production. As the vocal tract shape change during the production of vowels, different formant frequencies are produced. Frequency measures the rate of the number of cycles of waveforms that take place per second. They are measured in Hertz (Ogden, 2009, p. 175), see figure. 2.5.

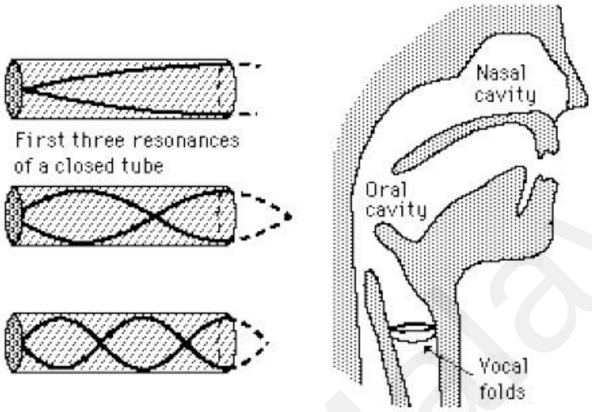
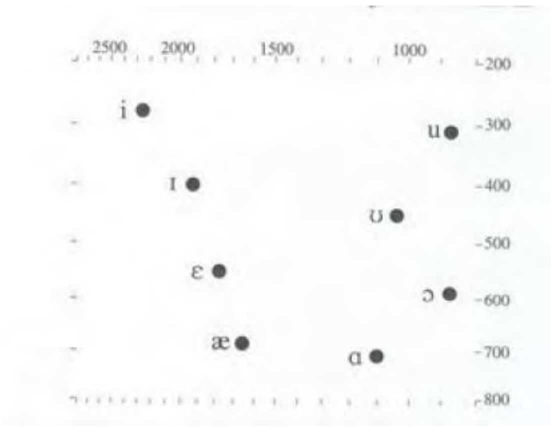


Figure 2.5: The cycles of formant frequency and the vocal tract

F1 refers to the first formant frequency, F2 to the second formant frequency, and F3 to the third formant frequency. According to (Peterson,1951; Strange, 1989; Peterson & Barney ;1952, Fant;1959 and Ladefoged,2001) the first and second formant frequencies matter most in determining the vowel quality. F4 and F5 are also important but they provide more information of the speaker's identity rather than the vowel's quality (Ladefoged and Johnson, 2011). F3 is significant in determining phonemic vowel quality, but its importance varies across different languages. Vowels can be plotted in an F1 x F2 vowel chart according to their F1 and F2 values. F2 represents the horizontal axe while F1 represents the vertical axe. Ladefoged (2001, p. 46) stated that "It is often sufficient to plot the frequencies of the first two formants on a formant chart".

F2



F1

Figure 2.6.: F1xF2 vowel chart of cardinal vowels (Ladefoged 2001, p. 177)

The articulatory movements of the tongue and the vocal tract correlates with the first and second formant frequencies values. In the acoustic vowel chart, F1 correlates with the vowel height dimension. The higher the tongue to the roof of the mouth (the less open the mouth jaw), the lower F1 frequency. F1 value varies from 300 Hz to 1000 Hz. F2 correlates with the front-back dimension. The more retracted the highest point of the tongue, the higher the F2 frequency. F2 value varies from 850 Hz to 2500 Hz (Alotaibi and Hussain,2009). Lip rounding has an in influence as well on formant frequencies, specifically the second formant frequency. Lip rounding increases the vocal tract length, thus lowering the second formant (Ladefoged 2001, p.39-43).

2.6. Vowel Duration

Vowel duration refers to vowel quantity or vowel length measured in secs or ms. It is defined as a physical property representing a measurable speech unit. It is also defined as the physical representation of the duration of speech sound as interpreted articulatory and acoustically (Hassan, 1981). Lehiste (1970, P.9) defines sound duration as the time dimension of the acoustical signal stating that a sound duration is "the physical correlate of the timing of the articulatory sequences". The acoustic investigation of vowel duration is very significant for vowel identification (Ferguson and Kewley-port, 2007; Mok, 2011). Vowel length distinction is quite common in the languages of the world (Maddieson, 1984). While Tsukada Kimiko (2009) stated that vowel duration is not contrastive in all languages, (Swadesh, 1937; Abercrombie, 1967; Lehiste, 1970) reported that vowel length is phonemically contrasted in many languages such as Arabic language and meaning distinguishing as well. The durational differences vary among different languages (Lehiste, 1970). Alani (1970) and Algamdy (1998), reviewed in section 2.8, founded that long vowels' duration in Arabic is double that of short counterparts. The same case is for English vowels as reported by (Umeda, 1975; Peterson and Lehiste, 1960). On the other hand, Mitleb (1984b) who studied Arabic language found that vowel length of long Arabic vowels is more than double the duration of their short counterparts. This could be attributed to the fact that Alani (1970) and Algamdy (1998) collected their data from isolated vowels and isolated monosyllabic words while Mitleb (1984b) used monosyllabic minimal pairs in carrier sentences. Umeda (1975), Peterson and Lehiste (1960) and Van Santen (1992) have stated that vowel duration is affected by many variables, such as vowel quality, contextual environment, and speech rate. One factor could have more effect on vowels' duration than the other, for example vowels are more susceptible to contextual environment than speech rate (Lehiste, 1970).

2.6.1. Vowel Duration and Tongue Height

Vowel quality as vowel height plays a major role in vowel duration; high vowels are shorter than low vowels (Peterson and Lehiste,1960; House and Fairbanks,1953; Sharf, 1962; Lehiste,1970). Lehiste (1970, p.18-19) attributed this to physiological factors as lowering the jaw stating that "It is quite probable that the differences in vowel length according to the degree of opening are physiologically conditioned and thus constitute a phonetic universal.". However, there was some controversy among scholars of whether this lengthening of low vowels over high vowels is linguistically determined as the language acquired in the brain of the speaker or physiologically occurred as a universal human being feature. House (1961) studied the durational differences between long and short vowels, distinguished as "tense" and "lax" vowels. He compared the durational variation 'tense' and 'lax' vowels and that between high and low vowels. He examined whether the variation in vowels duration is a result of a physiological process inherited or learned by the speaker as acquiring the language. He found out that the long duration of lax vowels is a result of the phonology of the language whereas the lengthening of the high vowels is a result of the articulatory configuration of high vowels. Lindblom (1968) states in his study analyzing high and low Swedish vowels that the lengthening of high vowels is a universal feature of human speech production. Other scholars testing the duration variation between long and short vowels were Condax and Krones (1976), they tested the same argument raised by House (1961) which is whether vowel length is a phonological process of the language acquired in the brain of the speakers or an articulatory physiological one. A computational speech synthesizer was used to eliminate the durational variation caused by physiological factors. Hence, during the experiment any durational variation would be a result of a phonological factor of the language as inherited. The researcher tested the difference between two short high and low vowels and their long counterparts. Findings indicate that there is no significant durational difference between high and low vowels, hence the durational variation is due to a physiological factor. Whereas the durational variation between short and long vowels remains significant, hence, it is due to the phonology of the language as acquired in the brain. Mitleb (1984) and Hussain (1985) also studied tongue height effect on vowel duration of Arabic vowels. Mitleb (1984) studied vowel duration of Jordanian dialect whereas Hussain (1985) studied vowel duration of Gulf Arabic dialect. Gulf Arabic average vowels' duration of high vowels was lower by 16% than low vowels. Whereas Jordanian average vowels' duration of high vowels was lower by 14% than low vowels. Their findings correlate with the assumption that low vowels are longer than high vowels. Lindblom (1967) and Klatt (1976) linked this increase in vowel duration of low vowels to the maximum energy needed to produce them as lowering the jaw. As Lindblom reports, "the temporal organization of speech sounds is determined by the amount of physiological energy that is consumed in producing them" (Lindblom 1967, p. 22).

2.6.2. Vowel Duration and Phonetic Context

The consonant before and after a vowel also has a major effect on vowel duration. Vowels before voiced consonants are significantly longer than those before voiceless ones (Peterson & Lehiste, 1960; Raphael, 1971; Chen, 1970). Klatt (1973) stated that when vowels are followed by voiceless consonants, they are shortened by 25% than when they are followed by a voiced consonant. However, this was not the case for Arabic language. Mitleb (1981) founded no significant durational difference between vowels of Jordanian Arabic before /s/ and /z/. Vowels of Saudi Arabic also did not show any significant effect as well. The researcher attributed this to the fact that vowel length is phonemically contrasted in Arabic language that is why it is maintained by the speakers (Flege, 1979, p. 64). No durational variation as well was found between vowels before voiced or voiceless consonants in either Polish or Czech (Keating, 1979). This variation of durational influence by voicing of the following consonants among different languages could be attributed to the assumption that more energy is used as producing these consonants despite their voicing. Lisker (1974) stated that the shortening of vowels precedes voiceless consonants is rather a result of their greater force involved in articulation rather than the voicing action itself. However, more investigation is required for further evident explanatory.

Moreover, that manner of articulation has an influence on vowel duration (Peterson & Lehiste, 1960). The findings of the experiment of (Peterson & Lehiste, 1960) on English vowel duration reveal that vowels before voiced plosives were 30 secs long. Whereas similar vowels before voiced fricative were 37.9 long. Hence, vowels before fricatives were longer. Gemination or consonant cluster which is defined by Mitchell (1962) as 'double consonant' also has an influence on the preceding vowels. Vowels before consonant clusters tend to be shorter than vowels before a single consonant. Delattre (1962) stated that it is true that /æ/ is shorter in /pæk/ and /pæt/ than in /pæd/, but it is more shortened than both cases before consonant cluster as in/pækt/.

2.6.3. Vowel Duration and Speech Rate

There is an agreement among scholars that speech rate affects vowel duration, as vowels tend to be shortened in fast speech and lengthened in slow one. Van Son and Pols (1990, 1992) found out that vowels in a fast speech rate are shorter by 15% than vowels in a slow rate. However, there are controversial claims about whether short or long vowels are more affected by speech rate. Picheny et al. (1986) pointed out that short "lax" vowels are more vulnerable to speech rate influence than long "tense" vowels. However, (Nooteboom & Slis, 1969) and (Svastikula, 1986) who studied Dutch and Thai vowels, respectively, have reported that long vowels showed more lengthening in slow speech than short vowels. On the other way around, Magen and Blumstein (1993) who studied the effect of speaking rate on Korean vowel duration stated that both short and long vowels are influenced to a similar extent by speech rate. Researchers agreed that sometimes some overlap in vowel length distinction could happen between short vowels spoken in a slow speech rate and long counterparts spoken in a fast speech rate. For example, the duration of the English short /ɪ/ spoken in slow speech rate overlaps with the long counterpart /i/ spoken in fast rate (Port, l981). An overlap was also found between the short Arabic /a/ spoken in slow speech rate and its long counterpart /a:/ spoken in fast rate (AI-Ani & Maeda, 1980). The same case was for Korean and Thai vowels (Magen and Blumstein ,1993; Svastikula, 1986). Moreover, there is a tendency for vowels to be scattered in the vowel space during slow speech rate, but be more centralized when speakers speak faster (Souza and De Mora, 2014).

Finally, Scholars as House & Fairbanks (1953), Fischer-Jørgensen (1964) and Lindblom (1968) link vowel duration to articulators' movement, which is the same movement responsible for the production of the following consonant. This is conceptualized in the articulatory distance hypothesis which states that the longer the time articulators' movement takes the longer the sound duration is. This hypothesis is used as well to explain the durational variation between vowels due to tongue height or voicing of the following consonant.

2.6.4. Vowel Duration and Stress

Stress is an articulatory gesture that refers to the force degree of speech and it is closely related to length and intonation (Lehiste, 1970). Klatt (1987), Crystal and House (1988) reported that stress has a major effect on vowel length. Unstressed vowels in syllables are shorter than stressed vowels (Van Santen, 1992). Ladefoged (1975) stated that it is very obvious for a listener to detect stress as it has a longer syllable. Therefore, researchers as O'Connor (1973) stated that lengthened syllabus help in the realization of stress. In a study by Fry (1955), he examined listeners' perception of stress in English words with different duration and intensity. Findings reveal that there was a good agreement among 100 subjects that when vowels are long and of increased intensity, listeners will perceive them as strongly stressed. When they were short and of decreased intensity, they were perceived as weakly stressed. But after all, the strong correlation between stress and long syllables is a language determined phenomena that vary among languages (Lehiste,1970). For example, stress in Polish is perceived higher by listeners than in English (Jassem J. Morton, and M. Steffen-Batog, 1968).

2.7. Arabic Vocalic System

Vowel inventories of the languages of the world vary considerably in terms of size and vowels' place in the acoustic space. According to Maddieson (1984), the vowels' vocalic system size of the languages of the world varies from 2 to 24 distinct vowels which vary in their articulatory and acoustic features. Semitic languages like Arabic are distinguished by a small vowel inventory and a big consonantal one (Watson, 2002, p.1). Arabic language has 36 phonemes. A phoneme is the smallest speech unit that is meaning distinguishing in a word or a sentence (Alotaibi & Husain, 2009). Those phonemes are 28 consonants; two are diphthongs and six of them are vowels with long and short versions of /a/, /i/, and /u/. The short vowels are called [´] Fatha, [´] Kasra and [´] Damma. The short vowels in Arabic are diacritic marks which are put above and below the Arabic written letter as a clue for readers to read the letters in the accurate intended pronunciation (Kotby et al., 2011; Daqrouq, 2013). [´] Fatha represents the short /a/, [´] Kasra represents the short /i /, and [´] Damma represents /u/ in the IPA. Whereas the long vowels /a:/, / i: /and / u: / are represented by ا (*alif*), ي (*yeh*) and و (*waaw*) (Al-Ani, 1970; Al-Ani, 1983; Mitchell, 1993; Newman &Verhoeven, 2002; Sabir & Alsaeed, 2014).

Every Arabic syllable must contain a vowel, as a consequence 60% - 70% of Arabic speech consists of vowels. Therefore, it is very important to give a reliable and objective description of Arabic vowels (Nabil and Hesham, 2010). The vocalic qualities of these diacritics and letters in Arabic language are the high front /i/, the high back /u/ and the low central /a/. Those are considered the fundamental vowels of modern standard Arabic sound inventory, they are represented in the literature by a triangular with three points that correspond to each vowel.

The vowel 'triangle' of the 'fundamental' Arabic vowels was first referred to by W. Gairdner (1925), the pioneer of modern Arabic phonetics. He was the first to plot the Arabic vowels in the cardinal vowel chart. Mitchell (1993) also stated that: "the vowel system of Classical Arabic/Modern Standard Arabic consists of three vowel segments – open, close front, close back – with a short/long distinction applicable to all the three" (1993, p.138). Mitchell states the three short vowels have three long counterparts, which are /i:/, /u:/ and /a:/, (Mitchell,1993, p. 138). He also clearly related the vowels of the classical language to the cardinal vowels. Lehiste (1970) reported that this length distinction is phonemic in Arabic Language and meaning distinguishing. Alani (1970) and Algamdy (1998) founded that the duration of the long vowels is double that of the short ones.

In addition to these six basic short and long vowels, there are additional vowels, which are distinctive to different dialectal varieties (Alghamdi,1998). These vowels positions fall alongside the triangular of Modern Standard Arabic fundamental vowels. It is assumed that these mid dialectal vowels emerge when glides come after vowels in Standard Arabic. This sequence leads to a coalescence such as bajt~beːt 'home' and nawm~noːm 'sleeping' (Youssef, 2010).

The work done by both W. Gairdner (1925) and Mitchell (1993) was an impressionistic one. The recent phonological research on Arabic vocalic system of Modern Standard Arabic (MSA) or colloquial Arabic (Ahmed, 2008; Saaddah, 2011; Saber and Al-Saeed, 2014) share the same perspective that Arabic language is less studied compared to English. However, there were some attempts to study the acoustic characteristics of Arabic vowels shedding the light on the two main parameters of the acoustic description of vowels, vowel quality and vowel duration. These studies were conducted for different purposes as standardizing Arabic vowels characterization, or tracing colloquial influence of dialectal Arabic in MSA or CA Arabic or even for medical practices. Most of them are using similar computerized acoustic analysis methods. These studies are illustrated in the following section. They vary in their sample as some studies study Arabic vowels as pronounced by male and female speakers while some studies have only one gender sample. It is worth mentioning that no studies that study HA vowels as produced by male and female speakers are reviewd in this section as no such study has ever been conducted as far as the researcher knows.

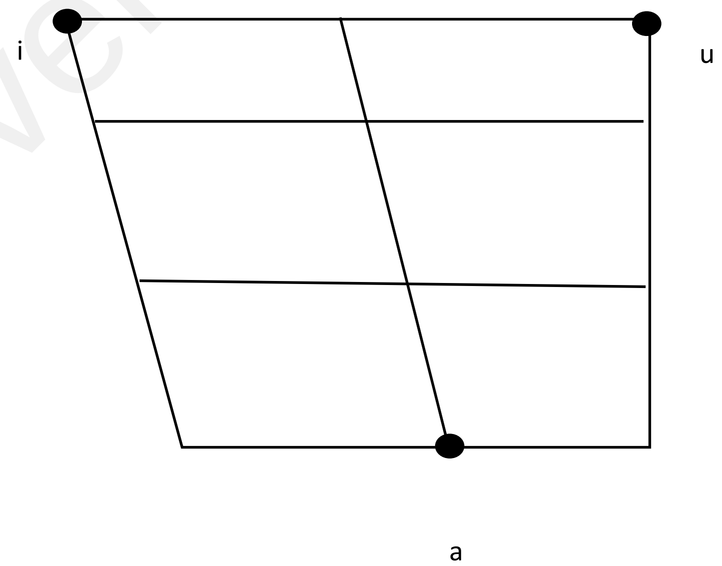


Figure 2.7: Vowel chart of Arabic Language, Al-Ani (1970)

2.8. Studies of Classical Arabic and Modern Standard Arabic

Among the very early attempts to study MSA vocalic system is a study done by Habib (1987). He tried to classify and characterize Arabic vowels using early computerized methods. The researcher stated that Arabic vowels have eleven distinct vowels which is the largest vocalic system ever proposed by a researcher. These vowels were analysed through collecting their first four formant frequencies. Nine male and six female speakers were recorded reading the targeted keywords in MSA. The participants were directed not to read the words in their own native dialect. The analysis was conducted via the kay 7030A sound sonograph, formants were extracted via spectrographs and the analysis was conducted through linear predictive coding. Habib (1987) referred to the eleven Arabic vowels and their symbols both in Arabic, and their equivalence in the IPA system which are /ə/ as in /təl/, /v/ as in /t̺vl/, /i/ as in /bærid/, /e/ as in /Bæred/ , /u/ as in /hum/, /o/ as in /hon/, /A/ as in /ʕħmAr/ , /@/ as in /mət̺@r/ , /æ/ as in /həmæm/ , /u:/ as in /hu:d/ , /i:/ as in /ʔi:d/, which are quite uncommon to the symbols assigned by other researchers coming later on. Findings of male and female speakers were separated and varied among each other. The formant values stated by Habib (1987) show that the long /i:/ has the most fronted position with the highest mean F2 of 2200 Hz and a close position with a low mean F1 value of 330 Hz for male speakers. /i/ and /e/ have low F1 values within the range of 370 - 400 Hz and strikingly low F2 values within the range of 800-840 Hz. Whereas all /u/, /o/ and /u:/ maintain low F1 and F2 values with F1 values within the range of 290 – 350 Hz and mean F2 values within the range of 700 – 850 Hz. Hence, they are pronounced in a close and back position. For the /ə/ vowel, it maintains a mid-low and central position as it has the highest F1 value of 800 Hz for female speakers and quite mid F2 value of 1240 Hz. Habib (1987) claimed that this distinction in the formant values confirms the view that Arabic has eleven distinctive vowels.

Another widely cited research that investigates the vocalic system of Classical Arabic was conducted by Newman & Verhoeven (2002). Newman & Verhoeven (2002) have acoustically analysed Arabic vowels in connected speech. The main purpose of the research is to examine traces of colloquial Arabic (Egyptian dialect) in speakers' Classical Arabic speech. The data were collected from Quranic recitation in a slow non-musical style, as a model of classical Arabic. A total number of 400 tokens were acoustically analysed using Praat software. Additional data were collected from a corpus of Egyptian Arabic in connected speech (the passage of the north wind and the sun) to investigate the vocalic system of Egyptian Arabic. The purpose is to conduct a comparison to test the common conception that there are traces of colloquial vocalic system that coexist in Standard Arabic vocalic system of the reader. As the qur'anic recitation investigated was read by an Egyptian reader. The average formant values were calculated and plotted in the vowel space. Overall findings indicate that short vowels of MSA are placed in a more central position than the long vowels. Both short /i/ and its long counterpart /i:/ are mid-high and more to the center in the vowel space with mean F1 values of 440 and 390 Hz and mean F2 values of 1770 and 1725 Hz, respectively. However, Egyptian Arabic short /i/ is more centred than all other /i/ vowels of Qur'anic recitation in the related studies reviewed with a mean F2 of 1575 Hz. For the short /u/ and its long counterpart /u:/, Newman & Verhoeven (2002) reported that they have a highly central and a mid-low position in the vowel space, with high F1 values of 480 and 470 Hz and high F2 values of 1170 and 1120 Hz. Whereas for Egyptian /u/ and /u:/, the researchers found that they are higher and more to the back than the vowels of Quranic recitation with mean F1 values of 360 and 390 Hz and mean F2 values of 912 and 830 Hz, respectively. Whereas the /a/ and /a:/ demonstrate a low and central position in the vowel space, with mean F1 values of 616 and 620 Hz and mean F2 values of 1460 and 1455 Hz, respectively. While the

Egyptian /a/ and /a:/ have a similar F1 and F2 range to that of MSA in connected speech. Finally, the findings proposed by Newman & Verhoeven (2002) do not prove the long-held perception that Classical Arabic as in Qur'anic speech is less influenced by a colloquial variety neither confirm the fact that classical Arabic is a purer variety of MSA, from an acoustic point of view. On the contrary, Newman & Verhoeven (2002) confirm that the high /a/ and /a:/ indicate more stability and less influence to Colloquial Arabic.

Another more recent study that investigates Classical Arabic was done by Seddiq and Alotaibi (2012). The researchers aim to study the acoustic properties of Arabic vowels in connected speech as a preliminary attempt to give a comprehensive description of Arabic vocalic system. Seddiq and Alotaibi (2012) stated that it is very important to have an accurate phonological modal of Arabic vowels for other implementations such as medical practices, speech synthesis and forensics, clarifying that using formants-based analysis is an adequate and sufficient acoustic attempt to describe vowels. The researchers have collected the data from a corpus of Quranic recitations, the researchers used this corpus in particular to eliminate any traces of dialectal Arabic varieties that might influence the vowels in normal speech as he proposed. The data analyzed were extracted from /svn/ syllables with 36 tokens, three tokens for each vowel. Wavesurfer Software was used to extract the first three formants. The findings show that the close front /i/ and its long counterpart /i:/ have low F1 frequencies and high F2 frequencies. While the back close long /u:/ has low F1 and F2 frequencies. In the case of /a:/ and /a/, F1 is high while F2 is medium. The researchers compared long and short vowels and plotted them in the vowel space. The findings indicate that short /a/ has less F1 comparing it to its long counterpart /a:/, the short /u/ has more F1 and F2 than its long counterpart, and the short /i/ has less F2 than its long counterpart /i:/. The long high /u:/ has the highest position in the vowel space as it has the lowest F1 value of 296 Hz. Whereas the long low /a:/ has the lowest position in the vowel space with the highest F1 value of 651 Hz. A further comparison between this study and previous research on the same vain is implemented and the results and differences between formant values were calculated and plotted in the vowel space for a more visual inspection. Seddiq and Alotaibi (2012) concluded that there is a need for further analytical work on the Arabic vocalic system in order to set the foundation for various scientific practices such as building speech processing and identification systems. A study that investigates Arabic vowels for the purpose of building speech recognition and classification systems using MSA data was conducted by Alotaibi & Husain (2009). Alotaibi & Husain (2009) conducted a formant analysis of the fundamental MSA vowels for the purpose of further research and classifications of MSA vocalic systems. A total number of 4000 tokens were recorded in monosyllabic CVC words by ten speakers, nine Saudi and one Egyptian. The utterances were the words, /ʒid/, /ʒi:d/, /ʒud/, /ʒu:d/, /ʒad/, /ʒa:d/;the short vowels represent the diacritics in Arabic Language and the long versions represent the three letters, Alef, waw and Ya'. The findings indicate that values of the first formant are high for /a/, medium for /u/ and low for /i/. For the second formant, it is medium for /a/, low for /u/, and high for /i/. For length influence on vowel quality, findings indicate that F1 and F2 of the short low /a/ are less than its long counterpart /a:/. While the short high back /u/ has a higher F1 and F2 than its long counterpart /u:/. Alotaibi & Husain (2009) found out that the short front high /i/ has a higher F1 and a lower F2 than its long counterpart. Hence, the researcher suggests that it can be generalized that F1 in a short MSA vowel is higher than F1 in its long counterpart except for /a/ and /a:/; and F2 in MSA short vowel is lower than F2 in its long counterpart except for /u/ and /u:/. Therefore, the long vowels are peripheral and the short vowels are centred in the acoustic vowel space.

Aloqayli and Alotaibi (2018) conducted the most recent study investigating CA and MSA vowels. Aloqayli and Alotaibi (2018) conducted a formant-based analysis of the three fundamental Arabic vowel qualities in both the MSA context and the CA context. The researchers' aim is to set the foundation for more accurate formant measurements of the Arabic vocalic system. Qur'anic recitations by five famous reciters were used to extract the data. 180 segments in CVC syllables were extracted from the Quranic recitations, in which the first C was /t/ or /s/, and the second C was /n/. MSA data were extracted from the KAPD[2] speech corpus recorded by seven males that contain MSA utterances of isolated words. CVC syllables with the target vowels were extracted where the first C was /b/, /n/, /t/, /r/, or /f/ and the second C was /z/. Praat software was used to extract the first two formants of the six Arabic vowels of CA in Quranic recitations and MSA vowels in KAPD speech corpus. Findings of CA indicate that the high front /i/ and /i:/ have a low F1 and a high F2. The long /i:/ has the lowest F1 value of 416 Hz and the highest F2 value of 2087 Hz. Moreover, /u/, and /u:/ have medium F1 and F2 with an F1 value around 550 Hz and an F2 value around 1500 Hz. For /a:/ and /a/, F1 is high and F2 is low. As the long /a:/ has the highest F1 value of 709 Hz. Hence, CA vowels formed two triangles when plotted in the vowel space; one inside the other. For MSA vowels only the three fundamental Arabic vocalic qualities were investigated. Findings show that the high vowel /i/ has a low F1 value and a high F2 value with a mean F1 value of 435 Hz and a mean F2 value of 1860 Hz. /u/ has a low F2 value and medium F1 value while /a/ has a high F1 value and a medium F2. The mean F1 value of /a/ is 624 Hz and the mean F2 value is 1851 Hz. Aloqayli and Alotaibi (2018) also compared the main three vowels in

[2] KAPD is an MSA speech corpus made by King Abdulaziz City for Science and Technology (KACST). The corpus is recorded by seven male speakers reading utterances of isolated words. Each word carries one target phoneme.

CA and MSA. The findings indicate that the value of F1 of /a/ in CA is lower than that of /a/ in MSA, whereas F2 was almost the same. For /u/ in CA, the values of F1 and F2 were both higher than the values of /u/ in MSA. For /i/ in MSA, the value of F1 was lower compared with that for /i/ in CA, while the F2 was almost the same.

These differences between formants values caused the triangle of the CA vowels to overlap with their counterparts in MSA. Comparative analysis between CA, related research of other dialects and English was conducted. Findings show that the variation is lower between short vowels than that of long ones.

As most conducted studies on vocalic systems of MSA and CA Arabic suggest a vowel system of six fundamental vocalic qualities, Algahtany et al. (2009) proposes that there is an extra seventh vowel that exists only in CA, which they referred to as “The 7th vowel in CA”. The researchers stated that the sixth word of the 41st verse of Houd Chapter of the holy Quran ([مجر اها] “its move”) contains this vowel. Hence, the Qur’anic recitation investigated was this verse in particular. As different certified qur’anic readers of the ten known reading dialects of The Holy Quran read this vowel in this verse of Quran in three different ways, formants measurements extracted for this vowel were divided into three parts according to three different realizations of this vowel; the lowest tilt referred to as 01 in the data, the normal vowel /a/ referred to as 02, and the highest tilt referred to as 03. The purpose of this division is to find out vowel acoustic features during all three ways of vocalization. That is to finalize if this vowel does exist in the vocalic system of Classical Arabic or it is an allophonic variant of one of the six basic vowels in MSA. Although Algahtany et al. (2009) illustrated the acoustic cues of this “The 7th vowel in CA” and stated differing acoustic values to the normal MSA /a/, there is a further need for comparison with the other six MSA vowels for in-depth confirmation that there is a further seventh Arabic vowel.

2.9. Studies of Colloquial Arabic Varieties

Arabic dialects are geographically classified into five dialectal zones (Arabian, Mesopotamian, Levantine, Egyptian, and Maghrebi) (Versteegh, 1997). They are indifferent according to these different Arabic geographical zones. Watson (2002) stated that children are brought up speaking a colloquial dialect rather than Modern Standard Arabic as a mother tongue. While MSA is used in formal settings, Colloquial Arabic is used informally on a daily basis. The coexistence of MSA and colloquial Arabic complementarily in formal and informal settings is a phenomenon known as diglossia (Wardhaugh 2002, p. 88). But both varieties are indifferent in the phonological, morphological, lexical, and syntactical levels (p.8). Different Arabic dialects are geographically scattered across 22 Arab countries spreading from Western Asia to North Africa. These countries are Morocco, Algeria, Tunisia, Libya, Mauritania, Egypt, Sudan, Jordan, Djibouti, Somalia, Syria, Lebanon, Iraq, Palestine, Kuwait, Saudi Arabia, Oman Bahrain, Qatar, the United Arab Emirates, and Yemen, see figure 2.7. Arabic dialects are not only classified in pure geographical bases but bedouin–urban distinction is involved too. While Bedouin dialects are more conservative and consistent, urban dialects are irresistible of dialect change and intra dialectal variation (Watson, 2002).

Figure 2.8: Map of the countries of the Arab world (Watson, 2002)

Watson (2002) stated that mutual understanding is problematic between different Arabic varieties. He reported that the dialects spoken in the eastern and western extremes of the Arab-speaking world are mutually unintelligible" (Watson, 2002, p.8). The more distant the dialects, the more indifferent and divergent dialects will be and vice versa. Despite the lack of conducted studies on dialectal Arabic verities, a number of studies were found in the literature investigating Arabic vocalic systems of different Arabic dialects. From the sociolinguistic point of view of such studies, the vowels of Arabic dialects are indifferent phonologically less than phonetically due to sociolinguistic factors (Salam and Embarki 2014, Bassiouney 2009). The acoustic characteristics of the vocalic systems of different Arabic dialects investigated are being reviewed in this section.

Saadah (2011) studied Palestinian Arabic vowels acoustically. This study was conducted for comparison purposes as a part of more extended research to investigate English second learners' Arabic vowels production. The purpose of the study is to investigate the coexisting of one or two phonological systems in the linguistic mentality of developing bilinguals. Six native Palestinian Arabic speakers, three males and three females, were recorded reading 1368 vowel tokens of CVC forms in both pharyngealized and non-pharyngealized environments. Vowel quality and quantity are the two parameters examined. Formants measures of F1 and F2 were taken from the midpoint of the targeted vowels. Findings contributed to the documentation of Palestinian dialect. Saddah (2011) stated that though there are some studies in the literature investigating Arabic vocalic systems, (al-Ani 1970; Belkaid 1984; Ghazeli 1979; Abou Haidar 1994; Alghamdi 1998), these studies have many shortcomings whether in methodology, design or number of informants. Hence, Saddah suggested that his Findings are a significant contribution to the Arabic vocalic system literature. The findings for vowel quality indicate that the short vowel /i/ has higher F1 values than its longer counterparts /i:/ while /i:/ has higher F2 formants. Whereas short /u/ has a higher F1 and F2 than its longer counterpart /u:/. On the other hand, short /a/ has slightly lower F1 and F2 values than its counterpart /a:/. In addition to vowel quality, Saddah (2011) investigated vowel quantity. Findings indicate that low Palestinian vowels are longer than high ones. This agrees with what is reported by (House and Fairbanks;1953, Lehiste;1970, Peterson and Lehiste;1960; Sharf;1962). Findings also show that vowel length has a considerable effect on F1 but not on F2. When it comes to gender variability, though findings of vowel quality indicate that male and female speakers' F1 and F2 were highly distinct from each other, the difference in vowel duration between male and female speakers is only in short vowels. As male speakers tend to have shorter durations for the short /i/, /a/, and /u/. Saddah (2011) stated that long vowels are more than two times longer than short vowels. The study also examines the pharyngealization effect on vowel quality. Saddah (2011) stated that no significant pharyngeal vs non-pharyngeal effect was found on F1, while for F2 there is a significant difference. Vowels in pharyngeal environments tend to have a more retracted position than their non pharyngealized counterparts. Thus, there is a significant shift for the vowel triangle in the acoustic space from a central position to a peripheral retracted one when vowels occur in a pharyngealized environment. Saddah (2011) attributed this to the narrowing in the pharynx caused by the production of pharyngeals. This narrowing effect reaches the following vowels causing this significant retraction in the pharyngeal environments. Moreover, low Palestinian vowels are more retracted in emphatic context than those of high ones; /i/, /i:/, /u/, /u:/. As Rosner & Pickering (1994, p. 22) Stated that the greater the difference in articulation between the emphatic consonants and the surrounding vowels, the more affected they are by this emphasis.

Palestinian vowels were also investigated by Adam (2014) for comparison purposes as well but for medical application. The study aims to investigate the first two formant values of Palestinian Arabic vowels (/i:/, /i/, /e:/, /a:/, /a/, /o:/, /u:/ and /u/) as produced by Brocha aphasic patients and normal speakers. Five male aphasic Palestinian Arabic native speakers and five male normal native Palestinian speakers with an average age of 51 were recorded reading CVC syllabic words where C was bilabial stops embedded in carrier sentences. The total number of tokens was 240 vowel tokens. PRAAT (Boersma & Weenink 2010) was used to extract F1 and F2 formants values and vowel duration. Findings of normal Palestinian speakers show that the high back Palestinian /u/ and /u:/ has the closest and most retracted position among all vowels. As they indicate the lowest F1 values with a mean F1 value of 341 Hz for the long /u:/ and a mean F1 value of 385 Hz for the short /u/. They also have the lowest F2 values with a mean F2 value of 1009 Hz for the long /u:/ and 1110 Hz for the short /u/. Moreover, the high /i/ and /i:/ are distinguished with equal F1 values of 430 Hz and with the highest F2 values of 1830 Hz for /i/ and 2000 Hz for /i:/. Hence, the long /i:/ is pronounced in the most fronted position among all vowels. The Palestinian /e:/ is pronounced in position within a similar range to /u/ and /u:/ with an average F1 value of 470 Hz and an average F2 value of 1860 Hz. The low /a/, /a:/ and the Palestinian /o:/ are pronounced with the lowest position in the acoustic space as they have high F1 values of 580, 560 and 570, respectively. The short /a/ has the highest F1 value of 580 Hz among all Palestinian vowels. Adam (2014) conducted a comparison between these values and the formants of the vowels of other Arabic dialects existed in the literature. He concluded that Palestinian vowels have medium values in comparison to other Arabic vowels. Adam (2014) also conducted a comparison between the Palestinian normal speakers' acoustic data and the Brocha aphasic patients' ones. Findings indicate a difference between the two groups. The researcher attributed the difference to abnormal tongue positioning and inadequate vocal tract configuration compared to normal vowels production. Findings of Brocha aphasic speakers also indicate an overlap between vowel categories and a close proximity between them in the acoustic vowel space. The acoustic parameter of vowel duration was also investigated. Means of long and short vowels length indicate that vowel length of long vowels is double the length of the short vowels, as the mean length of long vowels is 167 ms and that for the short vowel is 86 ms. Findings indicate that short high /i/ has the shortest length among all vowels and the long low /a:/ has the longest length among all Palestinian vowels. In addition to giving a precise description to the acoustic properties of the vocalic system in Palestinian Arabic, Adam (2014) states that his study is significante as a foundation for clinical practices as treating Arabic speech disorders.

Alani (1970) is among the preliminary studies that investigated dialectal Arabic varieties. The Iraqi vocalic system from an acoustic and physiological perspective was investigated. 2000 Spectrograms were recorded by the author himself as a primary informant. Three types of spectrographic analysis were used, broadband, narrowband and continuous amplitude display. Another physiological investigation was made through X-ray sound films to further explore accruing problematic physiological aspects. Vowels were investigated in four types of contexts, in isolation, CV syllables, minimal pairs, and short phrases and sentences. This method made it possible for the researcher to study vowels characteristics in isolation as well as with sounds' influence in sequences. The main acoustic parameters examined were the first three formant frequencies and vowel duration in cps (cycle per second) and ms (milliseconds). Findings of the vowels in the vowel space show a minor difference in quality between the short high front /i/ and its long counterpart represented with double simple/ii/. The same case is applied for the short high back /u/ and its long counterpart. However, for the low central vowel /a/ and its long counterpart /aa/ there is a high variation in terms of height and retraction. The long /aa/ vowel was pronounced in a lower and more retracted position. For vowel duration, Alani founded that all short vowels have the same duration values. Similarly, all long vowels have the same duration. Long vowels' duration is exactly double the duration of short vowels. It is because vowels were pronounced in isolation. This is similar to the findings concluded by Khattab, G., & Al-Tamimi, J. (2008) regarding vowel duration in Lebanese Arabic. Therefore, findings show that short and long vowel pairs differ in terms of quality as well as quantity. However, Saddah (2011) reported that the shortcoming in the method of data collection making it inadequate to make generalization of the acoustic characteristics of Iraqi vowels. On the contrary, an interesting finding by Alani (1970) shows an agreement between the acoustical results and the physiological vowel position in the vocal tract. Alani also included consonants in his study as well as Pharyngealized consonants, pharyngeal, glottals, gemination, and consonant clusters. He also studied syllables, stress, intonation, and pitch. All these phenomena are discussed in acoustic and physiological terms. Spectrographic displays, drawings depicting the physiology of a particular sound, diagrams, and charts are all used to illustrate the physical characteristics and relationships of the sounds in Iraqi variety.

Another more recent study that gives a comprehensive description of Iraqi vowels is done by Fathi and Qassim (2020). The main acoustic parameters investigated are vowel quality and vowel quantity. Fifteen Iraqi speakers (eight males and seven females) were recorded reading monosyllabic dialectal words in CVC syllables and disyllabic words in CVCCVC syllables. The C was either a fricative or a stop. The researcher justified that their boundaries in the spectrogram are clearer to extract the vowel. The total number of tokens was 720 tokens. Two different tokens per vowel were recorded, one ending in voiced consonants and the other in voiceless one. As one of the objectives of the study is to investigate voicing effect on vowel duration. Nasals, liquids, pharyngeals, pharyngealized (emphatic) consonants, geminated consonants and the uvulars /x/ and /ɣ/ were purposely avoided by the researcher to avoid any coarticulatory effect. Praat (Boersma and Weenink, 2017) was the software used for analysis. Fathi and Qassim (2020) investigated eight Iraqi vowels, /i/, and its long counterpart /i:/, /a/ and its long counterpart /a:/, and /u/ and its long counterpart /u:/ in addition to the /e: / and /o:/ which are distinguished to Iraqi Arabic. For the vowel quality, the researcher compared all the F1 and F2 vowels' frequencies and their place in the vowel space. The findings show that the short vowels /i/ and /u/ have higher F1 values than their long counterparts /i:/ and /u:/. Hence, they are pronounced in a lower position. Whereas the short /i/ has a lower F2 value than its long counterpart. Therefore, the long /i:/ is pronounced more to the front than its short counterpart /i/. While the two vowels /u/ and /a/ have higher F2 values than their long counterpart /u:/ and /a:/. Hence, they are pronounced in a more fronted position than their long counterparts. For the two Iraqi dialectal vowels /e:/ and /o:/, they have a higher F1 value than the high long vowels /i:/ and /u:/ and their short counterparts. But they have a lower F1 value than the low /a/ and its long counterpart /a:/. That is why they are situated in a mid-low position. The vowel /e:/ has a higher F2 value than all other Iraqi vowels except the high long vowel /i:/, consequently, it is more fronted. For the /o:/ vowel, it has a higher F1 value than all Iraqi vowels except the long /a:/. It also has a lower F2 value than all other Iraqi vowels. Hence, it is pronounced in a more retracted position than all other Iraqi vowels. Vowel duration was investigated as well. Fathi and Qassim (2020) reported that the short /i/ has the shortest length among all vowels. The short /a/ and /u/ has the same length. The dialectal long /o:/ vowel has the longest duration among all vowels. Overall, the long vowels are almost as twice as long as their short counterparts. Remarkably, these findings are dissimilar to the ones reported by Alani (1970) of the same dialect.

The acoustic properties of the Egyptian vocalic system (referred to as Carine Arabic) were investigated by Norlin (1984). Eight vowels were acoustically investigated, five long vowels and three short ones, in addition to three diphthongs /ai/, /au/ and an Egyptian dialectal /iu/. Five Egyptian speakers were recorded reading monosyllable and disyllabic words. The syllables were, CV, CVC, CVV, CVVC, and CVCC, where C was a dental consonant. Formant frequencies and vowel duration were calculated from broad-band spectrograms in a Kay Digital Sonagraph 7800. The findings indicate that the short vowels are more to the center than their long counterparts except for the short low /a/ and the long /a:/, the difference was not that significant. A variation was found between short vowels and their long counterparts in terms of their F1 and F2 values. Except for the short low /a/ and its long counterpart /a:/, the difference is only in the F2 value as /a/ is more retracted than its long counterpart. Norlin (1984) also examined vowels in a pharyngealized context. A comparison between plain and pharyngealized vowels was conducted. Findings indicate that there is a significant effect of pharyngealization on vowels, as they are all pronounced in a more retracted position, which is similar to Palestinian vowels' findings in emphatic context as reported by Saddah (2011). In this study the close long vowels /i:/ and /u:/ show more contrasting effect than low long vowels. For the low vowels, there is always a maximizing effect on F2 value for both the long /a:/ and the short vowel /a/. However, short vowels are more affected by emphasis than long vowels. For the vowel length, the difference is rather large between the short vowels and their long counterparts. The long vowels are as twice as long as their short counterparts. The short high /i/ has the shortest length among all vowels with a mean duration of 67 ms, whereas the long dialectal mid vowel /o:/ has the longest length among all Egyptian vowels with a mean duration of 185 ms. Overall, the study gives a comprehensive acoustic description of Egyptian vowels both in pharyngealized and plain contexts.

Another more recent study that examines the Egyptian vocalic system by Kotby et al. (2011) proposes that the Egyptian dialect has six distinguished vowels and their six long counterparts, in addition to a short central one. These short vowels are symbolized by the researcher as /i/ as in /ʕin/, /e/ as in /deb/, /ɛ/ as in /tɛb/, /ɑ/ as in /tɑb/, /ɔ/ as in /ṣɔb/, /u/ as in /muhamed/ and the central /ʊ/ as /fʊl/. The long vowels are symbolized as /i:/ as in /ti:n/, /e:/ as in /de:l/, /ɛ:/ as in /tɛ:b/, /ɑ:/ as in /tɑ:b/ and /ɔ:/ as in /ṣɔ:t/ and /u:/ as in /mu:sa/. This vocalic inventory is the largest Arabic vocalic system ever proposed by a researcher, in contrast to Norlin (1984) who suggested 8 vowels for Egyptian Vocalic system. Kotby et al. (2011) tested the hypothesis that each vowel of these twelve vowels stand alone as a distinctive sound and not an allophonic variant. Through analyzing their acoustic properties,14 dialectal real monosyllabic words were used without a carrier sentence. Sixty Egyptian informants were recorded, thirty males and thirty females. The six vowels were grouped together into three groups in terms of place of articulation; /i/ vs /e/, /ɛ/ vs /ɑ/ and /ɔ/ vs /u/. A comparison was done between these vowels in terms of their formant frequencies and duration. Kotby et al. (2011) indicate that the closest vowel produced was the high /u/ with a mean F1 value of 207 Hz for male speakers and 231 Hz for female speakers. It is also the most retracted one with the least mean F2 value of 715 Hz for male speakers and 742 Hz for female speakers. Whereas the lowest vowel was /ɑ/ vowel with a mean F1 value of 619 Hz for male speakers and 648 Hz for female speakers. Kotby et al. (2011) reported no clear difference between short vowels and their long counterparts in terms of vowel quality. A comparison between male and female speakers was also conducted. There was also no variation found between male and female speakers except for /i/, /e/, /ɛ/ and the central /ʊ/. For the vowel length, the long vowels were more than double the length of the short vowels. The mean length of the long vowel was 235 ms while the vowel length of the short vowels was 99 ms. The /ɛ/ and /u/ vowels have the shortest duration among all vowels with a mean duration of 84 and 86 ms, whereas their long counterparts have the longest duration among all vowels with a mean duration of 267 and 265 ms. The /i/ has the longest duration among all short vowels with a mean duration of 133 ms. The findings give a comprehensive acoustic description of the vocalic system of Egyptian Arabic as proposed by the researcher. Kotby et al. (2011) motive of the study was not only to identify the real number of vowels in the vowel inventory of Egyptian Arabic, but to utilize it for medical application treatment of speech disorders such as delayed language development in children.

Thesieres (2002) has investigated vowels in two Arabic dialects, Lebanese Arabic and Emirati Arabic. He stated that Lebanese Arabic has ten vowels, the six fundamental vocalic qualities, /i/, /i:/, /a/, /a:/, /u/, /u:/ in addition to dialectal /e/ and its long counterparts /e:/ and two other vowels, /o/ and /æ/ which were a consequence of loan words borrowed from other languages as the word 'chauffer'/ʃofær/. He also stated that Emirati Arabic has eight vowels, three short vowels as, /i/, /a/, /u/ and five long ones, /i:/, /a:/, /u:/, /e:/ and /o:/ as reported by Holes (1990). Thesieres (2002) compared Lebanese and Emirati vocalic systems together as well as with Iraqi vowels of Alani (1970). Thesieres (2002) specifically, studied the role the regional dialectal phonology plays in the vowel realizations of Modern Standard Arabic, suggesting that there is a difference between different regional speakers of MSA. In Thesieres's (2002) study, the Lebanese and Emirati informants speak both their native dialect and MSA. They were asked to read from a corpus of ninety-two Modern Standard Arabic words. Using articulatory phonology as a framework, the vowel realizations in MSA were analyzed in different consonantal environments such as pharyngeal, emphatic, uvular, rhotic, word-final and other environments. The vowel spaces were recognized according to both the guidelines of the Iraqi allo-phony rules set by Al-Alani (1970) and the regions of the informants. Formant values for each word were obtained and plotted then combined and the overall vowel space for each informant was identified. The main target of the study is to study the influence of Lebanese and Emirati dialects on the vowel allo-phony of Modern Standard Arabic through the theory of articulatory phonology. The results of Thesieres (2002) show that there were variations of vowel realizations of MSA as an influence of speakers' mother dialect. These variations were an unavoidable consequence of physical motions that were the reason for the founded variations. The researcher also concluded that these variations are not only a result of articulatory phonology, but cognitive factors interfere as well. Thesieres (2002) reached the target of his study as well that articulatory phonology is a successful analytical tool to describe phonological patterns in languages.

In studies, as Alghamdi (1998) and Haidar (1994), more than two dialects' acoustic characteristics were examined and compared. Alghamdi (1998) studied Saudi, Sudanese and Egyptian vowels inventory. He has investigated the six MSA vowels produced by different dialectal speakers of Saudi, Sudanese and Egyptian. Five informants read six CVC syllables, where C was s, stating that /s/ shows a very clear representation of sound waves, which makes it easier for the researcher to identify vowel's onset and offset. Alghamdi (1998) has measured F1, F2 and F0, in addition to vowel duration. The researcher's purpose was to prove that MSA vowels have distinctive phonetic implementation when pronounced by different dialectal speakers. Findings indicate different vowel quality for the different dialectal speakers. Saudi vowels are pronounced in a higher position than all other vowels. Speakers tend to pronounce all the Saudi vowels with higher F1 values than Egyptian and Sudanese, except /a:/ vowels for the three dialects are pronounced in a similar range. On the other hand, all Egyptian vowels are pronounced in a more retracted position than all the other Saudi and Sudanese vowels, as they have the highest F2 frequency. Overall, short vowels for all the three dialects are more to the centre in the acoustic space, while the long vowels are in a peripheral position. For F0 Frequency, the findings showed no significant statistical difference among all speakers of the three dialects. The Findings also indicate a significant distinction in terms of vowel quantity for all the three dialects. Long vowels were more than twice longer than their short counterparts.

Abo Haidar (1994, cited in Ahmed, 2008) is a study that has studied a wide range of Arabic dialects, Lebanese, Syrian, Qatari, Tunisian, Emirati, Jordanian, Saudi, and Sudanese. This cross dialectal study has shown that there is a variation in the formant values among all eight Arabic varieties. In this study, 232 monosyllabic words were recorded by eight informants, one informant per dialect. Abou Haidar used modern digital signal processing methods to extract the data.

Haidar's (1994) findings indicate that Arabic vocalic systems are classified into six vowels, three short vowels and three long ones. This cross dialectal comparison implemented by Haidar (1994) indicates various results among different dialects. Overall in terms of high-low dimension, the Jordanian long /u:/ vowel is the closest among all vowels with the lowest mean F1 value of 260 Hz, while the /a/ vowel for the same dialect has the lowest position among all vowels with a mean F1 value of 780 Hz. For the front-back dimension, long /u:/ by Syrian informants has the most retracted position among all vowels with the lowest F2 value of 620 Hz, while the most fronted vowel was the long /i:/ vowel produced by The Saudi informant with the highest F2 value of 2530 Hz. Though Haidar (1994) has studied a wide range of dialects more than other studies in the literature, Ahemd (2008) stated that one informant cannot be a reliable representative of each dialect.

Ahmed (2008) is one of the most comprehensive acoustic attempts to document an Arabic dialect. A detailed acoustic and auditory description of the production and perception of Libyan Arabic was conducted. Through linear predictive coding, a very comprehensive acoustic investigation was conducted to study the Libyan vocalic system as all the previous attempts to study the dialect were only impressionistic. Both vowel quality and quantity of the eight Libyan vowels were investigated. The Libyan vowels investigated were the short, /i/,/u/,/a/, their long counterpart /i:/,/u:/,/a:/ and the two dialectal /e:/ and /o:/ distinguished to Libyan Arabic. Dialectal monosyllabic CVC words were inserted in carrier sentences to be recorded and read by twenty male Libyan speakers. The total number of tokens was 3200 tokens. Using Praat (Boersma & Weenink 2006) the first two formants and the vowel duration were examined. The findings of the formant analysis show that the short Libyan vowels are triangulated in the vowel space and positioned inside the triangle of the long vowels. The Libyan vowels /e:/ and /o:/ fall along the sides of the triangle. As the short /i/ is more centralized and lower than its long counterpart /i:/, the high short /u/ is lower and more fronted than its long counterpart /u:/, and the low /a/ is higher and more retracted than its long counterpart /a:/. Ahmed (2008) stated that the vowel quality variation between short vowels and their long counterparts was very significant. The long /i:/ has the highest position in the acoustic space and the most fronted one with the lowest F1 mean value of 342 Hz and the highest F2 mean value of 2214 Hz. The long /a:/ has the lowest position in the vowel space with a mean F1 of 588. The long /u:/ has the most retracted vowel in the vowel space with the least F2 mean value of 907 Hz. Ahmed (2008) reported some overlap in the vowel space between different vowels. For example, the Libyan long /e:/ shares the same acoustic space with the high front /i/ and /i:/. Moreover, the Libyan long /o:/ overlaps with the long /u:/. The researcher justified that the vowels' overlap is common in natural speech as stated by Strange, et al. (1983). In regard to vowel duration, Libyan Arabic vowels are classified into three short vowels symbolized by Ahmed as /i/, /ʊ/, and, /ə/, and five long vowels, /i:/, /æ:/, /u:/, /o:/ and /e:/. Findings of vowel duration show that the high front vowels /i/ and /i:/ have the least duration among all vowels. The average length for short vowels is 60 ms whereas that of long vowels is 149 ms concluding that long vowels are double the length of short counterparts. The second part of the research is concerned with the perception of Libyan Arabic vowels. Ahmed's (2008) aim was to test how the participants perceive the results concluded in the production part of vowel quality and quantity. The perception of the pair /i/ and /i:/ was just tested. Findings indicate that participants relied on duration more than quality to make a distinction between the two long and short vowels. The boundary they draw between the two vowels varied significantly between them.

In the same region of North African Arabic countries, Ghania (2020) cross comparatively conducted a study dealing with vowel quality of MSA as spoken in six Algerian Regions. Other than setting the foundation for the acoustic description of the Algerian dialect, Ghania (2020) aims to contribute to bigger software projects such as building dialectal varieties' identification systems. Ghania (2020) also aims to test how speakers are influenced by their regional accents. Algerian Arabic speech database was used to collect

Algerian Arabic speech from 163 adults (83 females, 80 males) from six regions representing six pronunciation groups. The regions were three in the North referred to as, R1, R2 and R3, and three in the South referred to as R4, R5, and R6. The distribution of speakers per region depends on the density of population in the different regions. Computational analysis of the first three formants of the three fundamental Arabic vowels /a/, /i/, and /u/ were analyzed by Praat software through linear predictive coding. Ghania (2020) indicated that there is a more tendency for the /a/ and /u/ to be affected by regional dialect. As speakers of different regions of Algerian dialect have more varied formant values. When Ghania (2020) conducted this comparison in relation to speakers' gender, Female Algerian speakers were influenced by their regional dialect for the /a/ vowel only. Whereas male speakers indicate a tendency to be influenced by their regional dialect for the short vowels /a/ and /u/. Findings indicate that the short Algerian /i/ is pronounced with the highest position in the vowel space and most fronted one with a mean F1 value of 389 Hz and a mean F2 value of 2116 Hz. Whereas the short Algerian /a/ is pronounced with the lowest one with a low F2 value of 1548 Hz. And the short /u/ is pronounced in the most retracted position with a mean F2 value of 1101 Hz.

Moving to Levantine Arabic, Alhussein and Hellmuth (2015) have done a recent acoustic analysis of the vowel inventory of Syrian Arabic. The researchers expanded the work done by Cowell in 1964 who stated that Syrian Arabic has 11 vowels. The three fundamental vowels, similar to the ones in MSA, /i/, /u/ and /a/ and their long counterparts, the two mid long vowels /e:/ and /o:/ and their short counterparts /e/ and /o/, which are distinguished to Syrian Arabic. Many spoken dialectal Arabic have their own vowels which are neither identical to MSA nor any other dialect, in addition to a schwa vowel which exists in many other Arabic vowel systems such as Moroccan dialect (Al-Tamimi, 2007). Through investigating the acoustic correlates of Syrian Arabic vowel system, Alhussein and Hellmuth (2015) aim to investigate the short/long vowel differences in terms of quality and duration. It further explores the schwa and the mid vowels distinction in Syrian Arabic. Targeted vowels were pronounced in /hvd/ context and embedded in carrier sentences to be read by Fifteen informants, ten males and five females. Some of the words were Syrian Arabic monosyllabic words while some words were nonsense monosyllabic words. Automated Pratt scripts were used to extract the first and second formants and vowel duration. For vowel quality, findings show that Syrian Arabic has six vocalic qualities which are represented by similar vocalic triangular to the Modern Standard Arabic, in addition to two more long mid vowels distinguished to Syrian Arabic. There turns to be an overlap between the short /i/, the short mid /e/ and the schwa. Furthermore, Alhussein and Hellmuth (2015) reported an overlap between the short /u/ and the mid short /o/. Therefore, /e/, /o/, and the schwa were considered by the researchers as allophonic variants of /i/ and /u/. The researchers concluded that Syrian Arabic dialect spoken in the city of Damascus has eight vowels, five long ones and three short ones.

A more recent study by Kalaldeh (2018) acoustically described the vowel inventory of Modern Standard Arabic produced by Jordanian speakers. Ten male informants were recorded with an average age of 23 years old. A total number of 318 tokens in monosyllabic words was analyzed using the Praat software (Boersma and Weenink, 2009), with a /hvd/ syllable context to minimize any coarticulatory effect that might occur on the vowels. Both monophthongs and diphthongs were included in this research, acoustically analyzed in terms of both vowel quality and vowel length. The three fundamental Arabic vocalic qualities were acoustically examined in the vowel space, /a/, /i/, /u/ as well as their long counterpart /a:/, /i:/, /u:/. Findings show that the short /a/ occupies a low central position. It has a mean F1 value of 532 Hz and a mean F2 value of 1507 Hz. The short /i/ is considered a centralized-front and mid-high vowel with an F1 mean value of 400 Hz and an F2 mean value of 1844 Hz. For the third short vocalic quality /u/, it has a back and a mid-high position in the vowel space with an F1 mean value of 403 Hz and an F2 mean value of 1249 Hz. Furthermore, the three long vocalic qualities of MSA were positioned in the vowel space. The vowel /a:/ is located at a low and central position in the vowel space with an F1 mean value of 634 Hz and an F2 mean value of 1492 Hz. For the long vowel /i:/, it occupies a high and front position in the acoustic vowel space with an F1 mean value of 300 Hz and an F2 mean value of 2200 Hz. While for the /u:/, it has a high back position with an F1 mean value of 378 Hz and an F2 mean value of 990 Hz. Hence, Kalaldeh (2018) suggests that short-long vowels in Arabic are not only distinct in vowel duration but also in vowel quality similar to (Alghamdi, 1998; Saddah, 2011; Kotby et al.,2011; Fathi & Qassim, 2020). For the vowel duration, the findings show that the vowel duration for the long vowel is more than twice as long as its short counterpart and the long /u:/ has the longest duration among all vowels. Kalaldeh (2018) also implemented a comparison between his findings and earlier studies' findings by Saddah (2011) of Palestinian Arabic and Alghamdi (1998) of Sudanese Arabic. Findings indicate a more centralizing tendency for Jordanian vowels over the Palestinian and the Sudanese Arabic, as the Palestinian vowels are lower and more retracted, and the Sudanese are more fronted and higher than the other Arabic vocalic systems. However, for the vowel duration, Palestinian Arabic and Jordanian Arabic have similar vowel duration. Kalaldeh (2018) justifies this by the fact that both Palestinian and Jordanian Arabic are Levantine Arabic dialects that have similar phonetic characteristics. Through all of these findings, a more comprehensive acoustic description of the MSA vowels produced by Jordanian speakers is proposed. The researcher also suggests different phonetic symbols for short Arabic vowels to the ones suggested by earlier studies, which are /ɐ/, /ɪ/, and /ʊ/. Kalaldeh (2018) states that this is a more precise phonetic transcription of MSA vowels than the ones of earlier studies because the distinction between short and long vowels is not only in quantity but in quality as well.

Jordanian Arabic was also investigated by Natour et al. (2011). The first three formant frequencies of six long Arabic vowels were investigated, (/iː/, /eː/, /aː/, /ɑː/, /oː/, /uː/). Natour et al. (2011) stated that the study aims to give sufficient normative data of the acoustic description of Jordanian Arabic, and second to compare these findings with different racial backgrounds findings. The data were collected through a large number of participants to reach more normative data. 300 Jordanian speakers (100 males, 100 females and 100 children) were recorded saying the six Arabic vowels isolated in one breath with comfortable pitch and loudness. The researchers justified that this steady state of vowels has the highest intensity of formant frequency (Baken, 2000). Time frequency analysis software was used to extract the formants and the analysis was conducted using linear predictive coding. Data for the three participating groups were compared. Natour et al. (2011) indicated that there was a variation between males and females and between males and children. However, the difference between females and children was only in F1 values. Findings show as well that the /long /iː/ for male adults have the least F1 value and the highest F2 value than all other vowels by males and females, with a mean F1 value of 329 Hz and a mean F2 value of 2166 Hz. Hence, it is pronounced in the closest and the most fronted tongue position. On the contrary, the highest mean F1 value was 782 Hz for the low vowel /aː/ by female speakers. Whereas the lowest /F2/ value was 952 Hz for the high back /uː/ by the male speakers. Hence, it is pronounced in the most retracted position. As Natour et al. (2011) examined female and male speakers' formant frequencies independently, findings indicate that male speakers tend to have lower F1 and F2 values and higher F3 values, while female speakers' formants are higher in F1 and lower in F2 and F3.

Natour et al. (2011) conducted a comparison between the formants reported by the Jordanian speakers and the formants of the speakers of other ethnic groups such as French and German by Gendrot and Adda-Decker (2005), American by Peterson and Barney (1952), Korean by Lee et al. (2008), etc. The Findings indicate that there was a lowering tendency for F1, F2 and F3 values of the Jordanian in comparison to findings of previous studies in the literature. The researcher attributes acoustic differences between speakers of different races to the different dimensions of the vocal tract such as oral length, oral volume, pharyngeal length, pharyngeal volume, total vocal tract length, and total vocal tract volume as reported by Xue et al. (2006) and Roers et al. (2009). Finally, Natour et al. (2011) emphasized the need for cross-racial acoustic investigation of Arabic and more other regions.

Alotaibi (2018) investigated the vowel systems of Saudi Arabic and Tunisian Arabic. The two experiments were part of a larger project to study the role of native language dialect on the perception of second language, from a phonological perspective. Cross dialectal comparison and second language acquisition investigation are the main targets of documenting the acoustic characteristics of Tunisian and Saudi Arabic vowel systems by Alotaibi (2018). Fifteen male participants were recorded for each dialect. Disyllabic CV.CVC words were used to elicit the data for the three short Arabic vowels, /i/, /u/, and /a/ with a total number of 360 tokens. Praat 6.0.36 (Boersma & Weenink, 2017) was used to analyze speech tokens to collect the vowel quality and quantity and a cross dialectal comparison was carried out. Findings show some dialectal variations between the two dialects. For the vowel quality, the short high front /i/ was more fronted and higher for Saudi speakers than Tunisian speakers. Concisely, Saudi /i/ has an average F1 value of 300 Hz and F2 of 2220 Hz, while for Tunisian, it has an average of 340 Hz for F1 and 2100 Hz for F2. For the high back /u/, both Saudi and Tunisian showed similar dialectal variation. The mean F1 value for Saudi /u/ was 300 Hz and For Tunisian /u/ was 350Hz. While for F2, Saudi /u/ was 750 Hz and Tunisian /u/ was 800 Hz. Lastly, For the low central /a/, it is higher and more fronted in Tunisian than in Saudi dialect. F1 for Tunisian /a/ is 740 Hz while the mean F2 is 1600 Hz. Whereas the mean F1 for Saudi dialect is 780 and the F2 mean is 1550 Hz. Findings show that the Saudi dialect vowel system shows a wider vowel system compared to the Tunisian that has a more centralized one. For the vowel quantity, the vowel length was longer for Saudi dialect than Tunisian dialect for all the three vowels.

To sum up, in the Arab world a wide range of dialectal varieties are spoken in addition to MSA used as a formal official language. The vowel inventories of some of these dialectal Arabic varieties were investigated, such as Iraqi by Fathi and Qassim, (2020) and Alani (1970), Jordanian by Natour et al. (2011) and Kalaldeh (2018), Syrian by Alhussein and Hellmuth (2015), Lebanese and Emirati by Thesieres (2002), Palestinian by Saddah (2011) and Adam (2014), Egyptian by Kotby et al. (2011), Norlin (1984) and Newman & Verhoeven (2002). In addition to Maghrebi Arabic such as Libyan by Ahmed (2008), Algerian by Ghania (2020) and Tunisian Arabic by Alotaibi (2018), etc. Some other studies study MSA vocalic system and pure CA Arabic using Quranic recitations such as Habib (1987), Newman & Verhoeven (2002), Seddiq & Alotaibi (2012) and Aloqayli & Alotaibi (2018). These studies have been conducted for different purposes and research interests, mainly to give a comprehensive description of the phonology of Arabic vowels as (Al-Ani,1970; Habib,1987; Seddiq & Alotaibi, 2012; Aloqayli and Alotaibi, 2018). Some studies aim to conduct a cross-linguistic comparison between different Arabic varieties such as (Alghamdi,1998; Alotaibi & Husain, 2009) and Haidar (1994) who end up comparing Lebanese, Syrian, Qatari, Tunisian, Emirati, Jordanian, Saudi, and Sudanese. Some studies compare between Arabic languages and other languages like

English, French and German such as Alotaibi & Husain (2009). Many aims for dialect documentation due to the lack of reliable studies that acoustically describe the dialect vowel inventory such as (Ahmed, 2008; Norlin,1984; Fathi & Qassim, 2020). Some researchers aim to trace the coexistence of dialectal Arabic in native speakers' MSA speech such as (Thesieres, 2002; Newman & Verhoeven, 2002). Some aims to study first language effect on Second language acquisition such as (Saddah, 2011; Alotaibi, 2018). On the other hand, some researchers have interests that are a bit away from pure linguistics such as building a database for speech processing and recognition programs by (Alotaibi & Husain, 2009; Seddiq & Alotaibi, 2012). Some researches were conducted for medial application as treating speech disorder and delayed language development such as (Adam, 2014; Kotby et al., 2011).

As those studies have various aims and research interests, they have different methodological and analytical processes to conduct acoustic analysis of vowels. Early researches like (Al-Ani,1970; Norlin,1984; Habib,1987) used spectrogram reading in sonographs and x-rays. Analytical articulatory phonology was used by Thesieres (2002), while digital signal processing was utilized by Haidar (1994). Some used Wavesurfer software such as Seddiq and Alotaibi (2012), most of the researchers used linear predictive coding in Pratt software as (Ahmed, 2008; Adam, 2014; Alhussein & Hellmuth, 2015; Alotaibi, 2018; Kalaldeh, 2018; Fathi & Qassim, 2020).

The number of participants also varied as some researchers recorded a small number of informants as (Thesieres, 2002; Haidar, 1994; Alani,1970) (one informant per dialect), while some recorded a large number of participants such as Ghania (2020) with 163 adults (83 females, 80 males), Kotby et al. (2011) with 60 informants and Natour et al. (2011) with 300 informants (100 males, 100 females and 100 children).

Studies as Seddiq and Alotaibi (2012), Newman & Verhoeven (2002); Aloqayli and Alotaibi (2018) used already existing corpus as Quranic recitations in official sites and KAPD speech corpus for MSA. For gender variability, some studies used equal groups for both genders such as Saddah (2011); three male participants and three female ones, some used a variable number of male and female speakers as Alhussein and Hellmuth (2015); ten males and five females and Fathi and Qassim (2020); eight males and seven females, and some recorded only male speakers as Ahmed (2008); twenty male speakers, Adam (2014); five male informants and Kalaldeh (2018); ten male informants.

The phonological context at which these vowels were recorded varied as well; some used vowels in isolation such as Natour et al. (2011) and Alani (1970) who also utilized CV syllables, minimal pairs, and short phrases and sentences. Ahmed (2008), Alotaibi & Husain (2009), Seddiq & Alotaibi (2012) and Alhussein and Hellmuth (2015) used monosyllabic CVC words. Norlin (1984) and Fathi & Qassim (2020) used disyllabic words in CVCCVC syllables. The number of tokens in those studies also varied from a small number as 180 tokens by Aloqayli and Alotaibi (2018), 240 by Adam (2014), 318 by Kalaldeh (2018), to a large number of tokens such as 2000 by Alani (1970) and 3200 by Ahmed (2008).

The findings of all these studies reveal that there is a general agreement among the aforementioned studies that the fundamental vocalic qualities of CA and MSA are the short /a/, /i/ and /u/ and their long distinct counterparts /a:/, /i:/, and /u:/. Algahtany et al. (2009) referred to the so-called "The 7th vowel in CA" as an extra seventh vocalic quality. Those MSA vowels are indifferent when produced by different dialectal groups. Thesieres (2002) attributed this to physiological and cognitive factors related to mother tongue acquisition. However, the high MSA /a/ and /a:/ indicate more stability and less influence to Colloquial Arabic.

There is also a common tendency for the short vowels to be in a centred position in the vowel space and for long vowels to be in a peripheral one. How wide or centralized this triangle of different Arabic dialects in the vowels space is in great variation. Though there is some controversy about the real number of vowels in different Arabic dialects, most studies agree that colloquial Arabic has five long vowels (a:, u:, o:, e:, i:) and three short ones (a, u, i). The mid short /e/, /o/, and the schwa are considered allophonic variants of the main phonemes. The vowel duration findings in these studies also vary as Kalaldeh, (2018), Alghamdi (1998) and Kotby et al. (2011) findings show that vowel duration of long vowels is more than twice as that of short vowels, while Alani (1970), Norlin (1984), Saddah, (2011) and Adam, (2014) reported that vowel duration of long vowels is twice as long as the short ones. On the contrary, Alhussein and Hellmuth (2015) stated that vowel duration of long vowels is one and half the duration of the short ones.

Finally, though there is a need for more research and investigation on Arabic vocalic systems of MSA, CA and mostly colloquial Arabic, these studies represent a solid foundation and a baseline for future research to build one. Their findings do not only contribute to the literature of Arabic phonetics but also to long-held phonological concepts through reliable and objective evidence such as vowel height effect on vowel duration, coarticulatory effect of emphatic consonants on vowels. Further, physiological configuration of vocal tract correlation with acoustic data contributes to the essence of theories of acoustic phonetics which is considered a great contribution.

2.10. Previous Research on the Phonology of Yemeni Dialects

Though Yemen is among the very first civilizations in the Arabian Peninsula dating as early as 5000 BCE with a rich history of culture and diversity (McLaughlin, 2008, p. 9). There were very few studies conducted to investigate and document the Yemeni dialects;

the phonology of the dialects in particular. Watson (2002, p. 21) stated that Yemeni dialects have received little scholarly attention in terms of phonology and morphology. Despite the fact that Yemeni dialects are distinguished by a distinctive diversity and unique traits that do not exist in any other Arabic dialects (Versteegh, 2009). This section reviews the available studies related to the phonology of Yemeni dialects from the oldest to the most recent.

Versteegh (2009) traced the very first studies that give a descriptive account of the Yemeni dialects. Among the very first studies to study the Yemeni dialects was a study done by the Swedish scholar Carlo de Landberg (1901, 1905, 1909, 1913,1920-43). These studies give a descriptive account of the dialects spoken in the sultanates of Hadramawt, Fadli, High and Low Awlaqi, Awadil and the tribal Confederacy of Datinah. The work includes transcriptions and phonetic interpretations of authentic dialectal utterances of original stories and poems. An investigation as early as Carlo de Landberg's was the starting point for many following modern scholars to study the Yemeni dialects and the Arabian dialects.

Dawod (1952), a British scholar at the University of London, conducted a research on the phonetics and phonology of Adani dialect. The researcher collected raw recordings from locals and x-ray pictures to describe the phonology of the dialect. He described the phonetic and phonology of Adani consonants and vowels including a large number of transcribed Adani words. The researcher stated that physiological, acoustic and functional descriptions are sufficient to describe the sound system of a dialect. Prosodic features as aspiration, glottalization, nasalization, and intonation are investigated as well. Dawod (1952) stated that the vocalic inventory of the Adani dialect has three short vowels symbolized as /a/, /u/, /i/ and five long vowels symbolized by double symbols /aa/, /oo/, /uu/, /aa/, /ee/, and /ii/. There was also a descriptive account of the syllable structure in the dialect and the possible syllabifications that exist in Adani dialect, as VC, CV, CVC, CVV, CVVC and CVCC. The study was a consequence of the British dominance in Aden at the time Aden the capital of southern Yemen was colonized by Britain.

Another study done by Prochazka, (1987) described the spoken Arabic of Zabīd which belongs to the Tihamai dialect. A list of consonants and many transcribed words were mentioned with more elaboration on emphatics and ejectives in comparison to CA. The researcher also gave an account of oral and nasal vowels and diphthongs that only occur in final positions in the dialect. The vowels of the spoken dialect of Zabid are three short vowels /a/, /i/, /u/ and five long ones symbolized to as / â/ , /ê/ , /ô/ , /û/ , /î/. The dialect has an extra schwa vowel /ə/ as a 'fleeting vowel' that sometimes becomes voiced and sometimes unvoiced. Prochazka, (1987) reported a remarkable phenomenon which is the elision of close vowels /i/ and /u/ when followed by an open syllable. Hence, /klû/ would be kul when followed by the open syllable /û/. The /a/ vowel is also elided when founded in the syllable structure /C(a)CaC/, for example /katab/ would be /ktab/. The study also discussed morphological aspects of the dialect such as verbs, future forms, negation, and personal pronouns suffixes. It is worth mentioning that the Zabid is one of the oldest towns in Yemen, it has the 5^{th} built mosque in the history of Islam and it is listed by UNESCO as a world heritage centre since 1993.

Yefii dialect was also investigated by Vanhove, M. (1995), a dialect spoken in the mountainous area in southern Yemen situated in the governorate of Abyan. The study gives a morphological, phonotactic and lexical description of the dialect, based on numerous poems, songs, tales and proverbs. A phonetic and morphological questionnaire was used to collect the data. The researcher divided the area into four districts situated geographically and linguistically as sub-dialects, Yiharr, Labcus, al-Herr and al-Mufli. A distinctive phonetic feature for Yafii is the natural phonetic shift of sounds without changing meaning. Sounds as /qaf/ have more than one possible articulation without being meaning distinctive. It can be pronounced as a voiceless uvular stop /q/, a voiceless velar fricative /x/, or a voiced uvular fricative /ʁ/. Hence, the word 'he said' would have three possible pronunciations /qal/, /xal/, and /ʁal/. Moreover, there is a fourth rare possible articulation for /qaf/ which is a glottal stop /ʔ/ only common among older generations. Vanhove, M. (1995) stated that this natural phonetic shift is sometimes weakened among the younger generation, due to contact with other dialects as a consequence of traveling to Gulf or being exposed to radio and television. Therefore, Vanhove, M. (1995) referred to the dialect leveling and change that the dialect undergoes. The researcher emphasized the need for further studies on the Yemeni dialects in general and Yafii dialects in particular because if it was gone, the rich linguistic history of Yemen would be gone. Vanhove, M. (1995) also stated that the dialect is distinguished by another distinctive feature which is adding a -k consonant to the end of verbs instead of -t, for example, the verb 'write' would be /katabk/ instead of /katabt/ which is different to all the surrounding Arabic dialects. Therefore, it is called k- dialect. In regard to k- dialects, a widely spread linguistic phenomenon among k- dialects as the Yemeni dialects is the replacement of the second female singular pronoun as /ki/ or /k/ as in classical Arabic with /š/ or /iš/ referred to as kaškaša. Watson (1992) stated that this phenomenon 'kaškaša' is a result of a phonologically motivated occurrence of palatalization. Early Arab grammarian on the other hand attributed the emergence of such phenomenon to the aim of preserving the kasra /i/ of /ik/ in pauses to maintain the distinction between feminine and masculine, as vowels are deleted or devoiced in pauses in Classical Arabic. Watson (1999) also wrote an article discussing emphasis spread in Sanani dialect. Watson (1999) stated that Sanani dialect has two emphasis correlates; pharyngealization and labialization. Both of these phonological phenomena have different emphasis spread within the word. Pharyngealization spread from right to left whereas labialization spread from left to right. Therefore, there is a difference in the F2 value of the same vowel accruing before or after a labial or a pharyngealized consonant (Ladefoged and Maddieson ,1996). The same author has written a book on the phonology and morphology of Arabic. In her book, Watson (2002) described the Sanani dialect in comparison to Carine and MSA, the dialect spoken in the capital city in the northern part of Yemen. An articulatory description of the consonantal and vocalic inventory of Sanani is discussed, stating that the dialect has twenty-seven consonants and six vowels. The sounds' phonological features and the minimal and maximal possible syllable structures of the dialect are also discussed reporting that there are possible 'CVCCC' syllables in the dialect. Syllabification processes are discussed such as epenthesis, glottal stop prosthesis, closed syllable shortening and consonant clusters. Word stress systems are also elaborated including the theoretical model of word stress in Sanani dialect (Metrical Stress Theory of Hayes (1995)) and the algorithms for stressed words patterning. One of the rules reports that CVV and CVG syllables are more likely to be stressed than CVVC or CVCC. However, Watson (2002) stated that there is more of contextual fluctuation stress depending on the emphasis of the utterance and position of the word in the sentence. In addition to stress, phonological prosodic features, and empathetic spread in the dialect are also discussed along with its acoustic influence on neighbouring vowels. Shormani, M. (2010) studied other phonological processes in Yemeni dialects in general such as syllabification, consonant clustering and gemination in relation to the syllable structure of the dialect. He stated that the syllable patterning in Yemeni dialects are CCV, CCVV, CVCC, CCVC, CCVVC and CVVCC, clarifying that Yemeni Arabic has permitted initial consonant clusters indifferent to MSA. Other phonological processes that occur in Yemeni dialects are epenthesis, which is optional in the dialect, and closed syllable shortening. Shormani, M. (2010) stated that in closed syllable shortening the long vowel /a:/ is shortened to [a], /i:/ is shortened to [i], and /u:/ is shortened to [u] for example, /ba:b + kum/ (door + your) would be /babkum/ (your door). Syncope is elaborated taking place in vowel-final syllables to reduce the number of syllables. For example, /u/ vowel in the second word kbur is elided when attached to other words; /gadu: + kubur/ would be gadu kbur 'he has grown up' (Shormani, 2010, p.7). Moreover, Shormani, M. (2010) studied stress referring that stress placement in a word in Yemeni dialects is affected to a large extent by superheavy and light syllables. Though Shormani, M. (2010) has done a broad description of Yemeni dialects' syllable structures and studied a wide number of phonological processes, the study has not studied a particular Yemeni dialect on its own. Vowel deletion is another phonological phenomenon that exists in Yemeni dialects. It was studied by Yaari, et al. (2012) among different Yemeni dialects; Dhamari, Ibbi, Taizi, Tihami, Sana'ani, Hadrami, and Adeni within optimality theoretical framework. Findings show that vowel deletion in Yemeni dialects is only applicable to short vowels in middle and last syllables. Yaari, et al. (2012) reported that all Yemeni speakers delete short vowels in last syllables in past forms. However, there is a variation to what extent these short vowels are deleted among different dialects between high and low in the middle syllables. While Tazi and Ibbi dialects showed low vowel deletion, Tihami, Sana'ai and Hadrami showed high vowel deletion. Adani speakers, on the other hand, do not delete any vowels.

When it comes to using acoustic analysis as an analytical framework to study Yemeni dialects, scholarly attempts are very rare. Yeou, et al. (2007) is an acoustic study that investigates the fundamental formant frequency (F0) in a Yemeni dialect. Yeou et al. (2007) in particular study (F0) alignment in relation to focus contrast in dialectal Arabic utterances through a cross dialectal comparison between three Arabic dialects (Moroccan

Arabic, Kuwaiti Arabic, and Yemeni Arabic). Acoustic correlates such as fundamental formant frequencies (F0) and vowel length in ms were collected of the target words in closed syllables (CVC) and open syllables (CVCV) as read by five speakers for each dialect. The fundamental format frequencies (F0) were calculated to measure F0 peak alignment and rise size which is F0 change between F0 minimum and F0 maximum along the segmental string. The same authors in a similar study studying F0 alignments in Arabic dialects including Yemeni Arabic stated that every dialect has a distinctive F0 alignment that varies among different dialects (Yeou et al., 2007). Focus contrast was investigated through comparing acoustic attributes of both contrastive focus condition and non-contrastive focus condition. Longer vowel durations and large size rise were a consequence of contrastively focalized words. Yemeni dialect did not show any clear variation in size rise between contrastive and non-contrastive focus, but the lengthening effect was maintained. Moreover, Yemeni dialect did not indicate any significant difference in F0 peak alignment between CVC and CV syllables. However, the vowel duration of Yemeni dialect was also affected by syllable type, vowels in CVC syllables were longer by 17 ms. Intonation patterns in focalized words were also studied. Yeou, et al. (2007) stated that a falling rising movement is used to convey contrastive focus in Yemeni dialect. The acoustic attributes of increasing and decreasing fundamental formant frequencies in post focused and pre-focused positions are significant indications of intonation in focus contrast.

Salem (2014) is also among the very few attempts that utilizes acoustic analysis to study a Yemeni dialect. She studied the rhythm of Yemeni Arabic spoken in Taizz through measuring consonantal and vocalic durational intervals in spectrograms in Pratt, then compared the findings with Jordanian's Arabic. Five Tazzi speakers and five Jordanian speakers were recorded reading passages and spontaneous speech. Salem (2014) reported that Tazzi dialect doesnot have a single type rhythm but strikingly it has two different types of times rhythm. Consonantal durations indicate syllable timed rhythm while vocalic durations indicate stress timed rhythm. The results show that rhythmic structure is highly influenced by mixed phonological features as vowel duration and syllable structure of the dialect. The researcher emphasized on the need to investigate rhythm in the dialect in terms of other phonological features as vowel reduction and lexical stress.

Another study that used acoustic analysis to measure durations of sounds of a Yemeni dialect is a study done by Aldubai (2015) investigating gemination in a Tazzi dialect. Aldubai (2015) aims to study length differences between geminated and non-geminated syllables. He also aims to find out the influence of consonants on the length of the vowels before and after. More than twenty-five minimal pairs comprising geminated and non-geminated words of different manners of articulation. A comparison was conducted between durations as collected from spectrograms in ms. Findings show that geminated consonants are two times longer than non-geminated ones, that is why words with geminated consonants have a longer duration. In terms of the manner of articulation geminated trills have the longest duration while the geminated pharyngeals and semivowels have the shortest. In terms of voicing, voiceless geminated consonants are longer than voiced ones. Aldubai (2015) concluded that there is a reduction effect in the length of the vowels before and after geminated consonants.

To sum up, there are few researches investigating Yemeni dialects, such as Adani by Dawod (1952), Tihamai by Prochazka, (1987), Yafii by Vanhove, M. (1995), Sanani by Watson (2002) and Tazzi by Nada (2014). Those studies investigated different phonological aspects of the dialects. Some have given general descriptive accounts, such as Prochazka, (1987) and Vanhove, M. (1995), while some gave more in-depth phonological description such as Dawod (1952) and Watson (2002). Some studies examined particular phonological phenomena such as emphasis spread in Sanani dialect by Watson (1999), Gementaion in Tazzi dialect by Aldubai (2015) and rhythm in the same dialect by Nada (2014). Yaari, et al. (2012) studied vowel deletion as a phonological process in a large number of Yemeni dialects; Dhamari, Ibbi, Taizi, Tihami, Sana'ani, Hadrami, and Adeni.

To the best of the researcher's knowledge, Yeou, et al. (2007), Yeou, et al. (2007), Nada (2014) and Aldubai (2015) are the only studies that utilize acoustic analysis as an analytical framework to study a Yemeni dialect. Studies as Dawod (1952) and Prochazka, (1987) identified the number of vowels in Yemeni dialects as three short vowels and five long ones. However, the researcher did not come across any study that acoustically investigate the vocalic system of a Yemeni dialect. Through the review of the available researches on Yemeni dialects, the researcher identified many gaps regarding the investigation and documentation of Yemeni dialects, whether in terms of the acoustic analysis to describe the sounds of the dialects, or the phonological processes distinctive to a particular Yemeni dialect or even thorough descriptive documentation of a specific Yemeni dialect.

2.11. Previous Research on the Phonology of Hadrami Arabic

Hadrami Arabic as the target Yemeni dialect in this study is scarcely investigated. There are few attempts to study the phonology of the dialect in its both varieties, Hadrami Arabic of the valley and Hadrami Arabic of the coast. This section reviews those available scholarly attempts chronologically from the oldest to the most recent. Basalamah (1980, cited in Al-Saqqaf, 1999) is among the very first attempts to study the dialect through experimental investigation. Laboratorial methods were implemented as spectrographic, palatographic and kymographic techniques to study the consonants of HA. There was a brief account on vowels as well. The study was conducted on the dialect of Horah, a town near wadi Do'n in the valley of Hadramawt. Nevertheless, the very first attempt that gives a descriptive account of the dialect was done by the Swedish scholar Landberg (1901) accounting on folklore Hadrami samples. It is worth mentioning that the most comprehensive descriptive study on Hadrami Arabic is a study by Al-Saqqaf (1999) describing the phonology, morphology and syntax of HA of the valley specifically in the city of Seiyun. HA vocalic and consonantal systems are descriptively investigated. Possible syllable patterns as positioned in monosyllabic, disyllabic and trisyllabic words and rare cases of quadrisyllabic and pentasyllabic words are discussed. Phonological processes as vowel assimilation, consonant clusters, gemination and prosodic ones as stress shift and raising and falling intonation are investigated as well. Simplification processes are also discussed which is a phonological phenomenon in HA that involved the omission or reduction of certain sounds, for example */alga/* (he did) would be modified to *agga* (Al-Saqqaf, 1999, p. 86). The study also deals with morphological aspects as verb patterns and syntactic aspects as sentence types, in addition to the lexicon of the dialect. The study illustrates many examples of HA dialectal passages translated into English language. Another study by the same researcher involved more description of HA beyond the sentence level of connected speech. A comparison was done as well between both varieties of Hadrami Arabic of the valley and the coast from phonological and morphological perspectives by Al-Saqqaf (2006).

Most of the contributions to the phonological representation of the HA done later were on syllable structure and syllabification of HA within classical optimality theory. Bamakhramah (2009) conducted a research within classical optimality theory to study the syllable structure of superheavy syllables in HA. The research was conducted on the variety of Hadrami Arabic of the coast spoken in the city of Ghayl Bawazir, which has not been the subject of any previous phonological analyses. The researcher investigates related phonological phenomena such as stress assignment, epenthesis, syncope, and sonority. Bamakhramah (2009) aims also to investigate the syllabic variation in Classical Arabic, Meccan Arabic in addition to Hadrami Arabic. Bamakhramah's analysis laid out the various syllable structures and syllabification processes in Hadrami Arabic. A remarkable distinctive phenomenon to HA is that speakers tend to avoid non-final CV syllables through modification phonological processes as metathesis and epenthesis. In contrast to CA and MA, initial consonant clusters are permitted in HA. But unlike CA, HA avoids final consonant clusters through epenthesis. Al-Tairi, (2010) has done a further investigation on HA consonant clusters on the same variety of HA spoken in the city of Mukalla, Hadramawt. Permitted consonant distributions as onset into triconsonantal and quadric-consonantal clusters are investigated within an optimality theoretic approach. Al-Tairi, (2010) stated that triconsonantal (CCC) and quadric-consonantal (CCCC) string is not permitted in any other Yemeni or Arabic dialect other than Hadrami Arabic without being epenthesized with a vowel. They come in medial positions as onsets and complex codas such as /gultluh/ (I said to him) and /ṱabxtlhum/ (she cooked for them). He also stated that this sequence is mainly determined by the place and manner of articulation. For example, Consonants with identical place and manner of articulation never cluster in onsets. There is another study that has studied syllable structure but on Hadrami Arabic of the valley, specifically in the village of Naholah in Wadi Do'n by Mahfouz (2013). The study was studying syllable structure using the framework of auto-segmental phonology. The study mainly describes three syllable structure rules in Hadrami Arabic. Closed syllable shortening is studied in relation to morphological context that triggers the phenomenon and how VVC syllables are reduced to VC syllables. Both vocalic and consonantal epenthesis are discussed as well as high and low vowel deletion. Al-Gariri

(2020) studied the phenomena of permitted consonant clusters in initial positions and prohibited ones in final positions in the variety of HA of the coast the same as Al-Tairi, (2010) but within a different theoretical framework. Al-Gariri (2020) attempted to further investigate the explanation of the occurrence of such phenomena from the perspective of strict CV in a skeletal level. The research attributed the phenomenon to the nature of syllabification and syllable structures in HA. Particularly, nucleis' and onsets' ability to govern and license the existence of empty nuclei in initial and final positions in first and second syllables. It is noteworthy that this tolerance of consonant clusters in HA of the coast is not yet proved to exist in HA of the valley.

2.11.1 HA Vowels Described by Al-Saqqaf (1999)

Al-Saqqaf (1999) stated that the vowel inventory of Hadrami Arabic is made up of eight monophthongs, three short vowels /i /, /ɑ /, /u/ and five long ones symbolized as /ī/, /ē/, /ō/, /ū/and /ā/, in addition to diphthongs formed by combining any monophthong with *y* or w. The researcher phonetically described all the Hadrami sounds and their allophonic variants in different syllabic positions. Twenty-nine HA Consonants were described in terms of place and manner of articulation and eight HA vowels were described in terms of front-back dimension, high–low dimension and lip rounding. Al-Saqqaf (1999) allocated almost three allophones for each short vowel. /i/ is described as high front unrounded allophone as mid-high front unrounded [ɪ] in non-emphatic context as /bitt/ (girl), mid-high front (centralized) unrounded [ɨ] in emphatic or emphatic-like context as /ṭib/ (medicine) and mid-low front (slightly raised) unrounded [ ] in pharyngealized context of /ħ/ and /ʕ/ as /biʕ/ (sell). The short HA /ɑ/ has three common allophones which are low front (slightly raised) unrounded [æ̃] in non-emphatic context as /hat/ (give), mid-low central unrounded [ʌ] in emphatic-like context as /ʃak/ (doubt) and low back unrounded [ɑ] in emphatic context as /s̯arut̯/ (swallow). The short HA /u/ has four allophonic realizations which are mid-low (slightly raised) central unrounded [ə] which breaks final consonant clusters; a word as *nahr* would be /nahur/ (river), mid-high (slightly centralized) back rounded [ʊ] as /sufrah/ (dining table), mid-high central rounded [ʉ] in emphatic context with a labial consonant as /jus̯bi/ (absent-minded) and mid-high back rounded [o] in pharyngealized context with uvulars and pharyngeals as /χubiz/ (bread). For long vowels, Al-Saqqaf (1999) stated that HA long vowels have two allophonic variants in emphatic and non-emphatic environments. The HA long /ī/ is a high front unrounded [i:] in non-emphatic contexts as /si:f/ (beach) and [i:ᵊ] in emphatic contexts as /s̯i:t̯/ (reputation). The HA long /ē/ is described as unrounded mid-low (slightly raised) and slightly centralized [ɛ̝:] in non-emphatic contexts as /be:t/ (home) and [ɛ:ᶺ] in emphatic contexts as /be:ḍ/ (eggs). The HA long /ā/ is described as high front unrounded with an emphatic allophone [ɑ:] as in /t̯ɑ:r/ and non-emphatic allophone[æ:] as /bɑ:b/ (door). The HA long /ō/ is described as rounded mid-high back [o:] as /ħo:rah/ (City; Horah), with a mid-low back rounded variant symbolized by Al-Saqqaf (1999) [ɔ:ᵊ] as /χo:f/ (fear). Lastly, the HA long /ū/ is described as high back rounded with a nonemphatic variant [u:] as /ʕu:d/ (stick) and emphatic one [u:ᵊ] as /baʕu:ḍ/. (mosquitoes). However, all of these descriptions by Al-Saqqaf (1999) are impressionistic. Therefore, they do not grant the accurate description the acoustic analysis does. Al-Saqqaf (1999) declared that experimental investigation is out of the scope of his research. This research comes to fill that gap utilizing acoustic analysis to analyze those eight HA monophthong vowels through examining two main acoustic parameters; vowel quality and duration.

Table 2.1: Vowel system in HA (Al-Tairi, 2010)

front-back dimension	high – low dimension- lip rounding	
	Front	Round back
High	/i/ /iː/	/u/ /uː/
Mid	/eː/	/ɔː/
Low	/a/ /aː/	

Table 2.2: Consonantal system in HA (Alsaqqaf, 1999)

Consonant	IPA Symbol	Description
b	[b]	voiced bi-labial stop
t	[t̥]	voiceless lamino-alveolar stop
	[t̥ˤ]	voiceless lamino-alveolar emphatic
d	[d̺]	voiced apico-alveolar stop
j	[ɟ]~[ʤ]	voiced palatal stop/affricate
k	[k]	voiceless velar stop
g	[g]	voiced velar stop
(q)	[q]	voiceless uvular stop
’	[ʔ]	glottal stop
f	[f]	voiceless labio-dental fricative
ṯ	[Ɵ]	voiceless interdental fricative
ḏ	[ð]	voiced interdental fricative
ḍ	[ðˤ]	voiced interdental emphatic fricative
s	[s]	voiceless alveolar fricative
	[sˤ]	voiceless alveolar emphatic fricative

z	[z]	voiced alveolar fricative
š	[ʃ]	voiceless alveo-palatal fricative
ḵ	[χ]	voiceless uvular fricative
	[ʁ]	voiced uvular fricative
	[ħ]	voiceless pharyngeal fricative
ʿ	[ʕ]	voiced pharyngeal fricative
h	[h]	voiceless glottal fricative
m	[m]	voiced bilabial nasal
n	[n]	voiced alveolar nasal
r	[r]	voiced alveolar trill
l	[l]	voiced alveolar lateral
	[lˤ]	voiced alveolar emphatic lateral
y	[j]	voiced palatal approximant
w	[w]	voiced labio-velar approximant

2.12. Summary

This chapter starts by giving a brief introduction of vowels as defined by Early Arab phoneticians and modern scholars. The source filter theory providing the theoretical framework for acoustic analysis of vowels has been elaborated. Acoustic analysis involves exploring two main acoustic parameters which are vowel quality and quantity. They are discussed in this chapter. Moreover, a brief account about Arabic vocalic system is given. A thorough review of the most related studies to acoustic analysis of Arabic vocalic systems is conducted. Studies on MSA, CA and colloquial Arabic have been reviewed. Further review was done on the most available studies on the phonology of Yemeni dialect and Hadrami Arabic. The researcher reached a final gap that there is no study has ever been conducted to acoustically describe the vocalic system of Hadrami Arabic nor to any other Yemeni dialect which is why this research is conducted.

Chapter 3

Research methodology

This chapter provides a detailed explanation of the research methods. According to Alssagaf (1999), Hadrami Arabic has eight monophthongs which are three short vowels (/i/,/a/,/u/) and five long ones (/i:/,/a:/,/u:/,/e:/ and /ɔ:/). Those eight HA monophthongs were acoustically analyzed in terms of their vowel quality and quantity. The researcher adopted a quantitative approach of an acoustical analytical framework to instrumentally analyze HA vowels. The researcher put some focus on gender variation, phonetic context, syllable structures, and speech rate. Good attention was paid to sociolinguistic variables set by Chambers (2003) and Labov (1994) such as age, gender and region. Detailed accounts of the participants, reading materials, data collection and data analysis are given in the following four sections.

3.1. Participants

The speech data were obtained from ten participants, four males and six females. The selection criteria control the participants' linguistic background, level of education, age variable, place of birth, and residence in addition to spouses' linguistic background. To control the variable of dialectal variation, all the participants were born and raised in the city of Seiyun with no hearing or speech disorder. A Questionnaire was distributed to the participants, like the one used in Deterding (2003), see appendix A. The questionnaire specifies participants' age, educational background, personal details as well as their spouses' background, the participants' place of birth and for how long they have been living in the city of Seiyun. A participant in this study must be born and raised in the city of Seiyun and should have not been exposed to any other linguistic contexts other than

HA since birth. The questionnaire also collects data about participants' spouses' linguistic background. Participants or their spouses with bilingual linguistic background were eliminated. The aim is to reduce any linguistic influence that might occur if the participants' spouses have a different linguistic background other than native Hadrami Arabic. The participants who met the research criteria were selected for the research. 23 people were interviewed and only ten who fulfill the criteria were chosen for the study ranging in age from 36-60. The average age was 44 years old. The justification for choosing this age group is their less attachment to other linguistic contexts as younger generations are more exposed to the internet and open media (Rideout et al., 2010). Their level of education was a middle one in order to be able to read the prescribed sentences. Table 3.1 reports the background of the ten Hadrami Arabic speakers:

Table 3.1.: Background of Hadrami Arabic speakers

Speakers	Sex	Age	Language	Educational level	Occupation	Place of birth and residence
1	Female	60	Hadrami Arabic	Middle school	Government employee	Seiyun
2	Female	42	Hadrami Arabic	Middle school	Housewife	Seiyun
3	Female	58	Hadrami Arabic	Middle school	Nanny	Seiyun
4	Female	38	Hadrami Arabic	High school	Housewife	Seiyun
5	Female	36	Hadrami Arabic	Middle school	Housewife	Seiyun
6	Female	36	Hadrami Arabic	Middle school	Housewife	Seiyun
7	Male	41	Hadrami Arabic	Middle school	Gatekeeper	Seiyun
8	Male	46	Hadrami Arabic	Middle school	Government employee	Seiyun
9	Male	43	Hadrami Arabic	High school	Government employee	Seiyun
10	Male	41	Hadrami Arabic	Diploma	Government employee	Seiyun

3.2. Reading Materials

The reading materials are a set of prescribed sentences that include the target words. The target words are common dialectal Hadrami Arabic words containing the target vowels. The prescribed sentences were written by the researcher as a native speaker of the dialect paying a good attention to the phonetic context of the target vowels. The prescribed sentences were validated and double-checked by a native HA speaker. The target Hadrami Arabic vowels were embedded in the set of prescribed sentences. The tokens were inserted in natural sentences to be read spontaneously to avoid any listing intonation that might occur in isolated tokens (Alghamdi,1990, p.23). Port et al. (1980), Hassan (1981) and Alghamdi (1990) suggest that voicing might affect the length of the preceding vowels. Therefore, all the vowels were followed by voiceless consonants.

The aim of the sentences is to naturalize the speech and make it as much native as possible. The total number of the prescribed sentences is 16 sentences, four tokens for each vowel. Each sentence has two tokens with a total number of 32 tokens. The eight Hadrami Arabic vowels (/i/, /a/, /u/, /iː/, /aː/, /uː/, /eː/ and /ɔː/) were placed in between stressed CCVC and CVC in eighteen monosyllabic, twelve disyllabic and two multisyllabic words; /mas.ra.f**a**h/ and /il.ʕa.r**uː**s/. The tokens for the short HA /i/ are three disyllabic words; /ʃu.f**i**t/, /b**i**t.tak/, /t**i**k.kah/, and one monosyllabic word; /ħð**i**f/. The tokens for the short HA/u/ are two monosyllabic words; /χs**u**f/, /fr**u**ʃ/, and two disyllabic words; /wa.d**u**h/, /s**u**f.rah/. The tokens for the short HA /a/ are three monosyllabic words; /h**a**t/, /b**a**s/, /bg**a**ʃ/ and one multisyllabic word / mas.ra.f**a**h/. The tokens for the long HA /iː/ are three disyllabic words; / ħa.ʃ**iː**ʃ/, /χa.f**iː**f/, /ʕa.s**iː**s/ and one monosyllabic word; /s**iː**f/. The tokens for the long HA /uː/ are three disyllabic words; /maf.ħ**uː**s/, /sˤa.b**uː**ħ/, /bd.f**uː**f/, and one multisyllabic word /il.ʕa.r**uː**s/. The tokens for the long HA /eː/ are three monosyllabic words; /bʁ**eː**t/, /z**eː**t/, /b**eː**t/ and one disyllabic word; /hu.b**eː**ʃ/. The tokens for the long HA /a:/ are four monosyllabic words; /ʕs**a:**h/, / ʃ**a:**h/, /ð**a:**k/, and /ft**a:**h/. The tokens for the long HA/ɔ:/ are four monosyllabic words; /ħɔ:f/, / n**ɔ:**f/, / ħ**ɔ:**ʃ/, and /k**ɔ:**t/.

The first and second consonant (C) of the target syllables containing the target vowel was either a fricative or a plosive. Syllabuses with vowels that occur before or after approximats such as /w/, /j/, /r/ and /l/ were avoided. Nasals as /n/ and /m/ were avoided as well to avoid any possible co-articulatory effect (Deterding, 1997). Besides approximants and nasal consonants, emphatic Arabic consonants such as /tˤ, dˤ, ðˤ, sˤ/ were avoided, as Anani (1980), Hussain (1985), Ghazeli (1977) and many more found out that emphatic consonants lead to the lowering of F2 in neighbouring vowels. This limited the number of choices for selected target words. However, there are three occurrings in which the target vowel is preceded by approximats and a nasal consonant, which are /u/ in /fruʃ/, /u:/ in /ilʕaru:s/ and /ɔ:/ in /nɔ:f/. It could not be avoided by the researcher as they were appropriate native Hadrami Arabic words containing the target vowels. Moreover, the researcher was assured there was no coarticulatory effect on these vowels. The justification for this is that their formant frequencies calculated by the researcher were not odd or higher in range than the other vowel of the same category preceded by plosives or fricatives. Further, the decision to keep these words was necessary to maintain a sufficient number of tokens. As Hadrami Arabic does not have a formal written form, the prescribed sentences were written in modern standard Arabic in the context of dialectal HA speech.

3.3. Data Collection

The data collection consists of three parts: signing the consent form, filling the questionnaire and audio recording.

Prior to signing the consent form; see appendix B, the Hadrami native speakers were introduced to the research and given freedom upon deciding to participate or not. Then, the Hadrami Arabic speakers signed a consent form and answered a questionnaire. The participants were familiarized with the prescribed sentences pre-recording and given the chance to practice reading the sentences as they want. They were not told what the target tokens were or the specific linguistic aim of the study to guarantee authentic unbiased data. Nevertheless, they were aware of the importance of the study and fully corporative to participate. They were told as well to read as dialectal and natural as possible.

The audio recording sessions have been conducted from 1.1.2020 to 20.1.2020. The researcher was not present during the data collection process because of her inability to reach the setting of the research at the time of data collection. However, the interviewers were fully instructed by the researcher about data collection criteria step by step. Therefore, two interviewers were present at the time of the recording, one conducted the interviews and one facilitated the meetings with Hadrami native speakers as instructed by the researcher. The researcher was constantly updated with the data collection process.

The data was recorded in quiet and carpeted rooms to minimize eco. Ladefoged (2001) suggested that a good recording environment is required to minimize any outside noise. For the female participants, the recording was conducted at the participants' houses and for the male ones, it was at their offices, which all resided in the city of Seiyun. The atmosphere of data collection was very convenient and comfortable for the participants.

A high-quality recording device was used, which is Zoom h4n Pro model b93127827828 to guarantee quality sounds and accurate measurements. The recording device was put to few inches away from the participants and no time limit was set for the participants. The sampling rate was set to a mono with a sampling frequency of 22050 Hz as suggested by Ladefoged (2003). The recordings were saved in a memory card then saved as wave files.

3.4. Data Analysis

For data analysis, this research adopts a quantitative approach of acoustic analysis as an analytical framework. The Hadrami Arabic vowels' acoustic properties are investigated in terms of formant frequencies and vowel duration. The researcher used Praat version 6.0.37 (Boersma & Weenik, 2018) a free computer software used by phoneticians to analyze speech data. Recorded sentences were orthographically transcribed at a text grid in Praat with three tiers, one for the prescribed sentences written in IPA transcription, the second for the words containing the target vowel and the third for the target vowel, see figure 3.1. Analysis to extract formant frequencies and vowel duration was done using linear predictive coding overlaid in spectrograms. Linear predictive coding is the classical computational way for measuring formant frequencies from a speech signal in a spectrogram (Rosner & Pickering,1994, p. 8_11).

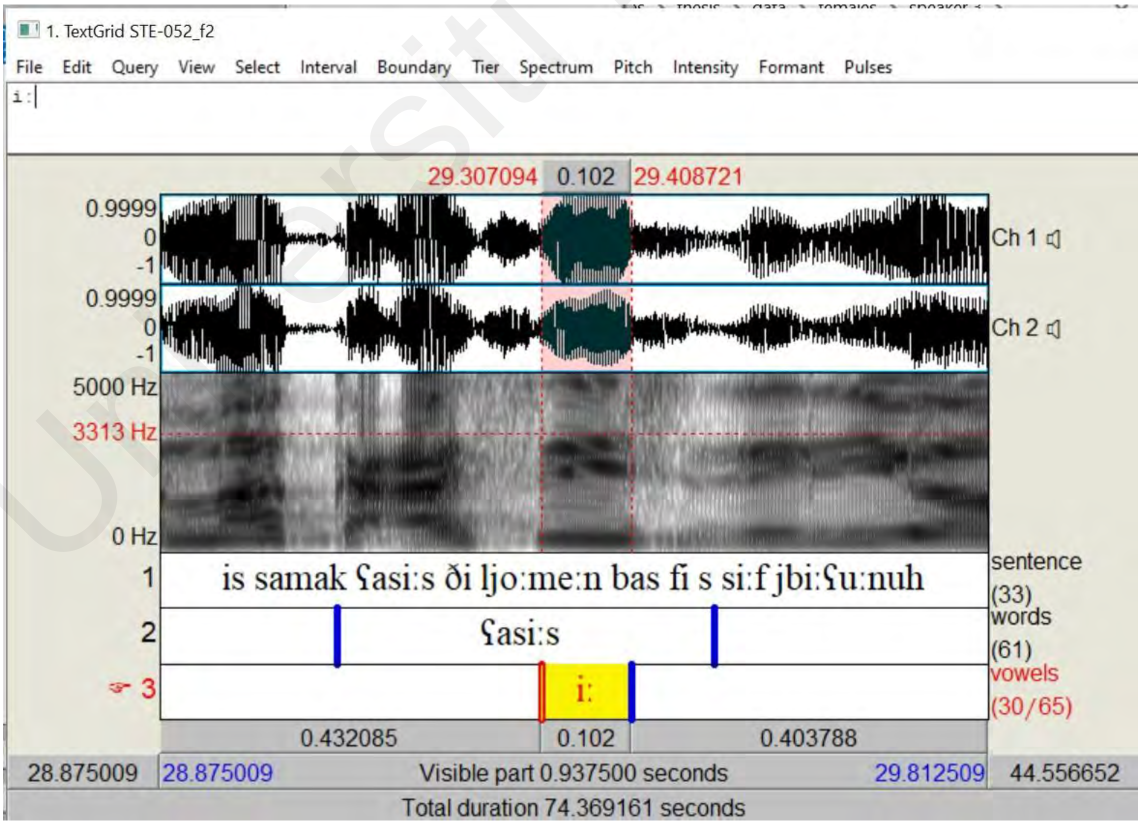


Figure 3.1: Screenshot of spectrogram and data annotation of Hadrami Arabic vowel

Forty tokens per vowel were set for data analysis. However, there were some data exclusions at this phase by the researcher. For the /i:/ long vowel, seven participants pronounced the /i:/ sound in /si:f/ as /e:/ sound /se:f/. The /u/ vowel in the word /χsuf/ was pronounced by most participants as /χsif/. Therefore, these tokens were excluded from the data analysis. According to Sibawayhi (1889) and Laufer (1988), emphasis is realized by valorization when the back of the tongue is raised towards the velum. It was the same case in this study for the uvular /ʁ/ in the word /bʁe:t/. The researcher made the decision to exclude this token as well from the data analysis, because there was a lowering tendency in the F2 values of the /e:/ vowel in the word /bʁe:t/. It was very clear in the data extractions compared to the other three /e:/ vowels' F2 values in /ze:t/, /be:t/, and /hube:ʃ/. As emphatic versions of vowels are not included in this research. Therefore, the total number of tokens for this research was 293 instead of 320. Table 3.2. illustrates the number of tokens per each speaker.

Table 3.2.: The number of tokens per speaker:

HA vowels	Number of tokens per speaker										
	Sp1	Sp2	Sp3	Sp4	Sp5	Sp6	Sp7	Sp8	Sp9	Sp10	Total
/i/	4	4	4	4	4	4	4	4	4	4	40
/i:/	3	3	4	3	3	3	4	3	3	4	33
/u/	3	3	3	3	3	3	3	3	3	3	30
/u:/	4	4	4	4	4	4	4	4	4	4	40
/a/	4	4	4	4	4	4	4	4	4	4	40
/a:/	4	4	4	4	4	4	4	4	4	4	40
/e:/	3	3	3	3	3	3	3	3	3	3	30
/ɔ:/	4	4	4	4	4	4	4	4	4	4	40
	Total										293

The first two formants frequencies were measured for each vowel token as they are the most defining feature of vowel quality (Ladefoged 2001, p. 46). In order to know the vowels' realizations in the acoustic vowel chart, the first two formants were identified.

Hayward (2000) reported that vowels are defined by a constant rate of vocal configurations. This constant vocal configuration is represented acoustically by a constant formant pattern (Di Benedetto, 1989, p. 59). The two vowel boundaries were highlighted according to the energy of F1 and F2 in the spectrogram. The first two formants were measured at the midpoint of the target vowel. According to Hayward (2000), the midpoint of the vowel is the least influenced and the most constant state of the vowel. The measurements were collected automatically through Praat scripts and double checked manually by the researcher. Sometimes there would be some variation on formant values of the same vowel on the spectrogram of the same participants. Therefore, a crosscheck of the four tokens was done comparing the range of all formants of the four tokens of the same vowel by the same speaker. This step was done to depict any odd variation in formants values of vowels of similar category.

To extract formant values of the target vowels, the maximum formant setting in Praat was adjusted at 5500 Hz for females and 5000 Hz for male speakers. For gender differences in the vocal tract, data were analyzed separately on gender basis. As Yang (1996) states gender is associated with vocal tract length and it has a major effect on formants values. The shorter the formant tract the higher the formant frequencies. That is why formant frequencies for female speakers are higher by 10% to 15% than male speakers (Wang and Van Heuven, 2006). Furthermore, gender is associated with linguistic variation and dialect change. Women are more prone to dialect change than men. Labov (1990) stated that when it comes to sociolinguistic change females are the innovators. That is why it is important to analysis data of different genders separately.

The formant values were measured in Hertz. Then, they were transferred into Bark. The Bark scale is a nonlinear transformation of frequency that estimates the analysis of the ear (Kent & Read, 1992). The formula suggested by Zwicker and Terhardt (1980) used to transform Hz into Bark scale was:

Z=13 arctan (0.00076f) + 3.5 arctan ((f/7500)2)

Z equals the frequency in Hertz and F equals the frequency in Bark. Furthermore, Bark scale transformation formula is used as a normalization procedure. Bark transformation scale is considered an intrinsic vowel normalization procedure (Calamai, 2006). The Bark values calculated are transformed into F1 vs F2 chart. The entire data of male and female speakers were tabulated in Excel spreadsheets and analysed separately on gender bases considering male and female vocal tract differences. Average F1 and F2 vowel values for each HA monophthong vowel and the standard deviations of male and female speakers were calculated and tabulated in this research. A further t-statistical test was conducted. The t-test was a two-tailed independent t-test and the alpha value was 0.05. It was conducted to verify whether the differences between male and female speakers' vowel is statistically significant.

For vowel duration, it was measured from the onset of energy in F1 to the offset of energy in F1 and F2 which according to Flege and Port (1981, p.128), mark the vowel boundaries in a spectrogram. Speech rate has a major influence on vowel duration (Van Son and Pols ,1990, 1992) and quick speech leads to a more coarticulatory effect (Lindblom,1963). Vowel undershot and reduction is also a result of fast speech rate (Lindblom,1963). That is why constant speech rate among selected participants was put into consideration during data analysis. The vowel duration extraction was done using automated Praat scripts. Manual extraction from visual spectrograms was sometimes used for verifications. The measurements of vowel duration were collected separately based on gender variation in seconds and transferred to milliseconds. Mean durations of HA vowels were calculated. Maximum and minimum values for short and long HA vowels were depicted. SD, ratios of short HA vowels to long HA vowels and long and short vowel differences were calculated. All the data of long and short vowels' duration of male and female speakers were tabulated and compared, see appendix E.

Speech variation poses a challenge for acoustic analysis methods to be accurate and competent. There are two types of speech variation. Inter speaker variation 'within speaker variation' results from physiological differences due to gender and age differences. Intra speaker variation 'between speaker variation' results from phonetic context and speech rate (Lindblom, 1990; Perkell, 1990). In this research to have as much as constant data as possible for both formants' values and duration, inter and intra speaker variation are controlled as much as possible. Inter speaker variation could be normalized through conducting the data separately on a gender basis and selecting participants within a similar age group. While intra speaker variation could be neutralized by eliminating coarticulatory effect as much as possible through selecting as less influential phonetic context as possible. In addition, the research made her best to choose consistent speech rates among all participants by auditory means.

3.5. Justification for Acoustic Analysis

Ladefoged (2006, p.6) and Ladefoged and Johnson (2011, p.6-7) give four motives for conducting an acoustic analysis as an analytical framework rather than an auditory or an impressionistic one. First, acoustic analysis best explains any vague occurrences that might happen during speech sounds production. Second speech sounds are sufficiently described in terms of their speech configuration in the vocal tract through figuring out formant frequencies. Third, acoustic phonetics helps to know how speech sounds are recognized, perceived and synthesized by computers. During the production of speech sounds, a recording is the best long-lasting representation of what the speaker is doing during speech production rather than an x-ray or a photograph which are difficult to get. Therefore, acoustic analysis is utilized as an analytical framework in this research design to describe HA monophthongs. Since formant frequencies and vowel duration are the most relevant acoustic properties to vowel quality and vowel quantity which sufficiently identify a vowel sound.

3.6. Conclusion

This chapter discusses the analytical framework used to study HA monophthongs' quality and quantity. It explains the criteria of the participants' selection considering their age and background. It discusses the reading materials and the selection of the Hadrami words. It also elaborates on the data collection procedure starting from signing a consent form, filling the questionnaire and data recording. And finally, the data analysis was explained thoroughly. The researcher paid a fair attention to inter and intra speaker variation due to physiological and phonological factors. Hence, normalization procedures were followed such as separating the data analyses based on gender and using Bark transformation scale.

Chapter 4

Findings and Discussion

This chapter discusses the findings of the study. One of the main objectives of this study is to describe the vowel quality of the monophthongs of Hadrami Arabic as produced by male and female speakers. The first section of this chapter discusses the acoustic properties of the eight HA monophthong vowels in terms of vowel quality for male and female speakers. Then, an overall discussion of Hadrami Arabic monophthongs in terms of their F1 and F2 mean values and their position in the scatter plot is provided. Then each vowel's acoustic properties of vowel quality are investigated individually based on gender variation. A comparison between the findings of HA vowels' quality and other Arabic vowels' quality found in the literature is then further conducted.

The second section is concerned with the quantity of vowels. Vowel duration of each HA vowel is discussed. Hadrami Arabic short and long vowels distinction is elaborated based on gender variation. A comparison between the findings of HA vowels' duration and other Arabic vowels' quantity found in the literature is further conducted.

Hence, this chapter tends to answer the research questions addressed in chapter 1;

1. What are the acoustic properties of monophthongs of Hadrami Arabic based on their formant values of male and female speakers?

2. To what extent is the distinction of short and long vowels in Hadrami Arabic based on the vowel duration of male and female speakers?

4.1. Vowel Quality of Hadrami Arabic Monophthongs

For this study, as reported by Alssagaf (1999), Hadrami Arabic vowel inventory has three short vowels (/i/, /u/, /a/) and their three long counterparts (/iː/, /uː/, /aː/,) in addition to the two long vowels (/eː/, and /ɔː/), which are distinguished to Hadrami Arabic. Table 4.1 and table 4.2 illustrate the mean values of F1 and F2 of HA monophthongs of male and female speakers and the distinction between male and female HA vowel mean formants is discussed below.

Table 4.1: Mean F1 and F2 values of HA monophthongs of male speakers

vowels	Avg. F1 (Hertz)	SD F1 (Hertz)	Avg. F2 (Hertz)	SD F2 (Hertz)	Avg. F1 (Bark)	SD F1 (Bark)	Avg. F2 (Bark)	SD F2 (Bark)
/i/	409	46	1812	190	3.93	0.42	12.46	0.69
/iː/	388	28	2184	173	3.74	0.25	13.67	0.50
/u/	449	35	1442	183	4.29	0.31	10.93	0.91
/uː/	455	47	1000	178	4.34	0.42	8.51	1.13
/a/	529	50	1648	224	4.99	0.43	11.83	0.96
/aː/	613	68	1704	150	5.69	0.56	12.05	0.60
/eː/	493	32	1929	160	4.68	0.28	12.87	0.52
/ɔː/	558	55	1270	156	5.23	0.46	10.08	0.82

Table 4.2: Mean F1 and F2 values of HA monophthongs of female speakers

vowels	Avg. F1 (Hertz)	SD F1 (Hertz)	Avg. F2 (Hertz)	SD F2 (Hertz)	Avg. F1 (Bark)	SD F1 (Bark)	Avg. F2 (Bark)	SD F2 (Bark)
/i/	532	97	1936	187	5.01	0.82	12.89	0.64
/i:/	435	93	2471	171	4.16	0.82	14.43	0.43
/u/	587	76	1750	187	5.48	0.61	12.23	0.71
/u:/	497	85	1114	235	4.71	0.73	9.21	1.36
/a/	720	92	1827	226	6.54	0.71	12.51	0.87
/a:/	810	140	1996	197	7.17	1.00	13.06	0.65
/e:/	597	57	2248	180	5.56	0.47	13.85	0.54
/ɔ:/	726	114	1304	112	6.59	0.85	10.26	0.56

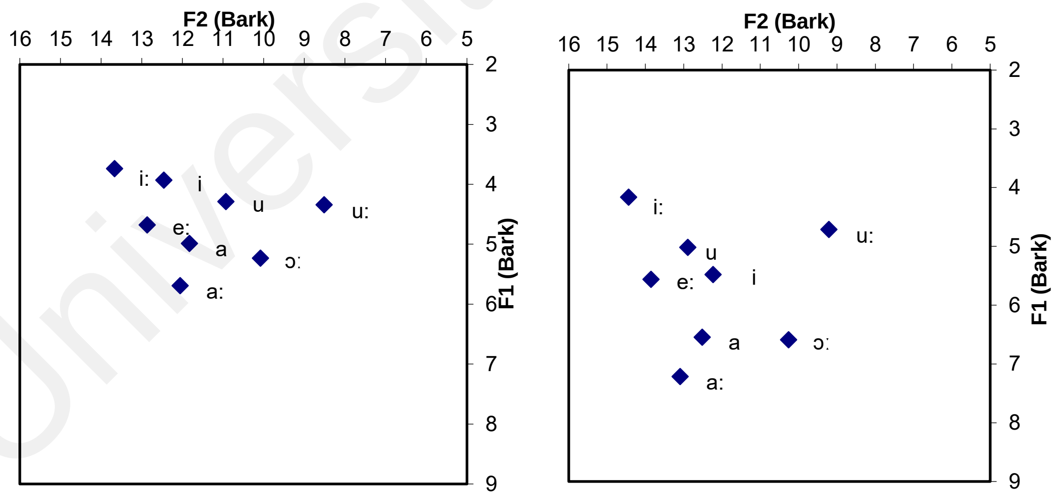


Figure 4.1: Scatter plot of mean HA vowels by male speakers (left) and female speakers (right)

The overall acoustic pattern of Hadrami Arabic vowel system is triangular and represented by eight vocalic qualities. Three short vowels (/i/,/u/, /a/,), their three long counterparts (/i:/, /u:/, /a:/), and two long vowels distinguished to Hadrami Arabic (/e:/, and /ɔ:/) .

This study not only analyses HA vowels instrumentally in terms of first and second formant frequencies, it also suggests a variation between male and female speakers' vowel production of the same vowel category and studies the difference. As can be noticed in the scatter plot of HA vowels of male and female speakers in figure 4.1, there is a difference in HA vowels in their F1 and F2 formant frequencies as produced by male and female speakers. For HA /i/, the mean F1 and F2 values for HA male speakers is 3.93 and 12.46 in bark scale while for female respondents the mean F1 and F2 values are 5.01 and 12.89, hence male HA speakers seem to pronounce higher /i/ vowels and a bit less fronted ones than female speakers. A T test was carried out and it shows that the difference between male and female speakers F1 and F2 is statistically significant for F1, ($t(8) = 2.92$, $p = 0.019$), but not statistically significant for F2, ($t(8) = 1.65$, $p = 0.14$). Hence, HA /i/ vowels pronounced by male speakers are higher than the ones pronounced by female ones but with similar degree of frontness for both genders. Examining the long HA /i:/, there is a difference in HA vowels in their F1 and F2 formant frequencies as pronounced by male and female speakers. For HA /i:/, the mean F1 and F2 values for HA male speakers is 3.74 and 13.67 in bark scale while for female speakers the mean F1 and F2 values are 4.16 and 14.43. Hence, male HA speakers seem to pronounce higher /i:/ vowels and more retracted ones than female speakers. A T test shows that the difference between male and female speakers F1 and F2 is not statistically significant for F1 ($t(8) = 0.988$, $p = 0.352$), but statistically significant for F2 ($t(8) = 3.359$, $p = 0.010$). Hence, HA /i:/ vowels pronounced by male and female speakers are similarly high but female speakers produce more fronted ones.

For HA /u/ vowel, the mean F1 and F2 values for HA male speakers is 4.29 and 10.93 in bark scale while for female speakers the mean F1 and F2 values are 5.48 and 12.23 in bark scale. Hence, male HA speakers seem to pronounce higher /u/ vowels and a less fronted ones than female speakers. The T test shows that this difference between male and female speakers' F1 and F2 is statistically significant for both F1 and F2 mean values, ($t(8) = 3.694$, $p = 0.006$), ($t(8) = 3.071$, $p = 0.015$). The data for HA long counterpart /u:/ vowel pronounced by male speakers is 4.34 in bark scale for F1 and 8.51 for F2. Whereas female speakers' HA /u:/ have a mean F1 value of 4.71 and a mean F2 value of 9.21 in bark scale. Hence, female speakers seem to pronounce lower and more fronted HA /u:/ vowel than male speakers. The T test shows that this difference between male and female speakers' F1 and F2 is not statistically significant neither for F1 nor F2 mean values, ($t(8) = 0.951$, $p = 0.369$), ($t(8) = 0.922$, $p = 0.384$). Hence, female and male speakers pronounce similar long HA /u:/ vowels in terms of frontness and retraction.

For HA /a/ vowel, the mean F1 and F2 values for HA male speakers are 4.99 and 11.83 in bark scale while for female speakers the mean F1 and F2 values are 6.54 and 12.51 in bark scale. Hence, female speakers tend to pronounce lower and more fronted HA /a/ vowel than male speakers. The T test shows that this difference between male and female speakers' F1 and F2 is statistically significant for both F1 and F2 mean values, ($t(8) = 5.84$, $p < 0.001$), ($t(8) = 3.66$, $p = 0.006$). For the long counterpart HA /a:/, the mean F1 and F2 values for HA male speakers are 5.69 and 12.05 in bark scale while for female speakers the mean F1 and F2 values are 7.17 and 13.06 in bark scale. Hence, female speakers tend to pronounce lower and more fronted HA /a:/ vowel than male speakers. The T test shows that this difference between male and female speakers' F1 and F2 is statistically significant for both F1 and F2 mean values, (t (8) = 3.601, p = 0.007), (t (8) = 5.297, p = 0.001).

For HA /e:/ vowel, the mean F1 and F2 values for HA male speakers is 4.68 and 12.87 in bark scale while for female speakers the mean F1 and F2 values are 5.56 and 13.85 in bark scale. Hence, female speakers tend to pronounce lower and more fronted HA /e:/ vowel than male speakers. The T test shows that this difference between male and female speakers' F1 and F2 is statistically significant for both F1 and F2 mean values, (t (8) = 5.514, p = 0.001), (t (8) = 3.579, p = 0.006).

For HA /ɔ:/ vowel, the mean F1 and F2 values for HA male speakers is 5.23 and 10.08 in bark scale while for female speakers the mean F1 and F2 values are 6.59 and 10.26 in bark scale. Hence, female speakers tend to pronounce lower and more fronted HA /e:/ vowel than male speakers. The T test shows that this difference between male and female speakers is statistically significant for F1, (t (8) = 3.732, p = 0.006), but not for F2 mean values, (t (8) = 0.004, p = 0.699). Hence, HA /ɔ:/ vowel is pronounced higher by male speakers but within a similar retracted range for both genders. The overall findings show male HA speakers tend to pronounce higher and more retracted HA vowels for (u, a, a:, and e:). For HA /i/ and /o:/ vowels the difference is only on height level; male speakers produce higher /i/ and /o:/ vowels while for HA /i:/ vowel the difference is only on retraction level; female speakers produce more fronted /i:/ vowels.

An overall representation of HA vowels in the acoustic vowel space is provided below, figure 4.2, and Hadrami Arabic vowels positioning in the vowels space is further discussed. The average values of HA monophthong vowels F1 and F2 in Hertz and bark scale along with their standard deviations are presented in table 4.3. The measurements of each vowel are presented in appendix D.

Table 4.3: Average F1 and F2 of Hadrami Arabic monophthongs

Vowel	Avg. F1 (Hertz)	SD F1 (Hertz)	Avg. F2 (Hertz)	SD F2 (Hertz)	Avg. F1 (Bark)	SD F1 (Bark)	Avg. F2 (Bark)	SD F2 (Bark)
/i/	483	101	1887	197	4.57	0.85	12.68	0.68
/i:/	415	76	2349	222	3.97	0.67	14.09	0.60
/u/	532	94	1627	238	5.01	0.78	11.74	1.02
/u:/	480	75	1068	219	4.55	0.64	8.84	1.30
/a/	643	122	1755	239	5.94	0.97	12.25	0.96
/a:/	731	151	1879	229	6.63	1.12	12.70	0.81
/e:/	556	70	2120	233	5.20	0.59	13.43	0.72
/ɔ:/	663	126	1291	129	6.16	0.97	10.16	0.67

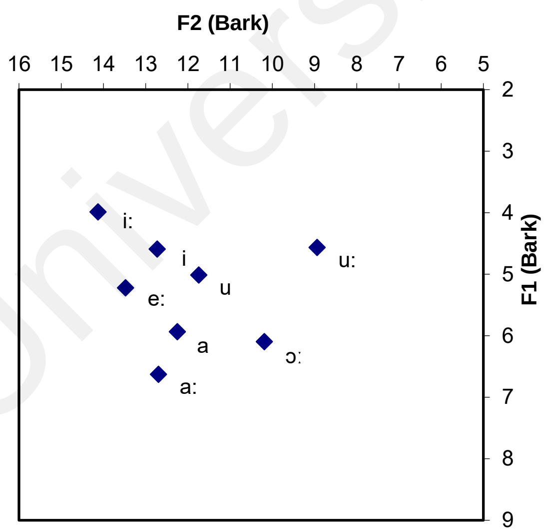


Figure 4.2: Vowel scatter plot for Hadrami Arabic monophthongs in Bark

As indicated in figure 4.2 The vowel plot indicates a clear centralizing tendency for short HA vowels over their long counterparts. /i/ is more centred than /i:/, /u/ is more centred than /u:/, and /a/ is more centred than /a:/. However, this centralization varies in the vowel space among the long and short vowel pairs, as /u/ appears to have the most obvious variation compared to the /u:/ vowel. In terms of height, /i:/ has the highest tongue position, as it has the lowest F1 value of 3.97 Bark. /u:/ vowel as well has a minimum F1 value of 4.55 Bark. Therefore, both maintain a close tongue position. For their short counterparts, both /i/, and /u/ are pronounced with a lower position than their long counterparts but they still have a close position with mean F1 values of 4.57 Bark and 5.01 Bark respectively. For the long /e:/, it is pronounced with a mid-high front position with a mean F1 of 5.20 Bark and a mean F2 of 13.43 Bark. Conversely, the long /ɔ:/ is pronounced with a low back position with a mean F1 of 6.16 Bark and a mean F2 of 10.16 Bark. Short /a/ vowel is pronounced with a low position, but its long counterpart /a:/ has the lowest position among all Hadrami Arabic vowels, as it has the highest mean F1 value of 6.63 Bark.

In terms of frontness and backness, /i:/ is not only the highest Hadrami Arabic vowel, but it is the most fronted one with the highest F2 value of 14.09 Bark. The second front vowel is /e:/ with an average F2 value of 13.43 Bark. The short /i/ is pronounced with a front position but less fronted than its long counterpart /i:/. The long /a:/ is more fronted than the short /a/. /u/ has a central position with an F2 value of 11.74 Bark. The long Hadrami Arabic vowel /ɔ:/ has a back position. The long /u:/ is pronounced with the most retracted tongue position among all Hadrami Arabic vowels, as it has the lowest F2 value of 8.84 Bark.

The scatter plot also indicates a significant qualitative difference among all short and long vowel pairs. The long /i:/ is higher and more fronted than the short counterpart /i/. The long /u:/ is higher and more retracted than the short counterpart /u/. The long /a:/ is lower and more fronted than the short counterpart /a/. This difference is illustrated in table 4.4.

Table 4.4: Formant mean values of HA long vs short vowels and their difference in Bark

	/i:/	/i/	/u:/	/u/	/a:/	/a/
F1	3.97	4.57	4.55	5.01	6.63	5.94
Difference	0.6		0.46		0.69	
F2	14.09	12.68	8.84	11.74	12.7	12.25
Difference	1.41		2.9		0.45	

The following section provides a more detailed description of each HA monophthong vowel as pronounced by male and female speakers. Male and female speakers' scatter plots are provided. A more detailed analysis of each HA vowel realization is discussed below:

4.1.1. HA /i /

This is a short high front vowel. The words with the target tokens are /ʃu.f**i**t/ (saw), /b**i**t.tak/ (your daughter), /ħð**i**f/(throw), and /t**i**k.kah/ (doorstep). Conversed to the long /i:/ vowel, the short /i/ is lower and more retracted than its long counterpart. There is a variation among male and female HA speakers in both F1 and F2 values, see figure 4.3. In terms of height, male speakers tend to pronounce /i/ vowels in a higher position than female speakers with a mean F1 value of 3.93 Bark over 5.01 Bark for female speakers. For female speakers, there is some variation in pronouncing HA /i / as speaker 4 and 5 pronounce the lowest /i/ vowel with a mean F1 value of 6.1 and 5.5 and speaker 6 tend to pronounce the highest one with a mean F1 value of 4.25. For frontness, the difference between female and male speakers is quite low as female speakers tend to pronounce HA /i/ in a more fronted position with an F2 overall mean value of 12.89 Bark for female speakers while for male speakers it is 12.46 Bark. However, the t-test shows no significant difference in retraction between the two genders, (t (8) = 1.65, p = 0.14) unlike the height dimension in which the difference was statistically significant (t (8) = 1.65, p = 0.14). Further, SD values indicate that the variation between speakers in the height dimension is quite high for female speakers, as illustrated in table 4.1 and 4.2 above.

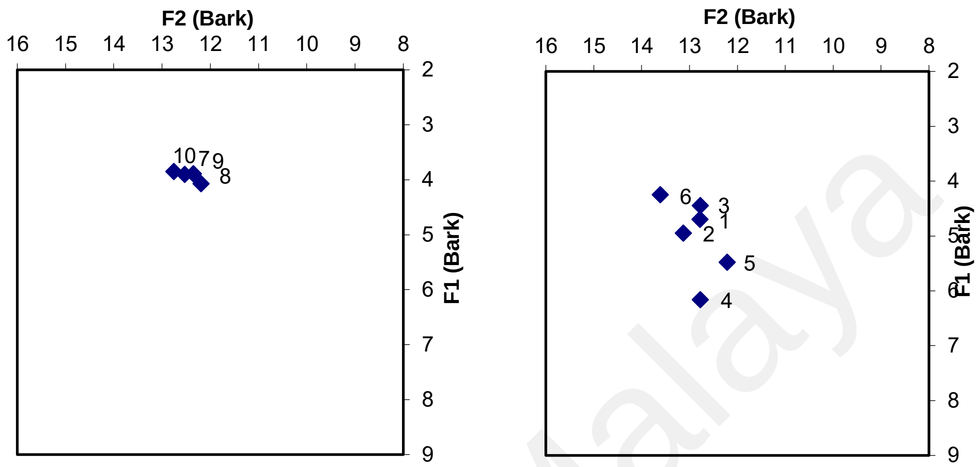


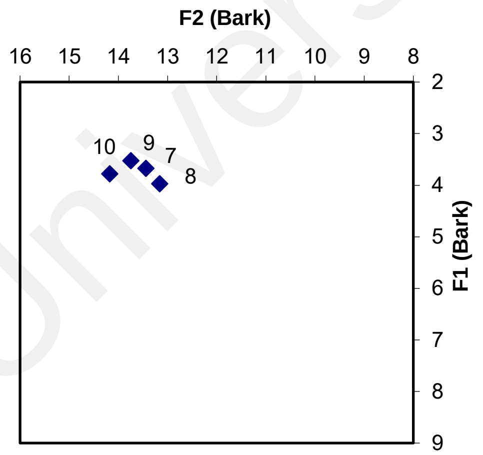
Figure 4.3: Scatter plot of HA /i/ by male speakers (left) and female speakers (right)

4.1.2. HA /i:/

HA long /i:/ is the closest and most fronted Hadrami Arabic monophthong vowel. The words with the target tokens are /ħa.ʃ**i:**ʃ/ (grass), /χa.f**i:**f/ (light weight), /ʕa.s**i:**s/ (hard to find), and /s**i:**f/ (beach). By examining the formant values of each speaker, the HA vowel /i:/ maintains a high front position. However, there is a considerable variation among male and female speakers in terms of closeness and frontness. Overall, male speakers tend to pronounce /i:/ in a higher position with a mean F1 value of 3.74 Bark. As all male speakers pronounce the F1 value in a similar high range with values of (3.6, 3.9, 3.5, 3.7) Bark, see figure 4.4. Most female speakers pronounce /i:/ in similar high positions, however, speaker four and five pronounce /i:/ in a less close position with a higher F1 value of 5.0 Bark and 5.4 Bark.

In terms of frontness, female speakers pronounce /i:/ vowel in a slightly more fronted position than male speakers with mean F2 values of 14.43 Bark for female speakers and 13.67 Bark for male ones. Female speaker three tends to pronounce it in the most fronted position among all speakers with a mean F2 bark value of 14.8 Bark. While male speaker eight pronounces /i:/ vowel in the least front position with an F2 value of 13.1 Bark. Vowel plots below illustrate male and female speakers' /i:/ vowel positions.

The described statistics show that the difference between male and female speakers is not statistically significant for F1 ($t(8) = 0.988$, $p = 0.352$) but significant for F2 ($t(8) = 3.359$, $p = 0.010$), and the standard deviation for female speakers is considerably higher than that of male ones which indicates that vowel quality is more variable among female speakers, as illustrated in table 4.1 and 4.2.



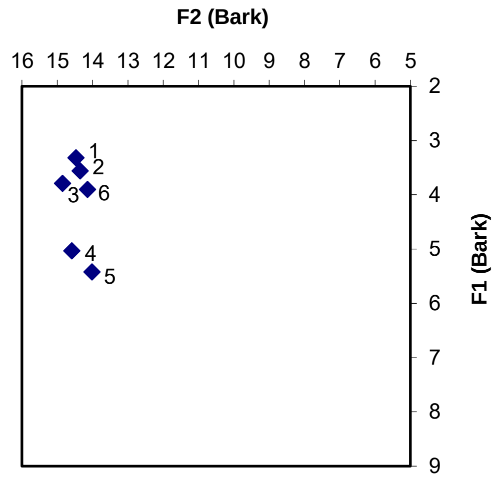


Figure 4.4: Scatter plot of HA /i:/ by male speakers (left) and female speakers (right)

4.1.3. HA /u/

This is a short high central vowel. The total number of tokens analyzed is 30. The words with the target tokens are /wa.duh/ (take it to), /fruʃ/ (lay it down), and /suf.rah/ (dinning sheet). There is a tendency for HA /u/ to be centralized in the vowel space over other HA monophthongs. A variation is clear among male and female speakers in F1 and F2 values. In terms of height, male speakers tend to pronounce the highest HA /u/ among female speakers. Male speaker seven tends to pronounce it in the highest position among all speakers with a mean F1 value of 4.0 Bark. While male speaker ten tends to pronounce the least close one among male speakers with a mean F1 value of 4.5 Bark. For female speaker four, HA /u/ maintains the least close position among all speakers with the highest F1 value of 6.6 Bark. While female speaker one, three and six maintain the highest position among other female speakers with mean F1 values of 5.04, 5.13, and 4.98 Bark.

For frontness, female speakers tend to pronounce HA /u/ in a more fronted position than male speakers with a higher mean F2 value of 12.19 Bark and a lower mean F2 of 10.88 Bark for male speakers. Female speaker two tends to pronounce it in the most fronted position among all speakers with a high F2 value of 13.1 Bark. The most retracted position among female speakers is pronounced by speaker one with a mean F2 value of 11.39 Bark. While male speaker nine tends to pronounce it in the most retracted position among all vowels with the lowest F2 value of 9.8 Bark.

Overall, the statistics show that the difference between male and female speakers /u/ vowel production is statistically significant in terms of height and retraction dimension as male speakers produce higher and more retracted HA /u/ vowels, (F1: $t(8) = 3.694$, $p = 0.006$), F2: $t(8) = 3.071$, $p = 0.015$).

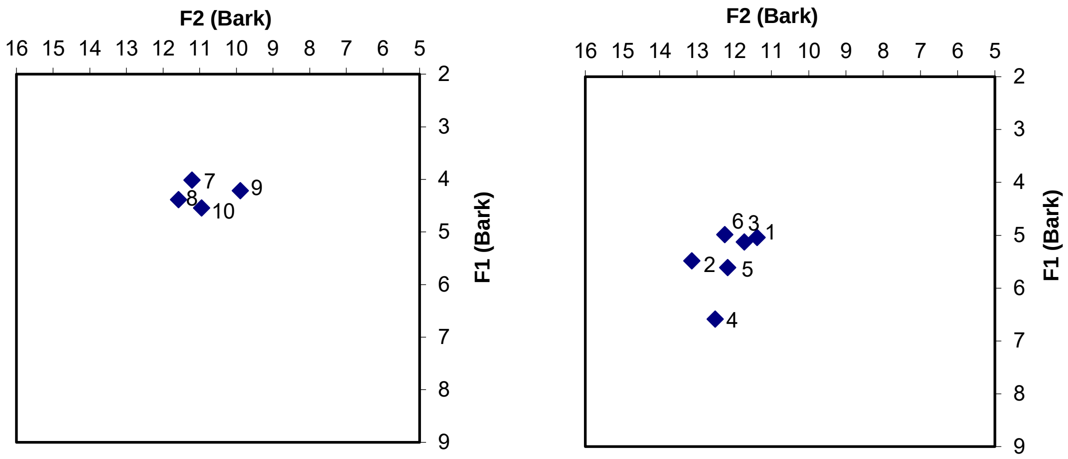


Figure 4.5: Scatter plot of HA /u/ by male speakers (left) and female speakers (right)

4.1.4. HA /u:/

This is a high back long vowel. The total number of tokens is 40. The tokens are /maf.ħ**<u>u:</u>**s/ (bread), /sˤa.b**<u>u:</u>**ħ/ (breakfast), /ilʕa.r**<u>u:</u>**s/(bride), and /bd.f**<u>u:</u>**f/(with tambourines). It is pronounced with a close tongue position; it is higher than its short counterpart but lower than the long HA /i:/. It has the maximum retracted position among all Hadrami Arabic vowels with the lowest F2 value. There is some variation among male and female speakers in pronouncing HA /u:/.

For height, most male speakers tend to pronounce HA /u:/ in a slightly higher position than female speakers a mean F1 value of 4.34 for male speakers and 4.71 for female speakers. Male speaker eight tends to pronounce it in the highest and most retracted position with F1 and F2 values of 3.77 and 7.37 Bark.

For frontness, female speakers pronounce slightly more fronted /u:/ than male speakers with a higher mean F2 value of 9.10 than male ones' F2 value of 8.44. Female speaker five pronounces it in a less close and retracted position among all speakers with F1 and F2 values of 5.7 and 11.1 which overlaps with its short counterpart /u/. There is a slight tendency for /u:/ by female speakers to be more scattered in the vowel space than the ones pronounced by male speakers.

However, t-test statistics show that this deference is not statistically significant neither height dimension nor for retraction, (F1: t (8) = 0.951, p = 0.369), (F2: t (8) = 0.922, p = 0.384).

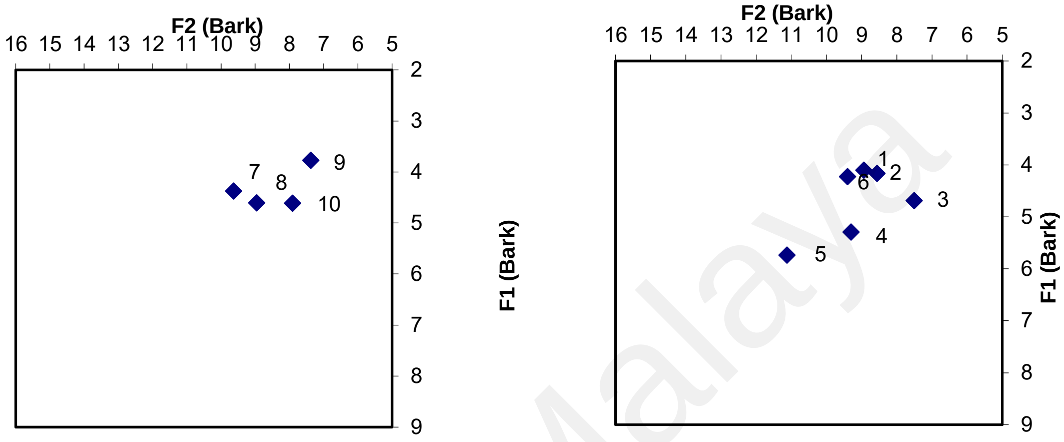


Figure 4.6: Scatter plot of HA /u:/ by male speakers (left) and female speakers (right)

4.1.5. HA /a/

This is a mid-low front short vowel. The total number of tokens is 40. The tokens are /h**a**t/ (bring), /bg**a**ʃ/(money), /mas.ra.f**a**h/ (dinning sheet), and /b**a**s/(but).

There is some variation among male and female speakers in terms of height and frontness. For height, male speakers pronounce higher /a/ vowels than female ones with a mean F1 value of 4.99 Bark and a lower mean F1 value of 6.54 Bark for female speakers. The highest position was pronounced by male speaker eight and nine with mean F1 values of 4.8 and 4.76 Bark but they are all within mid-low position in the vowel space. Female speakers vary the most in terms of height. Female speaker four pronounces the lowest HA /a/ with and the highest F1 mean value of 7.11 Bark among female speakers while female speaker one and six produce the highest one with mean F1 values of 5.98 Bark and 5.89 Bark. For frontness, female speakers produce slightly more fronted /a/ vowels with a mean F2 value of 12.51 Bark than male speakers that have a mean F2 value of 11.83 Bark. Male speaker eight pronounces the most retracted one with a mean F2 value of 11.44 Bark, whereas female speaker two pronounces the most fronted with a mean F2 value of 12.82 Bark.

The statistics show that the difference between male and female speakers /a/ vowel production is statistically significant in terms of height and retraction dimension as male speakers produce higher and more retracted HA /a/ vowels, (F1 (t (8) = 5.84, p < .001), (F2 (t (8) = 3.66, p = 0.006).

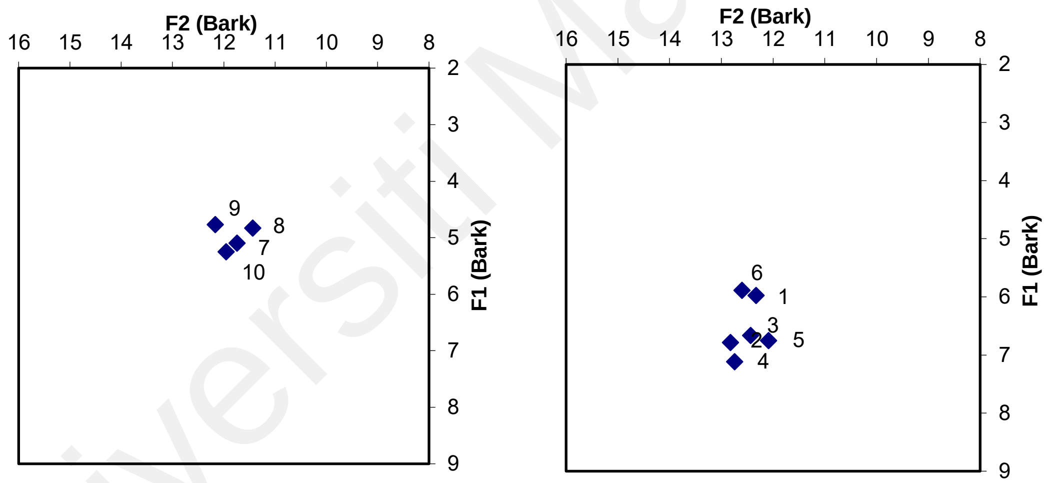


Figure 4.7: Scatter plot of HA /a/ by male speakers (left) and female speakers (right)

4.1.6. HA /a:/

This is a low front long vowel. The total number of tokens per speaker is 40. The tokens are /ʕs**a:**h/ (I hope), /ʃ**a:**h/(goat), /ð**a:**k/(that), and /ft**a:**h/(answer). HA /a:/ has the lowest position in Hadrami Arabic vowel inventory.

There is some variation among male and female speakers. For height, male speakers produce the least low /a:/ vowel with a mean F1 value of 5.69 Bark, while female speakers produce the lowest one with a mean high F1 value of 7.17 Bark. Female speaker four tends to pronounce HA /a:/ in the lowest position among all speakers with a mean F1 value of 8.32 Bark. While most male speakers tend to pronounce it in a similar position closer than the female speakers with mean F1 values of 5.96, 5.51, 5.57, 5.75 Bark. For frontness, female speakers tend to pronounce HA /a:/ in a slightly more fronted position than male speakers with a mean F2 value of 13.06 Bark for female speakers and a mean F2 value of 12.05 Bark for male speakers. Male speaker eight pronounces the most retracted /a:/ vowel among all speakers with a mean F2 value of 11.79 Bark while the most fronted position was pronounced by female speaker two with a mean F2 value of 13.55 Bark, see figure 4.7. Findings also show that HA /a:/ pronounced by male speakers are more clustered in the vowel space than the ones pronounced by female speakers.

The statistics of t-test show that the difference between male and female speakers /a:/ vowel production is statistically significant in terms of height and retraction dimension as male speakers produce higher and more retracted HA /a:/ vowels, (F1: $t(8) = 3.601$, $p = 0.007$), (F2: $t(8) = 5.297$, $p = 0.001$).

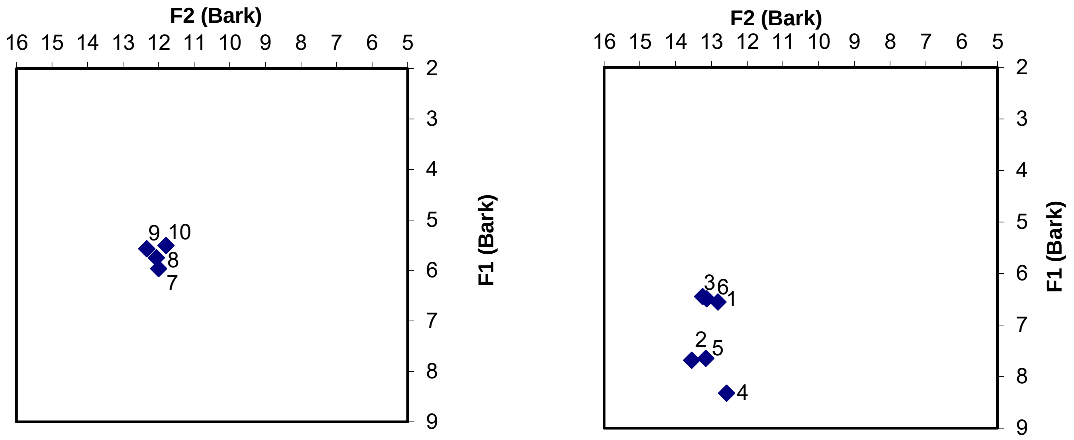


Figure 4.8: Scatter plot of HA /a:/ by male speakers (left) and female speakers (right)

4.1.7. HA /e:/

This is a mid-high front long vowel. The total number of tokens is 30. The words with the target tokens are /z**e:**t/ (oil), /b**e:**t/(home), and /hu.b**e:**ʃ/(name). /e:/ vowel is a distinguished vowel to Hadrami Arabic vowel inventory. There is a slight variation among male and female speakers in terms of height. Male speakers tend to pronounce HA /e:/ in a higher position than female ones with a mean F1 value of 4.68 Bark. Whereas female speakers tend to pronounce HA /e:/ in a lower position with mean F1 value of 5.56 Bark. Female speaker four pronounces HA /e:/ in the lowest position than all speakers with an F1 value of 6.0 Bark.

For frontness, female speakers produce more fronted /e:/ vowels than male speakers with a higher mean F2 value of 13.82 Bark. Female speakers three and six pronounce the most fronted ones with mean F2 values of 13.9 and 13.88 Bark, see figure 4.9.

The statistics of t-test show that the difference between male and female speakers /e:/ vowel production is statistically significant in terms of height and retraction dimension as male speakers produce higher and more retracted HA /e:/ vowels, (F1: $t(8) = 5.514$, $p = 0.001$), (F2: $t(8) = 3.579$, $p = 0.006$).

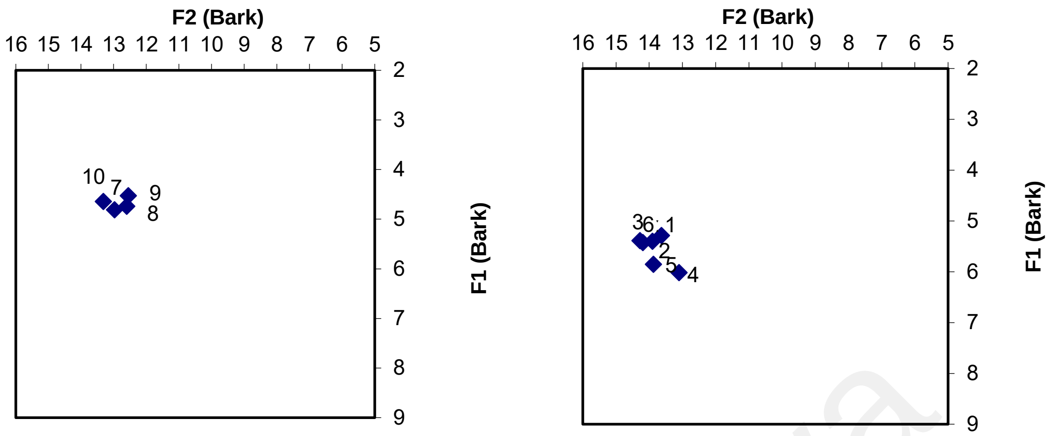


Figure 4.9: Scatter plot of HA /e:/ by male speakers (left) and female speakers (right)

4.1.8. HA /ɔ:/

This is a low back long vowel. The tokens analyzed for this vowel are /ħ**ɔ:**f/, /n**ɔ:**f/, /ħ**ɔ:**ʃ/, and /k**ɔ:**t/. The total number of tokens is 40. This vowel is distinguished to Hadrami Arabic vowel inventory. It is within a similar low position of the short vowel /a/ and a less retracted position than the long vowel /u:/.

The variation between male and female speakers is more significant in vowel height than front-back dimension. As female speakers tend to pronounce HA /ɔ:/ in a lower position than male speakers with a mean F1 value of 6.59 Bark and 5.23 Bark for male speakers but within similar retracted positions. Male speaker nine pronounces the least low HA /ɔ:/ vowel with a mean F1 value of 4.8 Bark. While the lowest one is pronounced by female speaker four with a mean F1 value of 4.7 Bark, see figure 4.10. The statistics of the t-test show that this difference between male and female speakers is statistically significant for F1, (t (8) = 3.732, p = 0.006), but not for F2 mean values, (t (8) = 0.004, p = 0.699).

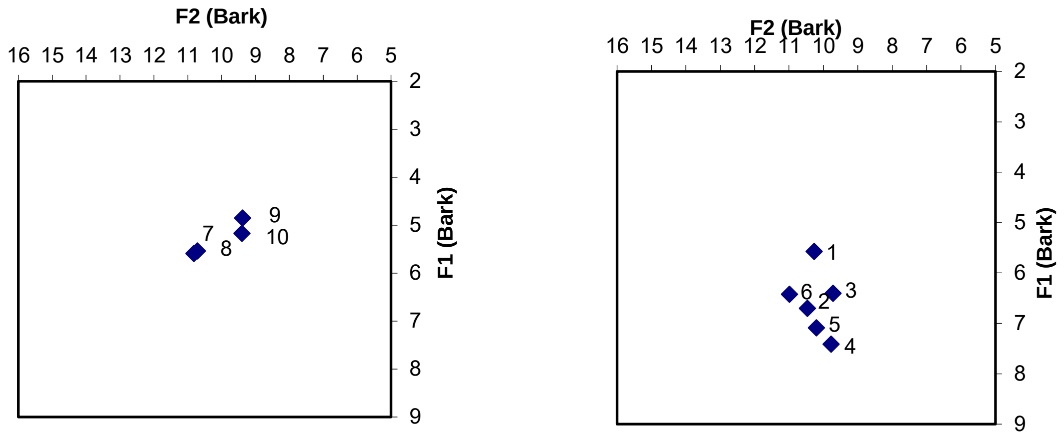


Figure 4.10: Scatter plot of HA /ɔ:/by male speakers (left) and female speakers (right)

To sum up, the discussed findings of vowel quality of Hadrami Arabic classify the HA vowels' quality according to their position in the vowel space. The HA /i/ and /i:/ are high front vowels. The HA /u/ is a high central vowel while the HA /u:/ is a high back vowel. The HA /a/ is a mid-low front vowel while the HA /a:/ is a low front vowel. The HA /e:/ is a mid-high front vowel whereas the HA /ɔ:/ is a low back vowel. Findings also indicate a considerable variation between male and female speakers' production of HA vowels. Male speakers tend to produce higher vowels while female speakers produce more fronted HA vowels than male speakers. All HA vowels' production indicated a significant difference between male and female speakers' vowel production except for long /u:/ vowel the difference was not significant neither for height dimension nor for front back dimension . For /i/ and /o:/ the difference was only significant for height dimension, and for the long /i:/ the difference was only significant for front back dimension. It is found that female speakers have overall higher formants' frequencies than male speakers. It is also found that vowels pronounced by female speakers tend to be more scattered in the vowel space than male ones. Sometimes there found some overlap between HA vowels pronounced by different speakers. For example, /i:/ production of female speaker four and five overlaps with first and second female speaker's /e:/ production and female speaker five's /u:/ production overlaps with its short counterpart production by female speakers. This overlap might be attributed to some interspeaker differences.

4.1.9. Findings of HA vowels' Quality in Comparison to other Arabic Vowels' Quality in the literature:

There are few studies in the literature conducted to investigate Arabic vocalic systems' quality through studying their formant frequencies as reviewed in section 2.8 in chapter two. Since HA is a variety of colloquial Arabic, this research adds to the existing literature of Arabic vocalic systems. Hence, a comparison between HA vowels' quality findings and other Arabic vowels' quality is worth conducting. Further, this comparison between this research findings and other Arabic varieties' findings is significant to allocate HA vowels' position in the vowel space and its categorization in comparison to other Arabic varieties; to know to what extent HA vowels are higher or lower in vowel space in relation to the general ranges of other Arabic vowels' findings. This section illustrates a comparison between HA vowel's quality and other Arabic vowels' quality through comparing their first and second formants findings. Seven Arabic varieties are being compared to HA based on their vowel formants findings. The Arabic verities compared are Libyan by (Ahmed, 2009), Saudi, Egyptian and Sudanese by (Algamid, 1998), Palestinian by (Saddah, 2011), Iraqi by (Fathi and Qassim 2020) and Jordanian by Kalaldeh (2018). The motive for selecting these studies in particular is their adequate number of participants and their use of a similar acoustic analytical framework to this study. For comparison purposes the researcher converted the mean first and second formants values of Arabic vowels of previous studies reported by Ahmed (2009), Algamid, (1998), Saddah(2011), Fathi and Qassim(2020) and Kalaldeh (2018) from Hertz to Bark scale using the same formula used for HA vowels in this study by Zwicker and Terhardt (1980). Table 4.5 illustrates the average values of F1 and F2 vowel frequencies of Arabic vowels of different Arabic varieties in Bark. The highest and lowest F1 and F2 values of Arabic vowels are written in bold in the table.

Table 4.5: Comparative values of F1 and F2 formant frequencies of different Arabic vowels in the literature in Bark:

vowels	/i/		/i:/		/a/		/a:/		/u/		/u:/		/e:/		/ɔ:/	
dialect	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
Hadrmi Arabic (Current study)	**4.57**	12.68	**3.97**	14.09	5.94	12.25	**6.63**	**12.7**	**5.01**	**11.74**	**4.55**	8.84	**5.20**	**13.43**	6.16	**10.16**
Libyan (Ahmed 2009)	3.88	12.62	3.31	13.75	5.21	11.38	5.49	11.80	4.23	**8.68**	3.99	7.90	**4.23**	**12.94**	**4.70**	**8.74**
Saudi (Algami1998)	3.87	12.56	2.84	13.96	5.36	11.36	6.03	11.58	4.31	10.25	3.39	8.24	n/a	n/a	n/a	n/a
Egyptian (Algamdi 1998)	3.45	**12.23**	**2.50**	13.64	**4.46**	11.22	**4.40**	11.95	3.57	10.16	3.10	8.13	n/a	n/a	n/a	n/a
Sudanese (Algamdi 1998)	**3.21**	**13.31**	2.66	13.87	4.95	11.48	5.87	11.16	**3.42**	10.28	3.10	8.41	n/a	n/a	n/a	n/a
Palestinian	4.41	12.78	2.82	**14.45**	**6.03**	**11.13**	6.55	11.15	4.41	9.09	**3.08**	**7.05**	n/a	n/a	n/a	n/a

Saddah (2011)																
Iraqi (Fathi and Qassim 2020)	3.73	12.91	3.42	**13.62**	5.40	**12.29**	6.59	**10.91**	4.32	10.43	3.93	**9.89**	4.69	13.25	**5.44**	9.22
Jordanian Kalaldeh (2018)	3.85	12.58	3.04	13.64	5.01	11.23	5.86	11.16	3.87	9.97	3.65	8.45	n/a	n/a	n/a	n/a

4.1.9.1. HA /i/ vs Arabic /i/

Comparing the formant frequencies of the main Arabic vocalic qualities, the Sudanese high front /i/ by (Algamdi, 1998) seems to have the highest and most fronted /i/ vowel among all Arabic /i/ vowels with the lowest mean F1 value of 3.12 Bark and the highest F2 value of 13.13 Bark. While the HA /i/ vowel maintains the least high position among all /i/ Arabic vowels with the highest main F1 value of 4.57 Bark. The most retracted Arabic /i/ vowel is pronounced by Egyptian speakers by (Algamdi, 1998) with the highest mean F2 value of 12.23 Bark.

4.1.9.2. HA /i:/ vs Arabic /i:/

Egyptian speakers by (Algamdi, 1998) produced the highest Arabic long /i:/ vowel with the lowest mean F1 value of 2.50 Bark, while HA speakers produced the least high one with the highest mean F1 value of 3.97 Bark. The most fronted Arabic long /i:/ vowel was the Palestinian by (Saddah, 2011) with the highest F2 mean value of 14.45 Bark while the most retracted one was the Iraqi by (Fathi and Qassim, 2020) but both maintain a front vowel quality.

4.1.9.3. HA /u/ vs Arabic /u/

For the Arabic /u/, The Libyan /u/ is the most retracted with the lowest mean F2 value of 8.68 Bark and the Sudanese /u/ was the highest one with the highest mean F1 value of 3.42 Bark among all Arabic /u/ vowels. HA /u/ vowel is the lowest and most fronted vowel among all Arabic /u/ vowels with mean F1 and F2 values of 5.01 and 11.74 Bark. That is why it is considered a high central vowel rather than a high back vowel for HA vocalic system. This centring of HA /u/ in the vowel space rather than being back vowel like all other Arabic vowels arose a supposition that this vowel might be a new vowel realization rather than being a counterpart of the long /u:/.

4.1.9.4. HA /u:/ vs Arabic /u:/

The Palestinian long /u:/ vowel is the highest and most retracted vowel among all Arabic vocalic qualities with the lowest mean F1 and F2 bark values of 3.08 and 7.05. While the HA long /u:/ maintains the least close position with the highest mean F1 bark value of 4.55 and the Iraqi long /u:/ vowel maintains the least retracted one among all Arabic long /u:/ vowels with a mean F2 bark value of 9.89.

4.1.9.5. HA /a/ vs Arabic /a/

For the Arabic /a/, Palestinian speakers pronounce the lowest and most retracted /a/ vowel among all Arabic /a/ vowels with the highest mean F1 and the lowest mean F2 values of 6.03 and 11.13 Bark. While the Egyptian /a/ maintains the highest position among all Arabic /a/ vowels with an F1 value of 4.46 Bark and the Iraqi /a/ vowel maintain the most fronted with the highest F2 value of 12.29 Bark among all Arabic /a/ vowels.

4.1.9.6. HA /a:/ vs Arabic /a:/

The HA long /a:/ vowel is the lowest and most fronted among all Arabic long /a:/ vowels with mean F1 and F2 values of 6.63 and 12.7 Bark. It is further the lowest vowel among all Arabic vocalic qualities. While the Egyptian long /a:/ vowel is the highest with the mean F1 value of 4.40 Bark, the Iraqi one is the most retracted one with a mean F2 value of 10.91 Bark.

4.1.9.7. HA /e:/ and /ɔ:/ vs Arabic /e:/ and /ɔ:/

Hadrami Arabic /e:/ and /ɔ:/ are compared to the Libyan and Iraqi ones. It turns out that HA /e:/ is lower and more fronted than the Libyan and Iraqi ones with mean F1 and F2 values of 5.20 and 13.43 Bark. While the Libyan /e:/ is the highest and least fronted one with mean F1 and F2 values of 4.23 and 12.94 Bark. The Libyan /ɔ:/ vowel is also the height and most retracted one with mean F1 and F2 values of 4.70 and 8.74 Bark. While the Iraqi /ɔ:/ vowel is the lowest with the higher F1 value of 5.44 Bark and the HA /ɔ:/ is the least retracted one with the highest F2 value of 10.16 Bark.

Lastly, because these studies have been conducted in different settings with different speakers using different phonetic contexts, inter and Intera speaker variation might interfere with the accuracy of this comparison. However, from the point of view of the researcher the use of Bark scale conversion and the similar analytical method used within the Arabic context overweighs this possible variation. A final conclusion can be summed up that distinguishes HA vocalic system is that all HA vowels have a slight tendency to be lower and more fronted than all other Arabic vowels.

4.2. Vowel Duration of Hadrami Arabic Monophthongs

The second acoustic parameter to consider for vowel identification is vowel duration. Acoustic studies have stated that vowel duration is essential for vowel identification (Ferguson and Kewley-port, 2007; Mok, 2011), especially for a language such as Arabic language with phonemic length contrast. To discuss the duration analysis of Hadrami Arabic vowels, the overall duration measurements are presented in table 4.6 below in milliseconds:

Table 4.6: Average Hadrami Arabic vowel duration in milliseconds

HA vowel	/i/	/i:/	/u/	/u:/	/a/	/a:/	/e:/	/ɔ:/
Mean	52	125	64	138	69	149	155	173
Max	85	485	99	243	109	245	274	342
Min	24	61	37	54	34	84	91	79
Ratio	0.42		0.47		0.47			
Difference	73		74		80			
SD	15	74	17	42	19	42	53	51

As examined in table 4.6 Hadrami Arabic vowels can be divided into two groups as far as duration is concerned, three short vowels and five long ones. The three short vowels are /i/, /u/, and /a/. and the five long vowels are /i:/, /u:/, /a:/, /e:/, and /ɔ:/. The table provides the mean duration for all short and long HA vowels. It also provides the ratio of vowels which is calculated from short vowels' duration to long ones. The standard deviation for short and long HA vowels is provided. The difference between short duration and their long counterparts is calculated in ms too through subtracting mean long vowel duration from short ones' mean duration.

The mean duration for the three short vowels is 61.6 ms and for the five long vowels it is 147.2 ms. Overall, HA long vowels are more than double the duration of their short HA pairs. The high short Hadrami Arabic vowel /i/ has the shortest duration among all short vowels, while its long counterpart /i:/ has the shortest duration among all long Hadrami Arabic vowels. The short low /a/ has the longest duration among all Hadrami Arabic short vowels. Whereas the long low /a:/ has a longer duration than the long high /i:/ and /u:/. As presented in table 4.6, Hadrami Arabic speakers tend to produce low vowels longer than high ones.

There is an obvious distinction in duration between short vowels and their long counterparts. Looking at maximum and minimum duration findings, it is found that there is a high variation in vowels' production within the same category when pronounced by different speakers. This high variation in vowel duration values among different speakers could be attributed to the stress the speakers intentionally put on some vowels during production. Longer vowels of the same vowels are more likely to be stressed than shorter ones in the same word when produced by different speakers. Because this stress is speaker determined and it is in a similar phonetic environment, it is considered an inter-speaker variation rather than a contextual linguistic one. The mean SD for short vowels of is 17 and for long vowels, it is 44. An interpretation of the low SD for short vowels and the high SD for long vowels is that short vowels' duration is less variable among speakers than long vowels. It is also presented in table 4.6 that when the duration of a short vowel is high, the duration of the long counterpart is relatively higher which preserves the distinction in duration between short and long vowels.

The length distinction between long and short vowels varies in the languages of the world. Some languages receive this distinction between vowel pairs as a length feature (Harms, 1968; Lisker, 1974), while some receive it as two identical phonemes (Hockett, 1955; Swadesh,1937). In this study of HA, HA short and long vowel pairs are received as two identical segments, this section provides a more in-depth analysis of HA long and short vowel pairs' distinction in relation to gender variation. Each pair of vowels' duration analysis of male and female speakers is elaborated. Table 4.7 shows the average values of duration of HA monophthongs in milliseconds for each gender.

Table 4.7: Average Hadrami Arabic vowel duration for male and female speakers in ms:

Females						Males				
vowels	Max	Min	Mean	SD	Ratio	Max	Min	Mean	SD	Ratio
/i/	67	39	55	15	0.40	51	39	47	13	0.40
/iː/	235	71	137	87		164	85	119	47	
/u/	88	52	67	17	0.46	70	50	61	17	0.45
/uː/	153	132	143	43		189	108	136	44	
/a/	86	56	70	20	0.45	78	58	69	16	0.50
/aː/	192	98	156	43		159	117	138	41	
/eː/	199	116	161	45		193	137	159	44	
/ɔː/	239	134	176	46		203	134	168	59	

4.2.1. Short /i/ vs Long /i:/ Vowel Duration

Findings indicate a clear length distinction between the short HA /i/ and the long HA /i:/ vowel pair. There is also a difference in length between male and female speakers' long and short vowels production. Findings indicate that female speakers have longer HA /i/ and HA /i:/ than male speakers. Though male and female speakers have differing length values for the short HA /i/ and the long HA /i:/, both sexes have a similar ratio of 0.40 for short HA /i/ vowel to long HA /i:/ vowel. SD for the short /i/ is lower than that for the long /i:/ for both genders. Hence, short /i/ vowels' duration is less varied among speakers than long /i/ vowels' duration. Findings show that the long HA /i:/ is more than double the duration of the short HA /i/. Hence, HA speakers maintain a distinction between short /i/ and long /i:/ vowel pair. Figure 4.11 illustrates the length distinction between short HA /i/ vowel and long HA /i:/ vowel for female and male speakers.

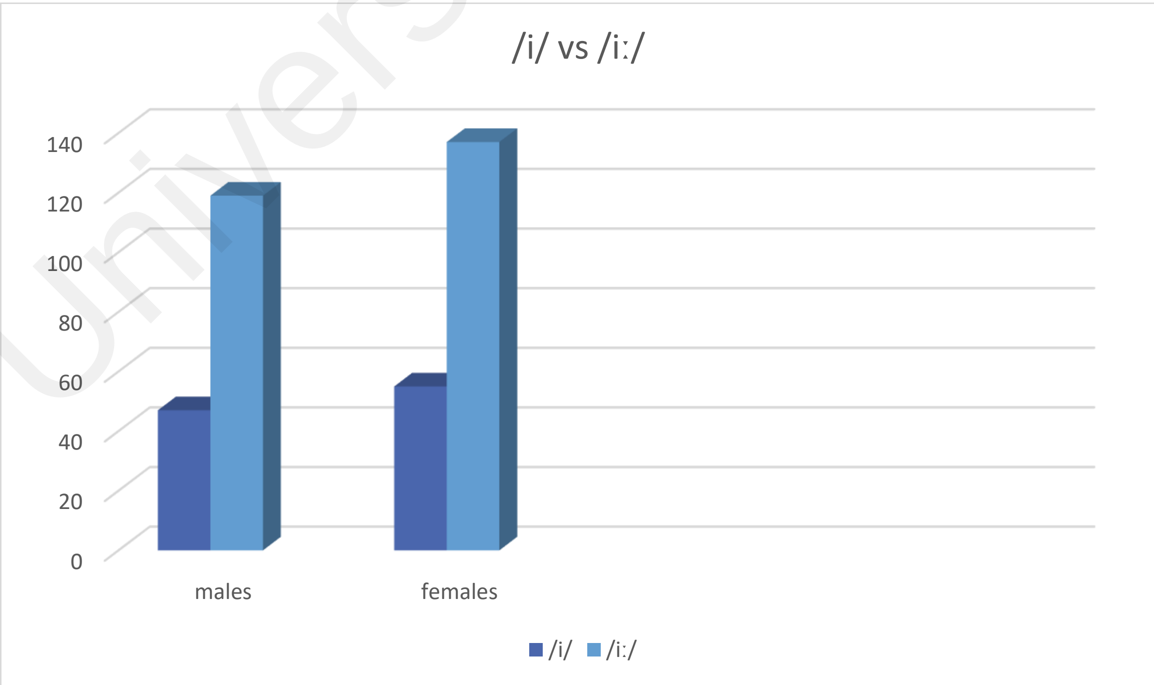


Figure 4.11: Short /i/ vs long /i:/ length distinction for male and female speakers in ms

4.2.2. Short /u/ vs Long /u:/ Vowel Duration

Findings indicate a clear length distinction between the short HA /u/ and the long HA /u:/. There is also a difference in length between male and female speakers' long and short vowels production. Findings indicate that female speakers have longer short HA /u/ and long HA /u:/ than male speakers. SD for short /u/ is lower than that for long /u:/. Hence, short /u/ vowels' duration production is less variable than long /u:/ for both genders. For female speakers, the ratio between short HA /u/ to long HA /u:/ is 0.46. While for male speakers, the ratio between short HA /u/ to long HA /u:/ is 0.45. Findings show that the long HA /u:/ is more than double the duration of the short HA /u/. HA speakers maintain a distinction between short /u/ and long /u:/ vowel pair. Figure 4.12 illustrates the length distinction between short HA /u/ vowel and long HA /u:/ vowel for female and male speakers.

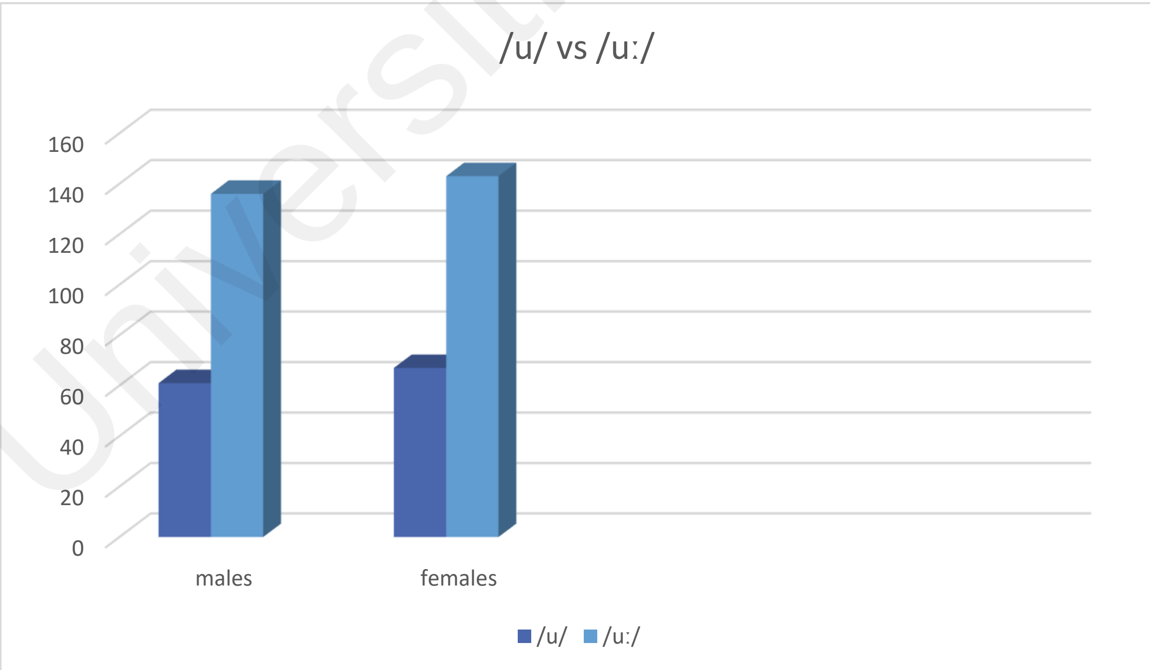


Figure 4.12: Short /u/ vs long /u:/ length distinction for male and female speakers in ms

4.2.3. Short /a/ vs Long /a:/ Vowel Duration

Findings indicate a clear length distinction between the short HA /a/ and the long HA /a:/. There is also a difference in length between male and female speakers' long and short vowel duration production. The distinction between male and female speakers' production in the long HA /a:/ is more obvious than the short HA /a/. Findings indicate that female speakers have longer HA /a:/ than male speakers. SD for short /a/ is lower than that for long /a:/. Hence, short /a/ vowels' duration production is less variable than long /a:/ for both male and female speakers. For female speakers, the ratio between short HA /a/ to long HA /a:/ is 0.45. While for male speakers, the ratio between the short HA /a/ to the long HA /a:/ is 0.50. Findings show that the long HA /a:/ is more than double the duration of the short HA /a/ in the case of female speakers. The long HA /a:/ is exactly double the duration of the short HA /a/ for male speakers. Hence, HA speakers maintain a distinction between short /a/ and long /a:/ vowel pair. Figure 4.13 illustrates the length distinction between short HA /a/ vowel and long HA /a:/ vowel for female and male speakers.

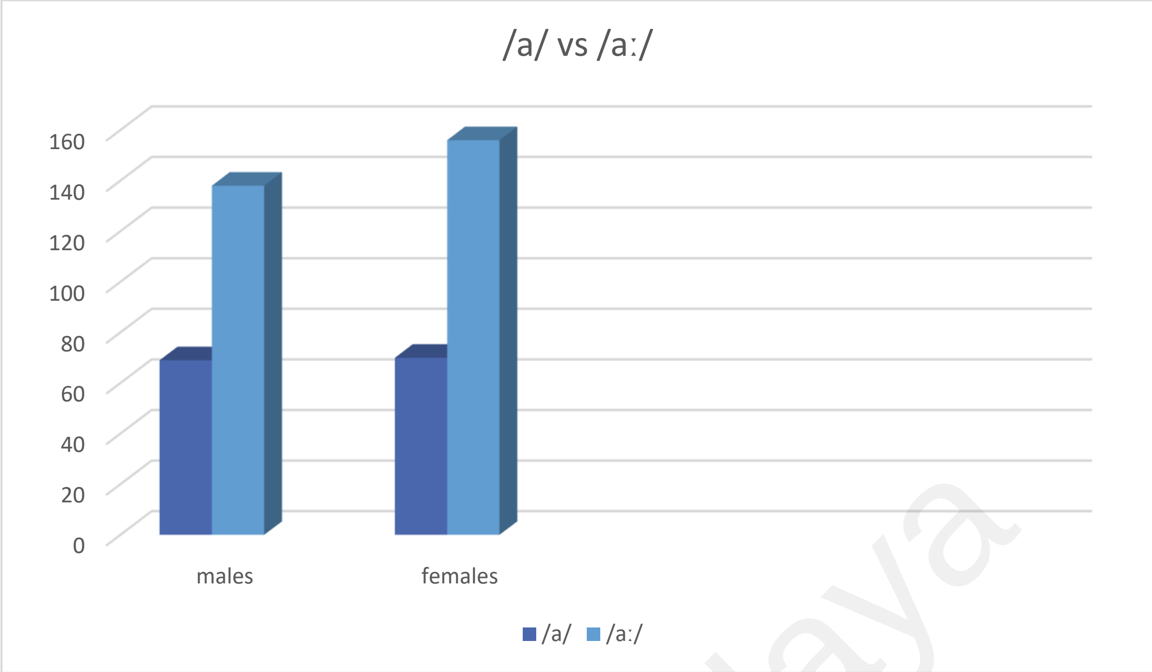


Figure 4.13: Short /a/ vs long /a:/ length distinction for male and female speakers in ms

4.2.4. /e:/ and /ɔ:/ Vowel Duration

The HA /e:/ is a long vowel distinguished to Hadrami Arabic. The gender variation in length distinction between female and male speakers is no that high. Figure 4.14 illustrates vowel length of the HA /e:/ for male and female speakers. The SD for male and female vowel /e:/ durations is not that high. Hence, the variation between male and female speakers' /e:/ vowel duration is quite similar. However, the gender variation in the case of the HA /ɔ:/ that is also distinguished to HA is very clear. SD for male speakers is higher than that for female speakers. Hence, vowel duration is more variable among male speakers. Figure 4.15 illustrates vowel length of the HA /ɔ:/ for male and female speakers.

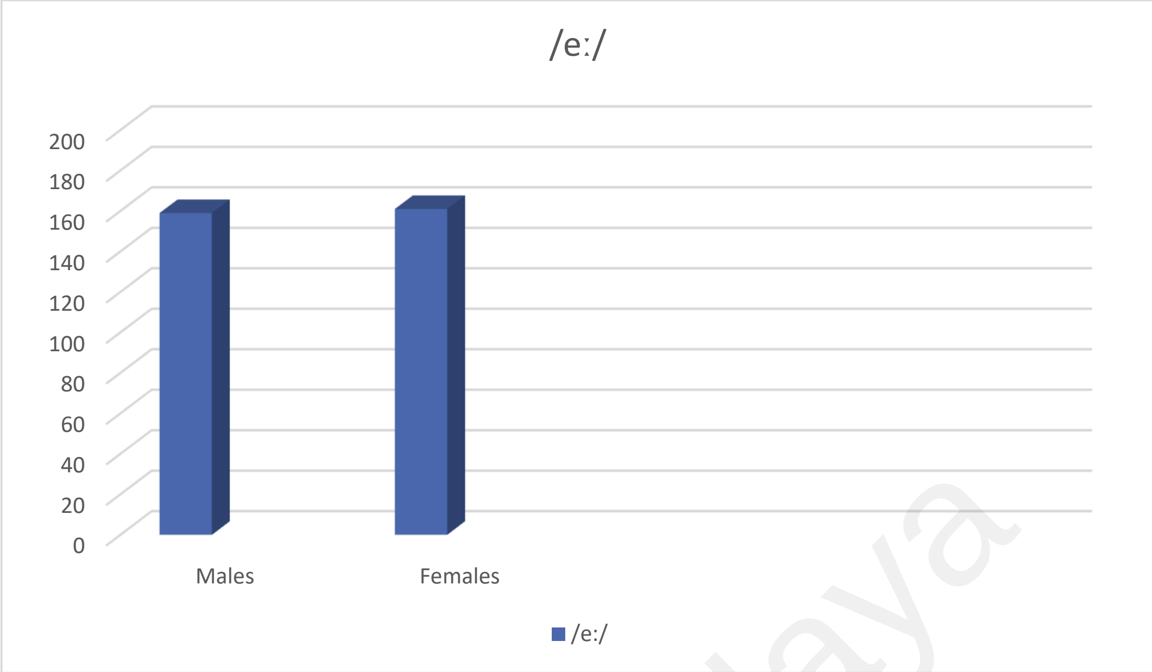


Figure 4.14: Vowel length of the HA /e:/ for male and female speakers in ms

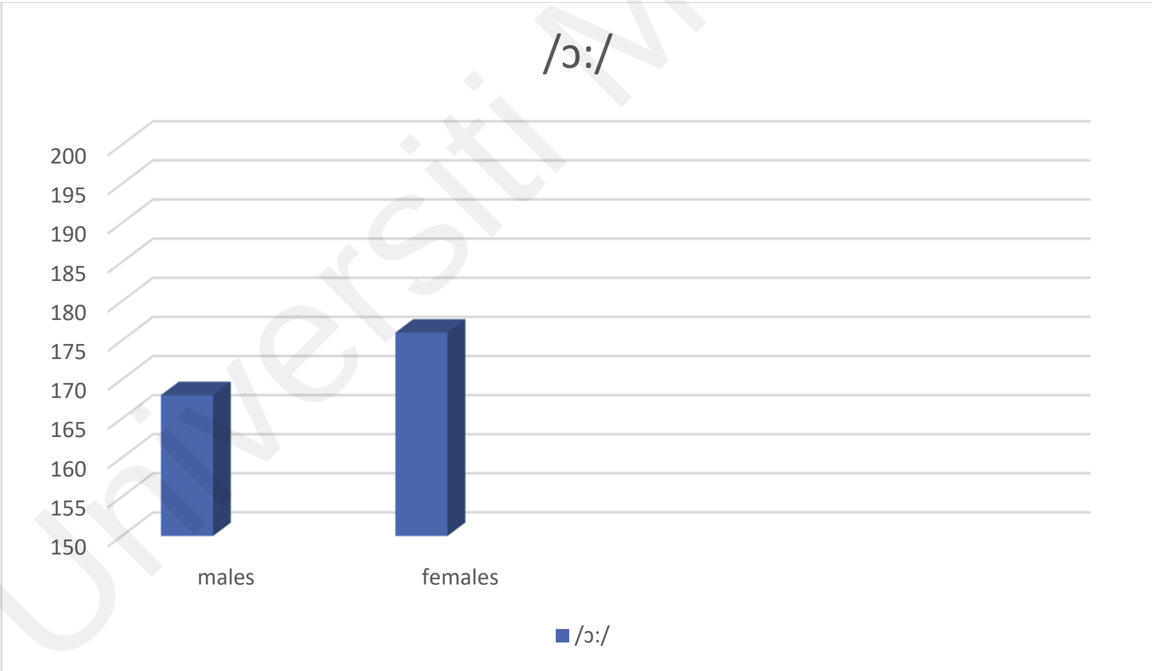


Figure 4.15: Vowel length of the HA /ɔ:/ for male and female speakers in ms

To sum up, findings indicate that HA speakers maintain a length distinction between all vowel pairs. Long HA vowels are more than double the duration of their short counterparts. Short vowels are less varied than long vowels for both male and female speakers as they have lower SD values. In terms of gender variation, female speakers tend to produce longer HA vowels. Except for the short /a/ and long /e:/, no difference is reported. Overall, low vowels are longer than high vowels for both genders.

4.2.5. Findings of HA Vowels' Duration in Comparison to other Arabic Vowels' Quantity in the Literature

There are few studies in the literature conducted to investigate Arabic vocalic systems' quantity through studying their vowel duration as reviewed in section 2.8 in chapter two. In this section, a comparison is conducted between HA vowels' duration and other Arabic verities' duration. The comparison is significant to see to what extent HA vowel length distinction is within a similar range to that of other Arabic vowels, since vowel duration is a main parameter for vowel identification in Arabic varieties. In this study, six colloquial Arabic varieties have been selected for vowel duration comparison due to their adequate number of participants and their similar use of acoustic method to this study. The Arabic vocalic systems compared are Libyan by (Ahmed, 2009), Saudi, Sudanese and Egyptian by (Algamdi,1998), Palestinian by Saddah (2011) and Iraqi by (Fathi and Qassim, 2020). Vowel duration is collected in ms and vowel pairs' ratios has been calculated too. Findings indicate that long vowels' length in most studies is almost two times longer than short vowels. Table 4.8 illustrates vowel length of Arabic vowels of different Arabic varieties in ms.

Table 4.8: Comparative vowel duration (ms) of different Arabic vowels in the literature:

vowels	/i/	/i:/	/u/	/u:/	/a/	/a:/	/e:/	/ɔ:/
Hadrami Arabic (current study)	52	125	64	138	69	149	**155**	**173**
Ratio HA	0.42		0.46		0.46			
Libyan (Ahmed 2009)	54	138	64	148	63	150	156	154
Saudi (Algamidi1998)	111	248	114	237	**133**	311	n/a	n/a
Ratio SA	0.45		0.48		0.43			
Egyptian (Algamidi 1998)	98	255	110	253	122	**316**	n/a	n/a
Ration EA	0.38		0.44		0.39			
Sudanese (Algamdi 1998)	**117**	**275**	**116**	**305**	128	295	n/a	n/a
Ratio SA	0.43		0.38		0.43			
Palestinian Arabic (Saddah 2011)	89	219	93	223	87	250	n/a	n/a
Ratio PA	0.41		0.42		0.35			

Iraqi vowels (Fathi and Qassim 2020)	**51**	**112**	76	139	76	144	**142**	**150**
Ratio IA	0.46		0.55		0.53			
Jordanian Arabic (Kalaldh 2018)	55	118	**48**	**136**	**59**	**125**	n/a	n/a
Ration JA	0.47		0.35		0.47			

4.2.5.1. Arabic Vowel /i/ and /i:/ Duration Comparison

Comparing the different findings of Arabic vowels duration, the Sudanese /i/ vowel has the longest duration among all Arabic /i/ vowels with a mean duration of 117 ms. The same dialect also reported the longest long Arabic /i:/ vowel with a mean duration of 275 ms. Whereas the Iraqi vowel system has the shortest duration for short Arabic /i/ vowel and long Arabic /i:/ vowel among all Arabic vowels of all dialects with mean durations of 51 ms and 112 ms for short /i/ and long /i:/ vowels respectively. The distinction between /i/ and /i:/ vowel pairs is quite high for Egyptian Arabic with a low ratio of 0.38. Jordanian Arabic, on the other hand, has the lowest /i/ and /i:/ vowel distinction with a high ratio of 0.47.

4.2.5.2. Arabic Vowel /u/ and /u:/ Duration Comparison

For the high short /u/ and /long /u:/ Arabic vowels, Jordanian speakers reported the shortest vowels with mean duration of 48 ms and 136 ms for short /u/ and long /u:/, they also have the highest distinction between /u/ and /u:/ vowel pair with low ratio of 0.35. Whereas the longest duration was reported by the Sudanese speakers with mean durations of 116 ms and 305 ms for short /u/ and /long /u:/ vowels respectively. Iraqi speakers maintained the least distinction between /u/ and /u:/ vowel pair with a high ratio of 0.55.

4.2.5.3. Arabic Vowel /a/ and /a:/ Duration Comparison

The shortest duration for the short /a/ and long /a:/ was reported by Kalaldeh (2018) for Jordanian speakers with mean duration of 59 ms and 125 ms. Whereas Saudi speakers reported the longest duration for the short /a/ Arabic vowel with a mean duration of 59 ms and Egyptian speakers reported the longest long /a:/ vowel among all Arabic speakers for all vowels with the longest mean duration of 316 ms. The distinction between /a/ and /a:/ vowel pairs is quite high for Palestinian speakers with a low ratio of 0.35. Conversely, Iraqi Arabic reported the least distinction between /a/ and /a:/ vowel pair with a high ratio of 0.53.

4.2.5.4. Arabic Vowel /e:/ and /ɔ:/Duration Comparison

For the dialectal Arabic /e:/ and /ɔ:/, HA /e:/ and /ɔ:/ reported longer vowel length compared to Libyan and Iraqi ones. Their mean duration is 155 ms and 173 ms for /e:/ and /ɔ:/ vowels.

To sum up, it is true that many variables could interfere with the accuracy of this comparison such as different phonetic context and gender variation, the similar analytical method used within the Arabic context overweighs this possible variation. Besides, the comparison gives an overall view of HA findings' position to other Arabic varieties ones.

It can be concluded that HA short and long vowel pairs are neither the longest nor the shortest among Arabic vowels. Further, HA speakers maintain a moderate range of distinction between long and short vowel pairs.

4.3. Conclusion

This chapter reports and discusses the findings of HA vowels' quality and quantity. It gives a clear acoustic explanation of the HA vowels formant frequencies and vowel pairs length distinction. Findings of formants frequencies set clear HA vowels positioning in the vowel space and their categorization in terms of height and frontness. It is found out that HA /i/ and /i:/ are high front vowels. HA /u/ is a high central vowel while HA /u:/ is a high back vowel. HA /a/ is a mid-low front vowel while the HA /a:/ is a low front vowel. HA /e:/ is a mid-high front vowel whereas the HA /ɔ:/ is a low back vowel. There is an obvious difference between male and female vowels' production. Male speakers tend to pronounce higher and more retracted HA vowels. Female speakers have higher formant frequencies than male speakers. The comparison between HA vowels' quality and other Arabic varieties indicates that HA vowel system has a slight tendency to be lower and more fronted than other Arabic vowel inventories. However, all HA vowels and other Arabic vowels are within similar categories of height and frontness. Except for the HA /u/ vowel, that is positioned as a high central vowel rather than a high back vowel as other Arabic vowels. This arose an assumption that HA /u/ vowel examined in this study could be another vowel realization rather than a counterpart of the long /u:/, hence further evident exploration is needed. For vowel duration, findings indicate that HA speakers maintain a distinction between long and short vowel pairs. HA long vowel duration is more than double the duration of the short one. However, female speakers tend to produce longer HA vowels than male speakers. It is also found that HA low vowels are longer than HA high vowels. SD values show that short vowels' duration indicates less variability among speakers than long vowels. The comparison between HA vowels' duration and other Arabic varieties' duration gives an overall view that HA vowels have medium vowel duration and medium Long and short vowel pairs distinction. The following chapter concludes the findings reported and discussed in this chapter.

Chapter 5

Conclusion

Since languages are an important identifier of nations' identities, there comes a must to preserve and document a language. This study comes as an attempt to give a comprehensive acoustic description of HA monophthongs as a major constituent of HA speech. Because vowel quality and quantity are the main identifying properties of vowel sounds, this study puts these two parameters under examination through an acoustic descriptive approach. The speech of ten native HA speakers (four males and six females) has been analyzed considering gender variation to give the most possible comprehensive description of the vocalic system of the dialect. This chapter summarizes the main findings of this research answering the main research questions illustrated in chapter 1.

The first section is concerned with vowels' quality description according to their first and second formants frequencies. The second section is concerned with the distinction of HA long and short vowel pairs in terms of vowel duration. Further elaboration is given regarding this study implications and further research directions.

5.1. Research question 1: What are the acoustic properties of Hadrami Arabic monophthongs based on their formant values of male and female speakers?

Findings of the formant values of HA vowels report that HA vocalic systems has eight monophthongs, (/i/, /i:/, /u/, /u:/, /a/, /a:/, /e:/, /ɔ:/). The short HA /i/ vowel and the long HA /i:/ are described as high front vowels in the vowel space pronounced with a higher and front tongue position. The long counterpart is the highest and most fronted HA vowel. HA /u/ vowel is described as a high central vowel pronounced with a high central tongue position. There is a qualitative difference between this /u/ vowel realization and its long HA /u:/ vowel which is described as a high back vowel. Findings show that HA /u:/ vowel is the most retracted HA vowel. The short HA /a/ vowel is a mid-low front vowel in the vowel space pronounced with a mid-low tongue position while the long HA /a:/ vowel is a low front vowel pronounced with a low front tongue position in the vocal tract. Findings show that the long HA /a:/ vowel is the lowest HA vowel. The long HA /e:/ vowel realization is as a mid-high front vowel pronounced with a mid-high front tongue position. The long HA /ɔ:/ vowel is described as a low back vowel pronounced with a low back tongue position. HA /e:/ and HA /ɔ:/ fall along the side of the vowel triangle in the vowel space. Overall, there is a tendency for short vowels to be more centralized in the vowel space than their long counterparts. There found a variation between male and female vowels production. Vowels pronounced by native Hadrami male speakers tend to be higher and more retracted in the vowel space than vowels pronounced by native Hadrami female speakers. Female speakers tend to have higher formant frequencies than male speakers. This correlates with studies as (Wang and Van Heuven, 2006) reporting that female speakers have higher formant frequencies by 10% to 15% than male speakers. A main reason for this is a physiological feature for women's vocal tract length, the shorter the formant tract the higher the formant frequencies (Yang (1996). Sometimes, some overlap occurs between some speakers' vowel production such as /i:/ and /e:/. The researcher attributes this to inter speaker variation. The Comparison between HA vowels' quality and other Arabic vowels' quality of previous studies shows that HA vowels' realizations are within similar categories of frontness and backness as other Arabic vowels. Except for the short HA vowel/u/, it is classified as a central vowel rather than a back one. Further investigation is needed to determine whether HA /u/ vowel is another vowel realization or a counterpart of the long HA /u:/. HA vowel inventory in general has a slight tendency to be lower and more fronted over other Arabic vocalic systems.

5.2. Research question 2: To what extent is the distinction of short and long vowels in Hadrami Arabic based on the vowel duration of male and female speakers?

Hadrami Arabic vowels can be divided into two groups as far as duration is concerned, three short vowels (/i/, /u/, and /a/) and five long vowels (/i:/, /u:/, /a:/, /e:/, and /ɔ:/). The mean duration for the three short vowels is 61.6 ms and for the five long vowels is 147.2 ms. There is a clear length distinction between HA short and long vowel pairs. When the duration of a short vowel is high, the duration of the long counterpart is relatively higher. The ratio of short vowels to long vowels is 0.45. The long HA vowels are more than double the duration of their short counterparts. The distinction between the low vowel pairs /a/ and /a:/ is quite higher than the other vowel pairs. Overall, HA short /i/ vowel has the shortest duration among all HA vowels while the long HA /ɔ:/ vowel has the longest duration among all HA. The high short and long HA vowels have longer duration than the low short and long HA vowels which correlates with previous research that reported this as a universal phonetic feature attributed to physiological factors. It is compatible with the claim made by Lindblom (1967), Klatt (1976) and others that low vowels are inherently longer than high vowels in the languages of the world. This is attributed to the fact that speakers need extra time for lowering the jaw when low vowels are produced (Lehiste, 1970; Lindblom, 1967). Female speakers tend to produce longer vowels than male speakers. The high variation in length between male and female speakers is attributed to physiological factors. Except for the HA /e:/ vowel, no clear difference was found.

5.3. Implication

This study investigates the acoustic properties of HA vowel quality and quantity as produced by ten native Hadrami speakers reading prescribed sentences containing the target eight Hadrami monophthongs (/i/, /u/, /a/, /i:/, /u:/, /a:/, /e:/, and /ɔ:/). The findings describe the HA vowels' quality in terms of first and second formant frequencies and quantity in terms of vowel duration in ms. Many aspects were considered during the process of data analysis such as gender variation, normalization procedures using bark scale, phonetic context and the use of dialectal validated HA words. The aim is to reach the most accurate and adequate description of Hadrami vowel inventory. The fact that HA is prone to dialect change raises an urgent need to document and acoustically study the dialect, that is why this research is conducted. The findings imply that the vowel inventory of HA like many other colloquial Arabic varieties (Norlin, 1984; Holes,1990; Ahmed, 2008; Adam,2014; Alhussein and Hellmuth, 2015; Fathi and Qassim, 2020) consists of eight vowels three short and five long ones. Those long and short counterparts (/i/, /u/, /a/, /i:/, /u:/, /a:/) are triangulated in the vowel space while the dialectal /e:/ and /ɔ:/ vowels fall along the side of the triangle. The researcher does not deny the possibility of the existence of an extra short vowel as a separate phoneme in HA vowel inventory. On the other hand, this research supports the claim made by the earlier descriptive study of Al-Saqqaf (1999) that HA vocalic system of the variety spoken in the city of Seiyun has eight vocalic qualities, three short vowels and five long ones. This research also supports the claim that high vowels are always longer than low vowels due to universal physiological factors. Further, there is an implication that vowel production varies based on gender variation which is also attributed to the physiological factor of vocal tract length.

5.4. Further Research Directions

Because this study is the only acoustic study describing the vocalic system of a Yemeni dialect, it is highly recommended that other Yemeni dialects shall be studied using a similar acoustic approach. It is also recommended that the other HA varieties shall be studied. Furthermore, the researcher suggests a comparative study between this study's findings and the vocalic system of the HA spoken by migrated Hadrami people in countries as Indonesia and Tanzania and figure out how their integration in the migrated countries has influenced their HA speech. Diphthongs and emphatic versions of vowels that are not covered in this research shall be studied too. A similar study using a more normative set of data with more control over the phonetic context shall be significant too. Furthermore, A study with other reading contexts such as spontaneous speech and conversational speech will enhance a more competent investigation of HA.

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