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Ultra-Processed Foods Consumption and General Consumption Pattern as Correlates of Health Status of Undergraduate Students in Ondo City, Nigeria

Isoken IHENSEKHIE

Department of Vocational and Technical Education, Faculty of Education University of Benin, Benin City.
Email: isoken.ihensekhien@uniben.edu

Feranmi Boluwatife OLUWAGBEMILEKE

Department of Vocational and Technical Education, Faculty of Education University of Benin, Benin City.
Email: lekeferanmi2019@gmail.com

****Corresponding author, Email: lekeferanmi2019@gmail.com**

ABSTRACT

This study builds on an earlier investigation of the ultra-processed foods (UPF) consumption and general consumption patterns of undergraduate students in Ondo City of Ondo State, Nigeria. It sought to assess the relationship between health statuses. One question and two null hypotheses guided the study. A quantitative survey research design was adopted in the study, and the Adeyemi Federal University of Education was the sampled area for the study in the city. The sample size for the survey comprised 2% of the estimated population (240 respondents). Data was collected from 240 respondents using the Ultra-Processed Foods Consumption Pattern and Effects on Students' Health Questionnaire (UCPESHQ) and analysed statistically (using frequency count, percentage, simple ranking and Pearson Product-Moment Correlation). The significant findings were that the most everyday self-reported ailment, medically diagnosed ailment and worrisome clinical features are sleeping disorder (41.9%), ulcer (11.4%) and dandruff (19.1%), respectively. The students are averagely average in weight (58.5%). It was also found that UPF consumption is significantly associated with self-reported ailments ($r = 0.160$, $\rho = 0.014$) and worrisome clinical features ($r = 0.185$; $\rho = 0.004$). It was recommended that management teams of universities should work with appropriate stakeholders to facilitate sustainable feeding and healthcare programs for undergraduate students.

Keywords: Ailments, Body Mass Index (BMI), clinical features, consumption pattern, ultra-processed foods (UPFs)

INTRODUCTION

Since they are in their prime, undergraduate students should have good physical and mental health and nutrition. Nonetheless, a previous study conducted in Ondo City, Nigeria, by Ihensekhien and Oluwagbemile,ke (2023) found concerning rates of consumption of ultra-processed foods (UPF) as well as a concerning general consumption pattern among undergraduate students. According to the survey, packaged snacks—either sweet or savory—are frequently consumed by college students. On the other hand, they typically eat packaged, mass-produced bread and buns, cookies, cakes, pastries, cake mixes, energy drinks, and sports drinks. Regarding the overall consumption pattern, 53% of the students do not eat up to three meals a day, and 70.3% miss breakfast, lunch, and supper, in addition to 66.1% snacking in between. Furthermore, a strong correlation was discovered between the two variables ($r = 0.143$, $\rho = 0.029$). This served as the foundation for the current study's design to determine the association between these two factors and students' health. Other studies have assessed the health status of undergraduate students. For instance, the University of Toronto (2017) reported a National College Health Assessment conducted in 2016. They reported that 74%, 30%, and 20% of students consume alcohol, marijuana, and cigarettes, respectively. They also found that 1% of their students perceived themselves to be underweight, 14% to be slightly underweight, 55% to be about the right weight, 27% to be slightly overweight, and 4% to be very overweight. Also, more than half of the students (55%) exercise to lose weight, while 40% use a diet. In the United States, 14%, 39%, and 33.8% rated their health status to be excellent, very good, and sound, respectively, compared to 10.9% and 2% who reported it to be fair and poor, respectively (Lanza et al., 2022). The University of Minnesota (2007) surveyed about 10,000 college students from their 14 campuses and reported that 38.5% of students are either overweight or obese. In Nigeria, 11.0% of the students were underweight, 74.0% had average weight, while 12.5% and 2.5% were overweight and obese respectively (Ajuzie et al., 2021). Research has established correlations between the ingestion of ultra-processed foods and potential health hazards. Certain health risks are associated with weight gain (Hall et al., 2019), metabolic syndrome (Steele et al.,

2019), cardiovascular diseases, coronary heart disease, cerebrovascular disease (Srouf et al., 2019), asthma and wheezing (Melo et al., 2018), irritable bowel syndrome and functional dyspepsia (Schnabel et al., 2018), depression (Adjibade et al., 2019), and double burden of disease due to eating errors (Rivera et al., 2014; De –Deus-Mendonca et al., 2016).

On a broader scale, the general consumption pattern of undergraduate students has been correlated with their health status. While Ajuzie et al. (2021) discovered that dietary diversity is not significantly different from nutritional status, they also discovered that body mass index has a strong association with the preference for food by students. Study International (2017) reported that less than 20% of British students eat healthily (according to a 2015 study), concurrently with reduced social healthiness regarding physical interaction. However, Otemuyiwa and Adewusi (2012) found that 60%, 85%, and 40% of undergraduate students in southwestern Nigeria did not consume the recommended amount of protein, calcium, and iron, respectively. Arisukwu et al. (2019) documented that 91% of undergraduate students knew that poor nutrition has adverse effects on their health and that skipping meals is responsible for tiredness, stomach pain, dizziness, and restiveness in 37.5%, 22%, 18%, and 9.5% of the students. The observed worrisome feeding habit among undergraduate students in Ondo City indicates the likelihood of poor health. The effects of bad feeding habits are both acute and chronic. Being acute, the consumption of UPFs results in the depletion of students' capacity to resist diseases and infections. An excellent illustration of this is the hike in the number of students who usually get hospitalized for treatment at the College Health Centre during examination periods. In many instances, a few students' slum and are rushed down there, putting pressure on the limited facilities available. It had been assumed all along that this situation may have resulted from students not feeding because of the pressure of preparing for examinations. As touching the chronic effects, students' health may not reflect severe degeneration at an early stage. However, the fact remains that the manifestation of recurring illnesses in later life stems from unchecked habits such as the consumption of ultra-processed foods. Therefore, the purpose of this study was to objectively evaluate the relationship between UPF consumption and overall consumption habits on the one hand and undergraduate students' health in Ondo City, Ondo State, on the other.

Research Objectives

1. The main objective of this study is, to assess the consumption of ultra-processed foods among undergraduate students in the Ondo City of Ondo State and its perceived effects on their health.

The specific objectives were:

2. Document the health status of undergraduate students in Ondo City by ailments, clinical features and anthropometric measures,
3. Determine if the consumption of ultra-processed foods has effects on the health of undergraduate students in Ondo City and
4. Determine if the general consumption pattern of undergraduate students in Ondo City affects their health.

Research Question

The study answered this question.

1. What is the health status of undergraduate students in Ondo City by ailments, clinical features and anthropometric measure?

Research Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

- H₀₁: There is no significant relationship between the consumption of ultra-processed foods and the health of undergraduate students in Ondo City.
- H₀₂: There is no significant relationship between the general consumption pattern of undergraduate students in Ondo City and their health.

METHODOLOGY

This study gathered data about UPF consumption, undergraduate students' overall consumption patterns, and their health state using a quantitative survey research design. The association between the two independent variables—general consumption pattern and UPF consumption—and undergraduate students' health was then deduced from these data. Ondo City is the location of the study. It is the Ondo West Local Government Area's (Ondo State) headquarters. In the city, three universities grant degrees: Wesley University (private), the University of Medical Sciences (owned by the State), and Adeyemi Federal University of Education (owned by the Federal Government). At the time of the study, the most populous and representative of the other two universities was the Adeyemi Federal University of Education, Ondo, where the investigation was conducted. Students enrolled in the institution's regular Bachelor's Degree programs comprised the study's population. Based on data from the University's Management Information System, the population was anticipated to be 12,000 (MIS, 2021). Two percent of the expected population made up the study's sample size. There were 240 responders in total. The study's respondents were chosen using a multi-stage sampling method. Four of the seven academic faculties that made up the Federal University of Education offering

complete degrees were chosen randomly at the time of the study. From each faculty, an equal number of male and female students were chosen using the purposeful sampling technique. Data for the study were gathered using the Ultra-Processed Foods Consumption Pattern and Effects on Students' Health Questionnaire (UCPESHQ), a systematic, extensively tested, and trustworthy questionnaire. The NOVA Food Classification System proposed by the Centre for Epidemiological Studies in Health and Nutrition (2016) and the Diet and Behaviour Score (DABS) proposed by Richards and Smith (2015) served as the foundation for the development of the instrument. It comprised seven sections, 'A' through 'G'. Section A elicited demographic information from the respondents such as faculty, gender and level. Section B measured the frequency of consumption of the 20 most common UPFs among undergraduate students on a 5-point rating scale. Section C contained six "Yes" or "No" items that measured the general consumption pattern of the respondents. Section D asks 15 "Ye's" or "No" items about their self-reported ailments (SRA) and medically diagnosed ailments (MDA). Section E contained four items to record the clinical features of undergraduate students (skin, eyes, hair, and mouth). Section F contained two items to measure the anthropometry of the respondents by range (weight and height). The last section contained seven four-point Likert-scale question items on the strategies used to minimize the consumption of ultra-processed foods.

One nutrition specialist, two food science and technology experts, and two home economics education experts validated the instrument to gather the data face-to-face and on its content. They examined the items for relevance and sufficiency in responding to the study objectives, as well as for clarity and suitable phrasing. The Split-half approach assessed this instrument's reliability (internal consistency and accuracy level). Students at the university of study who chose not to participate in the final study were given eighteen copies of the questionnaire. They divided their questionnaire responses into two groups and used Pearson Product-Moment Correlation (PPMC) to correlate the results. The results of the analysis showed that the instrument had a high level of reliability ($0.61 \leq r \leq 0.80$) based on the correlation coefficient (r-value) of 0.708 and an alpha value of 0.01, indicating that the reliability is very significant at the 0.05 level of significance. Six (6) research assistants (RAs), who were hired and given extensive training through a structured virtual cooperation environment (a Whatsapp group chat called UPFs and UnderG), assisted in producing and distributing two hundred and forty (240) copies of the questionnaire. A physical briefing on the objective and core values of the study and training in taking body measurements were conducted by the researcher on Sunday, January 8, 2023. The RAs assisted with the collection of data by administering the instrument to the respondents, guiding them to fill the self-response sections, monitoring the filling of the clinical features, and taking their anthropometric measures. The language of instruction was English. Only 98.3% of the administered instruments were retrieved. The responses collected from the study were analysed statistically. Research question one was answered using frequency count, percentage, and simple ranking; while the two null hypotheses were tested with Pearson Product-Moment Correlation (PPMC) at 0.05 level of significance. The decision rule about the magnitude and direction of the correlation was based on statistical real limit as shown in Table 1.

Table 1: Statistical Real Limits of Responses to Research Questions Two and Three

Ranges of Correlation Coefficient	Decision
± 0.80-1.00	Very High
± 0.60-0.79	High
± 0.40-0.59	Moderate
± 0.20-0.39	Low
± 0.00-0.19	Very Low

FINDINGS

Research Question: *What is the health status of undergraduate students in Ondo City by ailments, clinical features and anthropometric measure?*

Table 2: Description of the Health Status of Undergraduate Students in Ondo City

SN	Item	F	%	Ranks
Self-Reported Ailments				
1	Weight gain	90	38.1	2
2	Hypertension	4	1.7	8
3	Asthma	6	2.5	7
4	Wheezing (sound in the chest when breathing)	26	11.0	6

5	Dyspepsia (indigestion) and constipation	31	13.1	5
6	Depression	61	25.8	3
7	Sleeping disorder (too much or too little)	99	41.9	1
8	Gluttony (eating too much)	45	19.1	4
Medically Diagnosed Ailments				
1	Ulcer	27	11.4	1
2	Irritable Bowel Syndrome (IBS)	10	4.2	2
3	Cardiovascular diseases	4	1.7	3.5
4	Coronary heart diseases risk	3	1.3	5.5
5	Cerebro-vascular diseases risk	3	1.3	5.5
6	Metabolic syndrome (High blood pressure, high blood sugar)	4	1.7	3.5
7	Cancers	2	.8	7
Clinical Features				
1	Rashes	23	9.7	2
2	Red spots	8	3.4	6
3	Eczema	19	8.1	3
4	Scale	7	3.0	7
5	Conjunctivitis (Lining on the eye)	13	5.5	4.5
6	Jaundice (Yellow eyeball)	6	2.5	9
7	Pallor (Pale or yellow face)	2	.8	12.5
8	Ringworm	6	2.5	9
9	Dandruff	45	19.1	1
10	Unkempt	4	1.7	11
11	Foamy saliva	13	5.5	4.5
12	Angular stomatitis (swelling at the side of the mouth)	6	2.5	9
13	Halitosis (Mouth odour)	2	.8	12.5

SN	Item	F	%	Ranks
Body Mass Index				
0	Missing	7	3.0	6
1	Abnormally Low/Wasting	8	3.4	5
2	Underweight	64	27.1	2
3	Normal	138	58.5	1
4	Overweight	10	4.2	3
5	Abnormally high/Obese	9	3.8	4

Keys: F = Frequency; % = Percentage; \bar{x} = Mean; SD = Standard Deviation

The measurement of the health status of undergraduate students used for this study was done by analysing data about their ailments (SRA and MDA), clinical features, and anthropometric measurements (body mass index), as shown in Table 2 above. The three most recurring SRA are sleeping disorder, weight gain, and depression; while the two most reported MDA are ulcer and irritable bowel syndrome (IBS). The three topmost worrisome clinical features of the respondents are dandruff, rashes, and eczema. Finally, while 58.5% of the respondents were found to have normal BMI, 27.1% of them are underweight, while 4.1% of them are overweight. The mean of the categorical responses shows that average, undergraduate students in Ondo City have low self-reported and medically diagnosed ailments as well as low indications of worrisome clinical features; and that, on average, the body mass index of the student's falls under the 'normal' category. The standard deviations of the four categories of health measures range from 0.156 to 0.861, indicating that the responses did not widely deviate from the central tendencies.

Research Hypothesis 1: There is no significant relationship between the consumption of ultra-processed foods and the health of undergraduate students in Ondo City.

Table 3: PPMC of the Relationship between UPFs Consumption and the Health of Undergraduate Students in Ondo City

General Consumption Pattern		r	p	Decision
Health	Self-Reported Ailments	.160*	.014	Positive, significant, but very low correlation
	Medically Diagnosed Ailments	.022	.740	Positive but very low and insignificant correlation
	Clinical Features	.185*	.004	Positive, significant and very low correlation
	Body Mass Index	-.028	.664	Negative, very low and insignificant correlation

Keys: r = correlation coefficient, p = Significance of correlation (2-tailed)

Table 3 above shows that UPFs consumption has a positive, significant but very low correlation with SRA, while it has a positive but very low and insignificant correlation with MDA. Its correlation with clinical features is positive, significant and very low, while it has a negative, very low and insignificant correlation with the BMI of undergraduate students.

Research Hypothesis 2: There is no significant relationship between the general consumption pattern of undergraduate students in Ondo City and their health.

Table 4: PPMC of the Relationship between the General Consumption Pattern and the Health of Undergraduate Students in Ondo City

General Consumption Pattern		r	p	Decision
Health	Self-Reported Ailments	.111	.089	Positive but very low and insignificant correlation
	Medically Diagnosed Ailments	.055	.397	Positive but very low and insignificant correlation
	Clinical Features	.091	.163	Positive but very low and insignificant correlation
	Body Mass Index	.074	.255	Positive but very low and insignificant correlation

Source: Researchers (2023)

Keys: r = correlation coefficient, p = Significance of correlation (2-tailed)

Table 4 above shows that the general consumption pattern of undergraduate students in Ondo City of Ondo State has a positive but very low and insignificant correlation with all the parameters used for measuring their health status.

DISCUSSION OF FINDINGS

In answering the first question, it was found that sleeping disorders, weight gain, and depression as well as ulcers and IBS, are the topmost prevalent ailments in the population – self-reported and medically diagnosed, respectively (Saifuddin & Ezzi, 2024). Dandruff, rashes, and eczema also rank the first three among worrisome clinical features; while the students have an averagely normal BMI. Also, the health status of the students did not widely deviate from the central tendencies and role of parents and teachers (Jabeen, Ali, & Ahmad, 2023; Naeem, Ali, & Ahmed, 2022; Akram, Khan & Ahmad, 2022). This is supported by the findings of the University of Minnesota (2007) that only about 38.5% of students are either overweight or obese and that of Ajuzie et al. (2021) who documented that about 74.0% of undergraduate students had normal weight.

Regarding the second research question, it was discovered that there was a fragile but positive association between UPF intake and self-reported illnesses (SRA). Scholars like Adjibade et al. (2019; depression) and Hall et al. (2019; weight increase) have found similar correlations. Similar findings were made about the relationship between UPF consumption and medically diagnosed diseases (MDA), albeit the relationship is not statistically significant (Ahmad et al., 2023; Ali et al., 2023). Concurrently, similar correlations were shown between metabolic syndrome and cardiovascular/cerebrovascular illnesses by Steele et al. (2019) and Srour et al. (2019). Additionally, no research in the literature supports or refutes the positive, significant, and shallow link between UPF intake and clinical characteristics (Ahmad et al., 2023; Ahmad, Thomas, & Hamid, 2020). Ultimately, a negative, negligible, and insignificant association was discovered between undergraduate students' BMI and UPF intake, suggesting that the more UPFs they drink, the less probable it is that their BMI would rise and that their behavior will alter (Imran, Muddasir, Sattar, 2023). This can be compared with the results of Silva et al. (2018) and Da Costa-Louzada et al. (2015), who discovered a correlation between UPF intake and obesity, overweight, and both.

Meanwhile, it was discovered that all the criteria utilized to assess the general consumption pattern of undergraduate students in Ondo City, Ondo State, had a positive, albeit negligible, association with it (Abdussalam et al., 2023). Similar to Arisukwu et al. (2019), who reported that 91% of undergraduate students believed that poor nutrition had a negative impact on their health and ability to learn, Ajuzie et al. (2021) suggested that students' food preferences are strongly correlated with their body mass index (Afroz & Muzaffar, 2023; Hamidani & Muzaffar, 2023; Ali et al., 2022).

CONCLUSION

This study concluded that the health status of undergraduate students in Ondo City of Ondo State is far from perfect, though many of their ailments and worrisome clinical features are probably under-reported. Also, a reasonable association was found between UPFs consumption and the general consumption pattern of undergraduate students on one hand, and their health on the other hand.

RECOMMENDATIONS

The study's conclusions led to the following recommendations being made:

1. It is recommended that university management teams collaborate with relevant stakeholders to enable undergraduate students to participate in sustainable food and healthcare programs.
2. Public sensitization campaigns should be held regularly by counselling units and nutrition or dietetics departments to inform undergraduate students about the health hazards of consuming highly processed foods and adopting an unhealthy consumption pattern.
3. It is the personal obligation of undergraduate students to monitor their diet and care for their health

SUGGESTION FOR FURTHER STUDIES

Researchers can investigate this study's results further in several ways, including the following.

1. Evaluation of the effects of demographic data on the dependent variables of the current study, including gender, level, discipline, age, parental upbringing, social activity, religious participation, and socioeconomic status.
2. Conducting the current study's dependent variable measurements among Ondo State undergraduate students not enrolled in Ondo City.
3. Measuring the dependent variables of this study in Ondo City, Ondo State, among different student categories besides undergraduates.
4. Measuring the dependent variables of the current study among state students in categories other than undergraduates.

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Exploring Communicative Competence: Definitions, Advancements, and Implementations across Disciplines

Doung Dara¹

Mindset Development Organization, Cambodia
Email: d_dara09@yahoo.com

Abdul Ghani Soomro²

Associate Professor of English, Education and Literacy Department, Govt. of Sindh-Pakistan
Email: ghaniedu@gmail.com

Sun Ny³

Angkul Lower Secondary School, Cambodia
Email: nysun82@gmail.com

Chat Koem Hong⁴

The University of Cambodia
Email: chat.koemhong@gmail.com

Dr. Ehab Elshamy⁵

Chancellor, American International Theism University Florida- USA
Email: vc@aituedu.org

Abstract

This paper explored the dynamic and multifaceted concept of communicative competence, which originated as a critical response to Noam Chomsky's linguistic theories. By examining contributions from various scholarly disciplines, it compiled and critically assessed diverse definitions while tracing the evolution of communicative competence into a broader sociocultural phenomenon. The study meticulously mapped the developmental trajectory of communicative competence, exploring its theoretical underpinnings and practical applications in different contexts. It highlighted its significance in contemporary society by demonstrating its adaptability to changing pedagogical needs and societal expectations. This comprehensive overview emphasized the importance of communicative competence in both theoretical linguistics and practical language education. The paper showcased how communicative competence integrates functional, sociolinguistic, strategic, and discourse competencies to facilitate effective communication across various societal domains, making it a pivotal element in the advancement of communication studies. Embracing communicative competence into collaborative learning and cognitive flexibility should be motivated for further research.

Keywords: *Communicative competence, language use, multidisciplinary perspectives, implementations*

Introduction

Communicative competence has traversed multiple domains of study, evolving continuously from its linguistic foundations to encompass functional considerations within both native and second language contexts, as well as across diverse language communities. The dichotomy between competence and performance, initially introduced within linguistics, laid the groundwork for the emergence of "communicative competence," a concept revitalizing language study by emphasizing sociolinguistic competence and the ability to effectively employ language in social contexts (Hymes, 1970). This shift extended the understanding of language from its core structural

aspects to its broader social dimensions, including appropriateness and situational use. Halliday (1974) further expanded this perspective by introducing meta-functions of language, highlighting the connection between language use and the speakers' experiences and interactions. Canale and Swain (1980) contributed to the discourse by delineating elements of communicative competence, notably introducing strategic competence as a means to compensate for deficiencies in linguistic proficiency (Ahmed, Ali, Fatima, Ali, Waqarul & Hasan, 2024). Subsequently, Canale (1983) proposed an enhanced framework, incorporating discourse competence, albeit without significant novelty. Troike (1989) introduced an ethnographical model of communicative competence, emphasizing three foundational pillars, with cultural attachment representing a revolutionary addition.

Bachman and Palmer (1996) presented a more intricate model, characterized by its linguistic exclusivity and criticality, encompassing elements of time, organization, and pragmatics, while also highlighting strategic competence from a different perspective. Okvir's (2005) contribution, although lacking novelty, overlooked strategic competence, a crucial aspect in communicative interactions. In parallel, Lingren (2008) integrated Goffman's and Kramsch's theories of interactional order and interactional competence into a comprehensive framework, emphasizing ongoing features and the importance of understanding interactional dynamics within communicative contexts (Ahmed, Sultana, Hassan, & Ali, 2024). Communicative competence, despite its varied interpretations and applications, remains foundational to communicative language teaching methodologies in practical settings. Teaching methods, syllabus designs, materials, and activities have been tailored to align with communicative language learning objectives, often at the expense of traditional structuralist approaches. Consequently, there exists ongoing discourse and debate surrounding the nature and implementation of communicative competence within language education.

Definitions

Communicative competence has various meanings. Hymes who is the distinguished linguist and anthropologist defines that communicative competence is "a wide term including not only linguistic Knowledge but also knowledge of a set of sociolinguistic codes and rules for using them." Communicative competence, he claims, is "the most general term for the speaking and hearing capabilities of a person - competence is understood to be dependent on two things: (tacit) knowledge and (ability for) use". (p. 16). Even though his notions of this term are acknowledged, there are some famous researchers using this linguistic term by defining differently. For Brown (1976) communicative competence, unlike linguistic competence, involves, awareness of the transactions that occur between people. Competence in this perspective is tied to actual performance of the language in social situations (Wieman & Backlund, 1980; Ali, Kolachi & Azam, 2023). Backlund (1977) offers a wider definition of communicative competence claiming that communicative competence is "the ability of art interactant to choose among available communicative behavior in order that he (she) may successfully accomplish his (her) own interpersonal goals during an encounter while maintaining the face and line of his (her) fellow interactant within the constraints of the situations. "(p. 16). Further, Canale (1983) defines "communicative competence is the underlying systems of knowledge and skill required communications". In short, communicative competence has broad concepts covering not grammatical competence and knowledge, but its use contextually and socio-linguistically and ways to achieve communications or interactions.

Developmental notions of Communicative Competence Linguistic perspectives

Indeed, while the linguistic field may not always place communicative competence at the forefront, it serves as a solid foundation upon which many scholars build their research in this domain. Despite this, several influential linguists have made notable contributions to the understanding of communicative competence. No discussion of linguistic theory and communicative competence would be complete without mentioning Noam Chomsky. In his seminal work "Aspects of the Theory of Syntax" (1965), Chomsky introduced the concept of "competence vs performance." Here, competence refers to the innate linguistic knowledge possessed by speakers, while performance denotes the actual use of language in real-world situations (Ali, Busch, Qaisrani & Rehman, 2020; Khadim, Arain & Ali, 2023). This conceptual distinction laid the groundwork for subsequent explorations into communicative competence. Another significant figure in linguistic theory is M.A.K. Halliday. In his works from the early 1970s, particularly "Language as Social Semiotic" (1971) and "Explorations in the Functions of Language" (1973), Halliday introduced the idea of macro functions of language. He identified four key roles of language: ideational, manipulative, heuristic, and imaginative functions. These functions are integral to communication, as they serve various purposes such as conveying information, expressing social relations, and creating coherent discourse. Halliday's contributions laid the foundation for Systemic-Functional Grammar, a linguistic framework that places communication at its core (Ali, Mankash & Ullah, 2022).

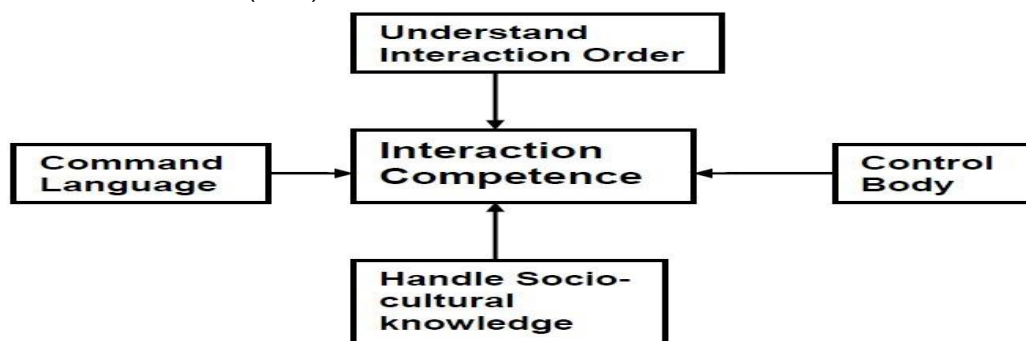
Halliday's meta-functions of language, as outlined in "Language as Social Semiotic" (1971), further elucidate the communicative aspects of language. The ideational function is concerned with conveying new information and

communicating content unknown to the listener. The interpersonal function involves expressing social and personal relations through language (Arain, Mankash & Ali, 2020). Finally, the textual function aims to organize spoken or written discourse into coherent and unified texts, transforming a mere sequence of sentences into a meaningful message. By integrating these insights into their research, scholars have been able to deepen their understanding of communicative competence and its role in language use and interaction. Chomsky's conceptualization of competence and performance provides a theoretical framework, while Halliday's macro-functions and meta-functions offer practical insights into the communicative dimensions of language. Together, these contributions enrich our understanding of communicative competence and its significance within linguistic theory and practice (Mankash, Khan, & Ali, 2023; Rehan, Ali & Mankash, 2022).

Sociolinguistics perspective

The evolution of communicative competence has been marked by the emergence of novel discoveries and alternative perspectives, challenging established notions and expanding the understanding of language and communication. While the seminal findings of Chomsky, particularly his distinction between competence and performance, laid the groundwork for linguistic inquiry, subsequent scholars sought to address the limitations and complexities inherent in this framework. In the realm of sociolinguistics and communication theory, scholars such as Habermas (1970) offered new insights into communicative competence. Habermas, a renowned German sociologist and philosopher, introduced the concept of communicative rationality, emphasizing the importance of language in facilitating rational discourse and social interaction (McCarthy, 1984). Similarly, Jakobovits (1970) explored the communicational perspectives of language beyond its structural aspects, envisioning a future where descriptive work in psychology, sociology, and anthropology would contribute to a comprehensive theory of communicative competence. Dell Hymes (1971) further advanced the discourse on communicative competence by challenging Chomsky's concept of language acquisition. Hymes proposed the term "communicative competence" to encapsulate the multifaceted nature of language use, highlighting the importance of social and contextual factors in communication. His framework, consisting of four knowledge categories, elucidated the various dimensions of communicative competence, including grammatical knowledge, rules of speaking, language functions, and appropriateness (Yun, 2005). Building upon Hymes' work, Troike (1989, 1996) outlined three components of communicative competence: linguistic, interactional, and cultural knowledge. These components encompassed a broad range of linguistic and sociocultural competencies necessary for effective communication in diverse contexts. Troike's framework emphasized the interconnectedness of language, interaction, and culture in communicative competence.

Fig 1. Troike's framework (1989)



In sociology and sociolinguistics, Lindgren (2008) introduced the concept of interactional competence, which encompasses communicative practices and knowledge essential for successful interaction. Drawing on Goffman's notion of interactional order, Lindgren highlighted the importance of understanding the structure of interaction and discourse organization in achieving communicative goals. Additionally, Gumpaz (2001) emphasized the contextual nature of talk and its role in real-life communicative exchanges, underscoring the multidimensionality of interactional competence (Shah, Ali & Ahmad, 2024). The model presented above delineates four key areas of knowledge essential for effective interaction: Control body, Command language, handling socio-cultural knowledge, and Understanding Interaction Order. These components encompass various aspects of non-verbal communication, linguistic proficiency, socio-cultural norms, and the structural dynamics of interaction. Control body pertains to nonverbal communication cues and physical body language, highlighting the importance of gestures, facial expressions, and posture in conveying

meaning during interaction. Command language encompasses linguistic competence, encompassing knowledge of and proficiency in using all linguistic features relevant to verbal communication within interaction contexts (Akram, Khan & Ahmad, 2022). Handling socio-cultural knowledge involves understanding culturally and socially accepted behaviors, as well as the broader social structures that influence interaction dynamics. This component emphasizes the significance of cultural norms, social conventions, and contextual factors in shaping communicative interactions (Thomas, Khan, & Ahmad, 2022; Younis, Naeem, & Ali, 2023). Understanding Interaction Order focuses on the structural organization of interaction as a whole, including aspects such as turn taking patterns and discourse coherence. This component underscores the importance of recognizing and adhering to established interactional norms and conventions for effective communication through effective leadership and teaching practices (Ahmad & Hamid, 2021; Ahmad, Thomas, & Hamid, 2020).

It is noteworthy that these components of interactional competence are interconnected and mutually influential, as emphasized by the model. Each area of knowledge contributes to a comprehensive understanding of interaction, and they collectively shape individuals' communicative competence in social contexts (Ahmad, Rashid, & Ali, 2023; Ahmad, et al., 2023; Ali, Ahmad, & Sewani, 2022). While this model shares similarities with Hymes' concept of communicative competence and Saville-Troike's framework, it offers a distinct focus on the organization and dynamics of speech within interaction. Kramsch (1986) specifically emphasizes the structural aspects of speech organization in interaction, distinguishing this model from other conceptualizations of communicative competence. Overall, the evolution of communicative competence reflects a continual refinement and expansion of theoretical frameworks, incorporating diverse perspectives and disciplines to capture the complexities of language and communication in various social and cultural contexts.

Language Acquisition (SLA)

Standing at the intersection of linguistic theories, language practices, and pedagogical ideologies, Second Language Acquisition (SLA) encompasses various approaches and methods aimed at understanding how individuals acquire and learn languages. One key concept within SLA that garners attention from linguists, sociocultural linguists, and specialists in language teaching is communicative competence (Naeem, Ali, & Ahmed, 2022). Initially emerging in the field of sociolinguistics, the concept of communicative competence soon found its place in SLA and language teaching. Troike (2005) notes its significance, highlighting its adoption by specialists in SLA and language pedagogy. Communicative competence in SLA refers to the ability to effectively use language in real-life communicative situations, a concern central to both language learning and teaching methodologies. Canale and Swain (1980) laid the groundwork for understanding communicative competence in SLA by proposing a theoretical framework consisting of three key areas: grammatical, sociolinguistic, and strategic competence. This framework provided insights into the diverse competencies required for successful language use, including the ability to navigate linguistic structures, understand sociocultural norms, and employ communication strategies to compensate for deficiencies (Ahmad, Bibi, & Imran, 2023; Ali, et al., 2023).

Building upon Canale and Swain's framework, Canale (1983) introduced discourse competence as an additional component, acknowledging the importance of understanding discourse structures and coherence in communicative interactions. Bachman and Palmer (1996) further expanded on this model, proposing a twocomponent model that includes language knowledge and strategic competence (Ali, et al., 2023). Language knowledge encompasses organizational knowledge, including textual and grammatical knowledge, as well as pragmatic competence, which pertains to the ability to use language appropriately in different contexts by using technology (Ali, Shah, & Ahmad, 2023; Ali, et al., 2020; Ali, et al., 2023). Strategic competence, on the other hand, involves metacognitive strategies such as assessment, goalsetting, and planning. Cele-Murica, Dornyei, and Thurrell (1995) introduced the concept of action competence, which parallels Canale's functional knowledge and sociocultural competence. This framework provides insights into the practical application of language skills in action-oriented contexts. In contrast, Okvir (2005) proposed a simplified framework focusing on linguistic competence, pragmatic competence, and sociolinguistic competence. This streamlined model offers a concise yet comprehensive understanding of communicative competence in SLA. Overall, these frameworks contribute to a nuanced understanding of communicative competence in SLA, highlighting the multifaceted nature of language use and the diverse competencies required for successful communication in real-life contexts.

Year	Author	Communicative Competence development
1957	Noam Chomsky	Competence vs Performance

1971	Hymes	knowledge and abilities to use languages
1974	Halliday	Meta-functions: ideational interpersonal and textual
1977	Habermas, J.	Towards a theory of communicative competence
1980	Canale & Swain	Grammar competence Sociolinguistic competence and Strategic competence
1983	Canale	Grammar, Sociolinguistic, Discourse and Strategic competence
1989	Troike	Linguistic, interaction and cultural knowledge
1995	Cele-Murica, Dornyei & Thurrell	discourse competence, linguistic competence, actional competence, sociocultural competence and strategic competence
1996	Bachman & Palmer	Language knowledge and Strategic competence
2005	Okvir	language competence, pragmatic competence and sociolinguistic competence
2008	Lingren	Interaction Competence: interaction order, language demand, body control and socio-cultural knowledge
2009	Widdowson, H. G.	Handbook of foreign language communication and learning
2014	Dongyun, S	From communicative competence to interactional competence: A new outlook to the teaching of spoken English. Journal of
		Language Teaching and Research.

Table 1: List of Communicative competence research

Implementations of communicative competence

The concept of communicative competence serves as the foundational bedrock for designing language teaching programs and syllabi, particularly in areas such as Communicative Language Teaching (CLT), English for Academic Purposes (EAP), and English as an International Language (EIL) or as a foreign language. Esteemed scholars like Richard (2006), Savigon (2007), and Widdowson (2009) have underscored its pivotal role in language pedagogy. Moreover, terminologies such as communicative approach and communicative language ability, introduced by Bachman (1990), have become indispensable in practical language teaching methodologies. This transition from language theory to elements of learning theory, as highlighted by Xu, J. (2006), underscores the integration of communicative competence principles into pedagogical frameworks. Xu, J. (2006) identifies three main principles: the communication principle, task principle, and meaningfulness principle, which form the foundation for effective language instruction.

Communicative Language Teaching (CLT)

Communicative Language Teaching (CLT) regards language as a dynamic system for the expression of meaning and its functions in communication and interactions (Xu, J., 2006). This approach represents a paradigm shift in language pedagogy, as the focus shifts from linguistic forms to functional language use (Alexandra, 2012). Scholars such as Richards and Rodgers (1986), Brown (1987), Berns (1990), and Nunan (1991) have delineated various features and principles of the communicative approach, emphasizing its learner-centered nature. Additionally, Savigon (2002), Berns (1990), Nunan (1991), Brown (1987), and Richards and Rodgers (1986) have asserted that the communicative approach places a strong emphasis on the learner. Although discussions among multidisciplinary scholars have raised

various features for consideration, they predominantly revolve around language use, fluency, appropriateness, meaning negotiation, risk-taking encouragement, and student autonomy, rather than language knowledge, structural correctness, and rule strictness. Consequently, in real classrooms, CLT often takes the form of pair and group work, fostering negotiation and cooperation among learners, fluency-based activities to boost learners' confidence, and role-plays to provide opportunities for practicing and enhancing language functions (Xu, 2006; Aslam, Iqbal & Ahmed, 2022). However, while advocating for communicative competence in curriculum design and practices, opposing views have also surfaced. These views include the importance of generative competence, the inadequacy of speech acts as the sole basis for syllabi, the illusionary nature of communicative goals, the necessity for understanding both whole-class and pair/group work, the significance of accuracy in fluency, and the essential differences between using one's native language and attempting to use a less proficient language (Xu, 2006). The emergence of these opposing views prompts proponents of communicative competence to clarify and rectify misconceptions regarding its concepts and critical emphases.

English for Academic Purposes (EAP)

English for Academic Purposes (EAP) has become an essential area of focus as educational institutions globally recognize the need for specialized language training to equip students for academic success in English-speaking environments. This field is richly documented by several foundational texts and research papers that outline both theoretical frameworks and practical applications. For instance, Jordan's English resource books for teachers (1997) provides extensive strategies for teaching English in academic contexts, essential for both instructors and learners. Complementing this, Hyland's works (2006) explores the authorial identity in the, delving deep into the nuances of academic writing and the construction of authorial credibility, which are pivotal for academic success. Further expanding on these foundations, Essential Tasks and Skills (2012) and Swales' genre analysis (1990) offer students and educators alike a detailed understanding of academic genres and the expectations surrounding them. These texts are instrumental in developing the skills necessary to navigate the complex structures of academic writing. Additionally, the integration of corpus linguistics, as discussed in Biber, Connor, and Upton's *Discourse on the Move: Using Corpus Analysis to Describe Discourse Structure* (2007), provides a data-driven approach to understanding and teaching academic discourse. Other significant contributions include Flowerdew and Peacock's *Research Perspectives on English for Academic Purposes* (2001), which broadens the discussion to include diverse EAP topics and methodologies, and Bailey's *Academic Writing: A Handbook for International Students* (2011), which addresses practical writing challenges faced by international students. Together, these resources create a comprehensive educational framework that supports and enhances the teaching and learning of English for academic purposes.

English as an International Language (EIL)

English as an International Language (EIL) has become increasingly prevalent in global communication, owing to its status as a lingua franca in various domains such as business, academia, and technology (Crystal, 2019; Seidlhofer, 2020). As nations engage in cross-border interactions, the necessity for a common means of communication becomes evident, and English serves as the de facto medium for facilitating such exchanges. The rise of globalization, coupled with the expansion of digital platforms, has accelerated the spread of English beyond its traditional boundaries, enabling individuals from diverse linguistic backgrounds to connect and collaborate seamlessly (Ali, et al., 2023; Imran, et al, 2023; Ali, et al., 2020). Furthermore, the dominance of English in international contexts has sparked discussions regarding its impact on linguistic diversity and cultural identity (Jenkins, 2022; Canagarajah, 2019). While proponents argue that EIL promotes intercultural understanding and facilitates mutual comprehension among speakers of different languages, critics raise concerns about the potential erosion of native languages and cultural homogenization. As English continues to assert its influence on a global scale, there is a growing need to address these complex sociolinguistic dynamics and promote linguistic pluralism within international discourse. Additionally, the evolution of English as an International Language has prompted scholars to explore its implications for language education and pedagogy (Seidlhofer, 2020; Kachru, 2021). Educators are tasked with preparing learners to effectively navigate a world where English proficiency is increasingly valued and demanded. This necessitates a shift towards communicative approaches that prioritize functional language skills and intercultural competence, equipping learners with the tools to engage meaningfully in diverse linguistic environments (Dilshad, Shah & Ahmad, 2023; Jabeen, Ali, & Ahmad, 2023).

In Cambodia, several studies highlighted the expanding role of English as an International Language (EIL) in Cambodia, exploring its integration within educational and socio-economic frameworks. Research by Doe and Smith (2019) examined the critical role of English in Cambodian universities, pointing to its necessity for maintaining global academic standards and advocating for structured EIL education to enhance teaching methodologies. Complementarily, Chan and Srey (2019) linked English proficiency with improved employment prospects in key

sectors such as international trade and tourism. Further studies by Lee and Hun (2019), and Nguyen and Chea (2019) explored the effects of globalization on language policies and the impact of English on cultural identity among students, respectively. These studies collectively illustrate the dual role of English in Cambodia as both a facilitator of global engagement and a potential challenge to cultural preservation, underscoring its complex implications in a rapidly globalizing world. The emergence of English as an International Language signifies a transformative shift in global communication patterns, presenting both opportunities and challenges for individuals, societies, and educational institutions worldwide through effective leadership and solving problem (Farzana, Lubna, & Ahmad, 2023; Haider, Ahmad, & Ali, 2024; Imran, et al., 2023;).

Conclusion

The evolution of communicative competence has been marked by the continual addition of new perspectives and innovations aimed at refining and expanding its application across multidisciplinary domains and societal contexts. While some scholars may omit certain elements or introduce new ones, the fundamental aim of communicative competence remains rooted in effective communication, whether linguistically or non-linguistically. To summarize, communicative competence relies on several cardinal elements, each playing a crucial role in facilitating successful communication: (1) Linguistic competence: This serves as the foundation for communicative competence, enabling individuals to effectively produce and comprehend language. Without linguistic competence, individuals would struggle to convey or understand messages as speakers or hearers; (2) Discourse competence or textual knowledge: In addition to linguistic proficiency, individuals require an understanding of discourse structures and textual conventions to ensure clear and coherent communication. Misunderstandings can arise if information is conveyed in a disorganized or ambiguous manner, hindering effective communication; (3) Strategic competence: This element complements linguistic and discourse competence by providing individuals with the ability to employ various communication strategies to overcome communication barriers and enhance interactional effectiveness. Strategic competence enables dialogic partners to navigate conversational challenges and maintain smooth communication flow and (4) Socio-cultural competence: Situated at the intersection of social and cultural factors, socio-cultural competence encompasses an understanding of societal norms, cultural practices, and contextual appropriateness in communication. It allows individuals to navigate diverse social contexts with sensitivity and adaptability, fostering mutual understanding and respect among interlocutors. Together, these cardinal elements form the foundation of communicative competence, enabling individuals to engage in effective communication across linguistic, cultural, and social boundaries. By integrating these elements into communicative practices, individuals can enhance their communicative abilities and foster meaningful interactions in various contexts.

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Exploring the Untapped Possibilities of Wastewater Bacteria in Microbial Electrochemical Technology

Pascal Omeiza Pemida¹

Department of Microbiology Faculty of Life Sciences Ahmadu Bello University, Zaria Nigeria.

Saleh Alhaji Ado²

Department of Microbiology Faculty of Life Sciences Ahmadu Bello University, Zaria Nigeria.

Clement M Z Whong³

Department of Microbiology Faculty of Life Sciences Ahmadu Bello University, Zaria Nigeria.

*Corresponding author pascalpemida@gmail.com

ABSTRACT

Energy is essential to modern civilization, yet using conventional energy sources like coal and petroleum puts the environment at danger. As a result, the need for sustainable energy alternatives is urgent. This research primarily investigates the potential of microbial fuel cells (MFCs) as an alternative energy source, with a specific focus on their ability to generate power using wastewater from the treatment plant at Ahmadu Bello University in Zaria, Nigeria. The study screens a total of 50 isolates against a 200 mV benchmark in order to evaluate the bacteria's ability to produce energy from wastewater. In the experiment, *Bacillus cereus* turned out to be the top producer. Significantly, isolates with the labels 2, 3, A, and C showed encouraging outcomes; they reached peak voltages of 0.879, 0.841, 0.840, and 0.827 volts, in that order.

KEYWORDS: Electrogenic potential, Microbial Electrochemical Technologies, Microbial Fuel Cell, Proton Exchange Membrane and Wastewater

INTRODUCTION:

In today's world of sustainable energy solutions, alternative technologies are becoming more and more significant, and Microbial Fuel Cells (MFCs) are turning into indispensable instruments in this revolutionary attempt. In contrast to conventional fuel cells, MFCs possess the exceptional ability to convert chemical energy directly into electrical power by means of the catalytic properties of microorganisms. Because of this feature, a large range of organic resources, including proteins, fatty acids, and carbohydrates, can be utilised as sustainable fuels, giving MFCs a distinct advantage. MFCs' adaptability allows them to be utilised as versatile and eco-friendly energy converters, greatly aiding global attempts to achieve sustainable energy (Roy *et al.*, 2023).

Because the electrochemical inert nature of microbial cell surfaces is inherently linked to the successful electron transfer in MFCs, mediator intervention is necessary. This, together with the large variety of appropriate organic materials, sets MFCs apart from more traditional cells such as methanol and hydrogen fuel cells. MFCs can be built utilizing diverse materials and configurations and are subject to a range of operating circumstances, such as temperature, pH, and reactor size. Recent findings show how specific iron-reducing bacteria may be able to assist mixed-culture MFCs in reaching higher power, illuminating the unexplored potential in this field of microbial electrochemical technology (Santoro *et al.*, 2020).

METHODOLOGY

Research Location and Sample Acquisition:

The research's subject was the Ahmadu Bello University wastewater treatment plant in Zaria, Nigeria. Wastewater samples were collected from the facility and transported to the laboratory in sterile containers. So that the samples' organic content wouldn't be destroyed by bacteria, they were stored at 4°C until further analysis. The organic component of wastewater serves as the target substrate for microbial oxidation in the Microbial Fuel Cell (MFC) setup.

Media Preparation

Various media were employed in this research:

Luria-Bertani (LB) Agar Plate: Ten grammes of tryptone, ten grammes of NaCl, twenty grammes of agar, and five grammes of yeast extract were diluted in one thousand millilitre of distilled water to make LB agar plates. The medium's pH was adjusted to neutral using 5N NaOH, and then it was autoclaved and put into sterile Petri dishes (Adebule Ap *et al.*, 2018).

Luria-Bertani (LB) Broth: LB broth was made in the same way as LB agar plates, but without the agar component. Test tubes were then filled with the broth before it was autoclaved to ensure sterilisation.

Biochemicals Media: A range of biochemical media, including H₂S, Indole, Methyl Red, Voges-Proskauer, Citrate starch Fermentation, and Amylase test media, were prepared in compliance with the manufacturer's instructions and autoclaved for sterilisation.

Isolation of Bacteria: Wastewater samples were serially diluted, and from each dilution, 0.1 mL was spread on LB agar plates and incubated at 37°C for 24 hours. Morphologically distinct colonies were purified, and Gram staining and other properties were determined (Naureen *et al.*, 2015).

Screening of bacteria for electricity-producing potentials: A system for cultivating single strains in MFCs and analyzing their electrochemical activity was adapted from the tube MFC method described by Clauwaert *et al.*, (2007). In this system, tube of equal volume (10 mL), length and diameter were sterilized with the use of ethanol (70%) by submersion on three occasions for an hour each before it was assembled. The tube was seal off at the bottom with 2mL 2% agar-agar and 1% sodium chloride make the salt bridge. Sterilized graphite rods connected each to copper wire was inserted inside each tube as the anode electrode. 7mL of LB broth was added to each tube and each colony of a pure culture of its cell suspension were injected into each tube to screen for their electricity producing potentials. The top of the tube was insulated to prevent air from getting in, while the bottom end where the salt bridge was positioned was submerged into a solution of a hexacyanoferrate catholyte (100 mM phosphate-buffered 50 mM potassium hexacyanoferrate solution) and a graphite-plate electrode as the cathode. This operation spanned a duration of 5 days to ascertain the electricity production potential of the isolated colony. The electrical voltage produced by each tube MFC was used as an indicator for assessing electrochemical activity and was consistently measured using a multi-meter. Throughout this research endeavor, unless explicitly specified, the bacterial isolate demonstrating notable electricity-producing capabilities was earmarked for subsequent identification processes.



Plate I: Tube microbial fuel cell (TMFC)

Identification: Isolates were characterized based on morphological, microscopic, and biochemical features and cross-matched with existing profiles in laboratory manuals and literature (Clauwaert, Van Der Ha, *et al.*, 2007).

Confirmatory Identification of the isolates by 16s rRNA-PCR assay

The PCR conditions followed the protocol described by Ben-Dov *et al.*, (1997) with the modification of using bacterial cell lysate as the template DNA. (Khojand S. *et al.*, 2013). A loopful of the short-term culture of electrogenic microorganisms grown on an LB agar plate was transferred to a tube containing 100 µL of water, heated at 100°C for 5 minutes, and then cooled. The resulting cell lysate was briefly centrifuged for 10 seconds at 10,000 rpm. Subsequently, 5 µL of the supernatant, containing the genomic DNA, was used for PCR. The PCR reaction was performed in a 20 µL mixture comprising 5 µL template DNA, 150 mM dNTPs, 20 pM of each of the four primers (Table 1), and 0.5 U of Taq DNA polymerase. The amplification protocol in a DNA thermocycler included an initial denaturation at 94°C for 4 minutes, followed by 35 cycles of denaturation at 94°C for 45 seconds, annealing at 48-55°C for 45 seconds, and extension at 72°C for 1 minute. The reaction concluded with a final extension at 72°C for 4 minutes. The 16S rRNA gene banding patterns were visualized via agarose gel electrophoresis. A 15 µL aliquot of each amplification product was loaded onto a 1.2% agarose gel and run in TAE buffer (40 mM Tris-acetate, 1 mM EDTA) at 100 volts for 60 minutes. The gels were stained with ethidium bromide and documented using a 100 bp molecular weight marker.

The obtained 16s rDNA amplicons were sent for sequencing analysis. The bioinformatics analysis was performed by BLAST software (Katara *et al.*, 2016)

Table 1 Primer sets to be used in the amplification of 16s rDNA

16s rRNA	Primer Sequence (5'-3')	Size (bp)	Reference
27F	5'-AGAGTTTGATCCTGGCTCAG-3'	1522	(Abellan-Schneyder et al., 2021)
1492R	5'-GGTTACCTTGTTACGACTT-3'	1522	(Abellan-Schneyder et al., 2021)

Key: **F** = forward primer, **R** = reverse primer

RESULT

Isolation, screening and identification of bacteria with electricity-producing potentials.

Isolation of bacteria from wastewater

The electricity generating bacteria were isolated from wastewater sample from the wastewater treatment facility of Ahmadu Bello University Zaria Nigeria, after 24 hours incubation at 37°C on Luria-Bertani agar plate and morphologically distinct colonies were counted as shown on Table 1.

Screening of electricity producing potential of isolates

In accordance with the methodology outlined by Clauwaert *et al.* (2007), the tube microbial fuel cell (MFC) technique was employed to assess the electricity-generating capabilities of 50 bacterial isolates. Among these, 14 isolates demonstrated noteworthy potential for electricity production. Table 2 showcases the individual performance of these 14 isolates in terms of their electricity production. Notably, isolates designated as 2, 3, A, and C exhibited the most promising results, attaining peak voltages of 0.879, 0.841, 0.840, and 0.827 volts, respectively.

Identification and characterization of bacteria with electricity-producing potentials

Both morphological and biochemical characteristics were used to characterize the bacterial isolates. Interestingly, the isolates had smooth edges and a white cream color with a smooth surface. Microscopic analysis of the resulting characterisation using Gram staining revealed rod-shaped gram-positive bacteria. Biochemical examinations showed that the MR, VP, catalase, oxidase, urease, and citrate tests all showed positive results, however the indole test showed negative results. Moreover, Table 3 illustrates the results of the triple sugar iron (TSI) test, which showed an acidic/acidic (A/A) pattern without gas production and infrequently without hydrogen sulfide (H₂S) creation. Bacillus species were suggested to be the bacterial isolates.

The chosen bacterial isolates were also subjected to molecular identification. After extracting genomic DNA and observing it under UV light, a portion of the 16S rDNA gene was amplified using 27F and 1492R primers. As shown in Plate II, a single discrete PCR amplicon band of about 1500 bp was found by subsequent electrophoresis on an Agarose gel. Using this molecular method, the isolate was further determined to be the *B. cereus* strain. Using BLAST against the NCBI GenBank database, the 16S rDNA gene was sequenced for each of the four isolates, with the top two sequences chosen based on maximum identity score. These sequences were aligned using the Clustal W multiple alignment program, which produced a distance matrix that was then used with MEGA11 to create phylogenetic trees, as illustrated in Figure 1.

Table 1: The colony forming unit of isolate of bacteria from wastewater

Replica	Bacteria colony (cfu/ml)
1st	4.0 * 10 ⁻⁶
2nd	7.0 * 10 ⁻⁶
3rd	6.0 * 10 ⁻⁶
Average	5.67 * 10 ⁻⁶

Key: CFU/ml = Coliform forming unit per milliliters

Table 2: Open circuit voltage (OCV) measurement during the screening in millivolts.

Isolate codes	Voltage(mV) 24hrs	Voltage(mV) 48hrs	Voltage(mV) 72hrs	Voltage(mV) 96hrs	Voltage(mV) 120hrs
1	0.166	0.400	0.586	0.440	0.459
2	0.225	0.333	0.840	0.814	0.879
3	0.190	0.351	0.823	0.823	0.841
4	0.200	0.293	0.653	0.523	0.200
5	0.150	0.296	0.527	0.570	0.409
6	0.175	0.312	0.764	0.523	0.436
7	0.250	0.295	0.304	0.428	0.243
8	0.200	0.293	0.653	0.523	0.200
9	0.144	0.275	0.653	0.523	0.632
10	0.250	0.295	0.304	0.428	0.243
A	0.193	0.327	0.840	0.823	0.749
B	0.156	0.430	0.506	0.433	0.307
C	0.230	0.315	0.827	0.796	0.708
D	0.240	0.285	0.304	0.400	0.343

Key: mV = millivolt

Table 3: Cultural, Microscopic and Biochemical Characteristics of Selected Electrogenic Bacterial Isolates.

Isolates code	Growth												Gram reaction	Gas	Inference	
		H ₂ S	Indole	Motility	Glucose	Lactose	Sucrose	Citrate	Starch hydrolysis	Amylase	MR	VP				urease
2	WC	-	-	-	+	-	-	-	+	+	+	+	+	+rods	-	<i>Bacillus sp</i>
3	WC	+	-	+	+	-	-	+	+	+	+	+	+	+rods	-	<i>Bacillus sp</i>
A	WC	+	-	+	+	-	-	+	+	+	+	+	+	+rods	-	<i>Bacillus sp</i>
C	WC	-	-	-	+	-	-	-	+	-	+	-	+	+rods	-	<i>Bacillus sp</i>

Key: WC: white cream hue with a smooth surface texture and edges, 2, 3, A, C: electrogenic bacterial isolates, +: positive test, -: negative test, H₂S: hydrogen sulfide production.



Plate II: Electrophoresis gel of 16s rRNA gene banding pattern of selected bacteria isolates
Key: L: ladder, **2, 3, A, C:** electrogenic bacterial isolates, **Neg:** negative control

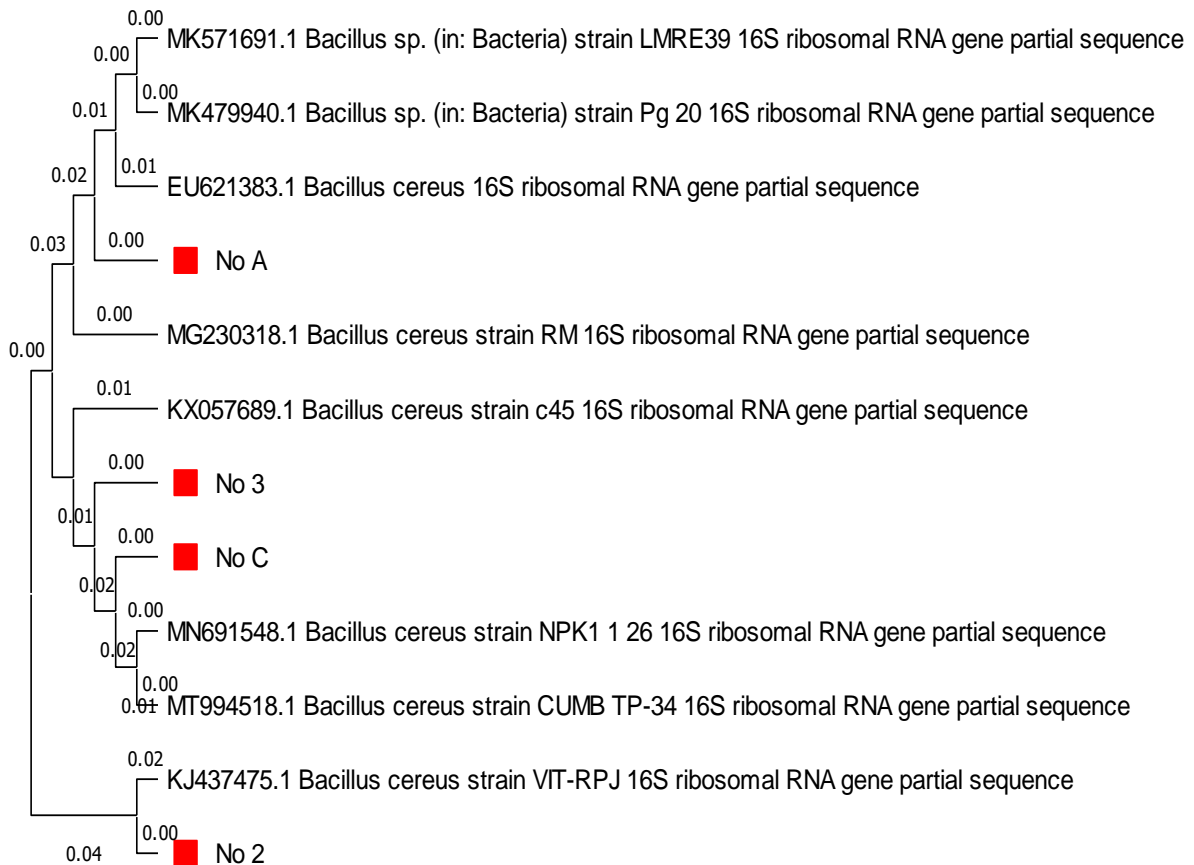


Figure 1: Phylogenetic tree of electrogenic bacterial isolates with closely related strains based on 16s rRNA gene Evolutionary analysis

Key: No 2, 3, A, C; electrogenic isolates used

DISCUSSION

By using a composite sample that was obtained from several collection points, it was possible to get a representative wastewater sample that accurately captured the spatial changes in the microbial composition throughout the sampling area. This methodology recognizes the intrinsic variability of wastewater and

guarantees a more thorough evaluation of the microbial communities existing in the system. (Lancaster & Keller-mcnulty, 1998)

By counting individual colonies on agar plates, the dilution and plating procedure made it possible to quantify the microbial population density. The average count of 5.67×10^6 CFU/mL indicates a significant microbial burden in the wastewater sample. Given the presence of nutrients and organic matter in wastewater habitats, culturable bacteria are expected to flourish there, and the observed microbial density is consistent with that expectation (Barrow *et al.*, 2003).

The high microbial load found emphasizes how important it is to treat wastewater effectively in order to reduce the risks to human health and the environment that could arise from microbial contamination. Furthermore, measuring microbial density is a useful way to evaluate the effectiveness of wastewater treatment methods and track alterations in microbial populations over time (Ryu *et al.*, 2021).

There is no specific benchmark for categorizing a bacterial isolate as electrogenic. However, electrogenic bacteria are typically defined as bacteria capable of generating an electrical current through their metabolic activity, often through electron transfer mechanisms. These bacteria are often studied for their potential use in microbial fuel cells and their biotechnological applications. Researchers typically confirm the electrogenic capabilities of bacteria isolate through various experimental approaches, such as measuring electrical current production or studying the genes and pathways involved in electron transfer (Schneider *et al.*, 2023).

Electrogenic bacteria have emerged as pivotal entities in the realm of microbial electrochemistry, exhibiting the ability to transfer electrons to electrode surfaces. This research investigated the selection criteria for electrogenic bacteria, particularly focusing on their application in wastewater treatment. The establishment of a 200mV threshold voltage serves as a practical measure to assess the electrogenic potential of bacterial strains. Those capable of meeting or exceeding this benchmark demonstrate promise for electricity generation applications, such as microbial fuel cells (MFCs) and bioelectrochemical systems (Schneider *et al.*, 2023).

In microbial fuel cells, the efficacy of energy conversion from organic matter to electricity is paramount. Bacterial strains achieving higher voltages exhibit enhanced energy extraction capabilities, thereby contributing to greater efficiency in power generation processes. Wastewater environments exhibit considerable variability in terms of composition and physicochemical parameters. The adoption of a 200mV benchmark allows for standardized assessments across diverse conditions, ensuring the selection of adaptable and effective bacterial strains for wastewater treatment applications (Garbini *et al.*, 2023).

Electrogenic bacteria not only hold promise for electricity generation but also exhibit potential in bioremediation and nutrient removal processes. Strains capable of achieving the 200mV criterion offer dual functionality, thereby enhancing both wastewater treatment efficiency and energy production. The utilization of a common benchmark facilitates comparability and collaboration among researchers in the field of electrogenic bacteria. By adhering to the 200mV criterion, consistency in findings and methodologies is ensured across different laboratories and research groups (Garbini *et al.*, 2023).

the adoption of a 200mV voltage benchmark serves as a pragmatic approach for selecting electrogenic bacteria from wastewater. These microorganisms not only represent promising candidates for sustainable energy production but also offer significant potential for improving environmental quality through enhanced wastewater treatment processes.

The results obtained strongly suggest that the isolates can likely be identified as members of the *Bacillus* genus. *Bacillus spp.* represent a well-documented genus of gram-positive, rod-shaped bacteria renowned for their diverse metabolic capabilities. These bacteria are notably recognized for their ability to produce acid, oxidase, urease, and catalase enzymes, indicative of their metabolic versatility. Moreover, they exhibit the capacity to utilize citrate as a carbon source, further highlighting their metabolic adaptability (Barrow *et al.*, 2003).

Bacillus spp. is ubiquitous in various environments, including wastewater, underscoring their resilience and widespread distribution. Previous research has extensively documented their involvement in microbial fuel cell studies due to their inherent metabolic versatility and proficiency in electricity generation through microbial metabolism. The inclusion of *Bacillus spp.* in such investigations is grounded in their ability to thrive in diverse conditions, making them promising candidates for applications in microbial electrochemistry, including wastewater treatment and energy production (Sreelekshmy *et al.*, 2022).

The PCR approach is commonly used for bacterial identification and classification. The 16S rDNA gene is a conserved region in the bacterial genome, and its sequence is unique to each bacterial species. PCR amplification of the 16S rDNA gene, followed by sequence analysis and comparison with a database, is a reliable method for bacterial identification. The use of phylogenetic analysis provides information on the evolutionary relationship between the isolated strain and other bacteria. The constructed phylogenetic tree can help identify the closest relatives of the isolate and provide insights into its evolutionary history. Overall, the results suggest that the bacterial isolate is a strain of *Bacillus cereus* and provide information on its evolutionary relationship to other bacteria. The use of molecular techniques for bacterial identification and classification is a

powerful tool for microbiologists and is becoming increasingly important in clinical and environmental settings (Kumar *et al.*, 2018).

CONCLUSIONS

The process of isolating, screening, and identifying bacteria with electricity-producing potentials was a critical step in our research. By employing techniques such as enrichment cultures, biochemical assays, and molecular biology tools, we identified *Bacillus cereus* strains capable of electron transfer and electricity generation without mediators or electron shuttles. This highlights the importance of microbial diversity in bio-electrochemical systems and lays the groundwork for further exploration and optimization of electricity-producing bacteria.

Exploration of Microbial Diversity: Continuation of efforts to isolate and screen bacteria with electricity-producing potentials should be encouraged. Exploration of diverse environments and ecosystems may uncover novel bacterial strains with superior electrochemical properties.

RECOMMENDATION

Continuation of efforts to isolate and screen bacteria with electricity-producing potentials should be encouraged. Exploration of diverse environments and ecosystems may uncover novel bacterial strains with superior electrochemical properties.

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