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CONTENTS

CONGRESS PROGRAM	33
INVITED SPEAKERS	25
(K-01) DAILY LIFE AND HALAL AWARENESS	
Abdurrahman Haçkalı.....	32
(K-02) TRACEABILITY IN HALAL PRODUCTS AND SERVICES: CONCEPTUAL FRAMEWORK, SCOPE, OPERATION AND SUSTAINABILITY	
Hamzah Mohd Salleh	34
(K-03) ACCREDITATION CRITERIA FOR HALAL CONFORMITY ASSESSMENT BODIES	
Erdem Başdemirci.....	37
(K-04) RECENT DEVELOPMENTS ON OIC/SMIIC HALAL ACCREDITATION AND IFHAB (ISLAMIC FORUM FOR HALAL ACCREDITATION BODIES)	
Zafer Soylu.....	40
(K-05) CONSUMER AND PRODUCER FRIENDLY APPLICATION MODEL: GIDA ÖLÇER®	
Fatih Gültekin, Sümeyye Koç	42
(K-06) EVALUATION OF BIOTECHNOLOGICAL APPROACHES IN FOOD AND FEED PRODUCTION WITHIN THE SCOPE OF HALAL FOOD	
Osman Sağdıç, Şefik Tekle	45
(K-07) ARTIFICIAL MEAT PRODUCTION: FROM THE LABORATORY TO THE TABLE	
Halit Canatan	48
(K-08) ETHYL ALCOHOL USED AS A SOLVENT IN FOODS: ALTERNATIVE METHODS AND SOURCES	
Mehmet Akbulut, Hatice Feyza Akbulut.....	57
(K-09) HALAL CONCEPT HOTEL MANAGEMENT AND STANDARDIZATION AND HALAL TOURISM AND CONSUMER BEHAVIOR	
Orhan Batman	66
(K-10) HALAL TOURISM: A STANDARDIZATION PERSPECTIVE	
Yasin Zülfikaroğlu	72
(K-11) THE CONCEPT OF HALAL AND ISLAMIC FINANCE IN THE CONTEXT OF MAQASID-I SHARIA	
Abdurrahim Kozalı.....	82
(K-12) COMPONENTS OF HALAL FINANCE	
Mustafa Dereci.....	87
(K-13) LIVING LIFE WITH GRACE	
Saadettin Ökten	88
(K-14) ISLAMIC ARCHITECTURE AND ENVIRONMENTAL PSYCHOLOGY	
Navid Khaleghimoghaddam.....	99
(K-15) SACRED PLACES AND PRIVACY IN THE HISTORICAL PROCESS	
Zekiye Sönmez	107

(K-16) POWER AND MORALITY IN SPACE Savaş Ş. Barkçin	109
(K-17) IMPORTANCE OF STANDARDS AND QUALITY INFRASTRUCTURE FOR THE HALAL ECONOMY Ihsan Övüt.....	111
(K-18) NATIONAL EXPERIENCES IN THE HALAL INDUSTRY IN INDONESIA: REGULATORY, LEGISLATIVE AND PRACTICAL EXPERIENCES Mr. Muhammad Aqil Irham.....	112
(K-19) NATIONAL EXPERIENCES IN THE HALAL INDUSTRY IN MALAYSIA: REGULATORY, LEGISLATIVE AND PRACTICAL EXPERIENCES Johari Ab Latiff.....	113
(K-20) CURRENT DEVELOPMENTS IN THE HALAL CONCEPT IN NIGERIA Mohammed Zakir Ibrahim.....	115
(K-21) IMPLEMENTATION OF OIC/SMIIC HALAL STANDARDS IN AFRICA: CURRENT STATUS AND CHALLENGES Abdoul Fathi Sanogo.....	117
(K-22) HEALTHY NUTRITION PRINCIPLES WITH THE CONSIDERATION OF OUR PROPHET'S, MUHAMMED (PUH) PRACTICES Tülay Omma.....	126
(K-23) ANIMAL CELLS-DERIVED SUPPLEMENTS AND BIOPHARMACEUTICALS Seyfullah Oktay Arslan.....	130
(K-24) HALAL COSMETICS: NAVIGATING CHALLENGES AND SEIZING MARKET OPPORTUNITIES Amal A.M. Elgharbawy.....	132
(K-25) HALAL CONCEPT IN HEALTH SERVICE DELIVERY Aminud Che-Ahmad	134

ORAL PRESENTATIONS	141
(S-01) ETHYL ALCOHOL CONTENT IN SOME FERMENTED AND FLAVORED BEVERAGES	
Fatma Nur Gümüş, Hacer Çoklar, Mehmet Akbulut	150
(S-02) DETERMINING THE FACTORS AFFECTING HALALNESS IN THE BOZA PRODUCTION PROCESS	
Nazire Kardelen Tabaklar	157
(S-03) DETERMINATION OF ADULTERATED OLIVE OIL BY GC METHOD	
Abdullah Öksüz, Şenay Burçin Alkan	159
(S-04) DEVELOPMENT OF AN APTASENSOR FOR RAPID AND ON-SITE DETECTION OF PORCINE MEAT	
Mediha Esra Altuntop Yayla, Canan Doğan Ekinci	167
(S-05) EVALUATION OF CULTURED MEAT IN TERMS OF SMIIC HALAL CERTIFICATION APPROACH	
İsra Yiğitvar	169
(S-06) GENOTOXICITY OF SUNFLOWER LECITHIN ON HUMAN PERIPHERAL LYMPHOCYTES	
Doğukan Eroğlu, Selçuk Çeker	175
(S-07) THE IMPORTANCE OF SEAWEED AS FOOD	
Belma Konuklugil	177
(S-08) EXTRACTION METHODS IN FOOD AND EVALUATION OF FOOD EXTRACTS IN TERMS OF HALAL	
Serdar Yeşil, Mehmet Akbulut, Hacer Çoklar	179
(S-09) SPIRITUAL SATISFACTION OR ABSTRACT NUTRITION AS A MEASURE TO PREVENT OVER-EATING	
Hediye Gültekin	186
(S-10) THE RELATIONSHIP BETWEEN NUTRITION AND HEALTH FROM AN ISLAMIC PERSPECTIVE	
Hasan Hüseyin Yıldırım	188
(S-11) ETHICAL EPISTEMOLOGY OF HALAL NUTRITION	
Nurefşan Bulut Uslu	190
(S-12) EFFECTS OF PROTEIN SUPPLEMENTS ON EXERCISE PERFORMANCE AND MUSCLE MASS	
Fatih Gültekin, Kübra İzler, Sümeyye Koç, Ayşe Şeyma Çoban	202
(S-13) CONCEPTS OF HALAL AND HARAM IN THE RELIGIOUS CULTURE AND ETHICS CURRICULUM IN THE CONTEXT OF HALAL AWARENESS FORMATION	
Muharrem Atabay, H. Yusuf Acuner	204

(S-14) A DIFFERENT PERSPECTIVE ON HALAL: EVALUATING EARLY SUFI VIEWS ON HALAL FOOD IN THE CONTEXT OF MORAL COMPETENCE Edibe Taş	206
(S-15) MATERIAL AND SPIRITUAL GENERAL PRINCIPLES OF HALAL TRADE IN ISLAMIC ECONOMIC THOUGHT AND THE ROLE OF HİSBE ORGANIZATION Mehmet Emin Nas	208
(S-16) THE CONTRIBUTION OF THE ATTITUDE OF TAQWA TO THE DEVELOPMENT OF HALAL EARNINGS AWARENESS- AN EVALUATION IN TERMS OF SUFI PSYCHOLOGY İbrahim Işıtan.....	210
(S-17) ETHICS OF DIGITAL COMMUNICATION IN THE BUSINESS WORLD Hasan Fehmi Atasagun, Ayça Gökyer, Ebru Gönülal, Yasemin Fındık	219
(S-18) THE EFFECT OF DIGITAL CONSUMPTION ON WASTE IN THE CONTEXT OF HALAL LIFE Büşra Ökten	229
(S-19) DETERMINING ZAKAT MATRAH FROM THE FINANCIAL STATEMENTS OF COMPANIES WITHIN THE SCOPE OF HALAL EARNINGS Mehmet Ali Durmuş, Yunus Ceran.....	231
(S-20) THE HALAL INDUSTRY: RAPID GROWTH, COMPLEXITIES AND CHALLENGES Sümeyye Aktas, Cengiz Caner, Muhammed Yüceer	233
(S-21) A SWOT ANALYSIS ON HALAL MEDICAL TOURISM MARKET IN TURKIYE Muhammet Raşit Aksoy, Mehmet Yorulmaz, İlhan Çiftçi.....	235
(S-22) RIGOROUS CONTROL OF HALAL BOOSTS TRUST AND IMPROVE HALAL ECOSYSTEM Ali Abd El-Razig Ali Lutfi	237
(S-23) COOPERATION BETWEEN UZBEKISTAN AND TURKEY IN THE CULTURAL SPHERE Imamov Bobir Khojanazarovich.....	239
(S-24) EMPOWERING HALAL INTEGRITY: THE PIVOTAL ROLE OF DIGITAL SOLUTIONS IN ENHANCING CERTIFICATION TRANSPARENCY, EFFICIENCY, AND ACCESSIBILITY Musab Talha Akpınar, Muhammed Emin Karabacak	249
(S-25) ENHANCING HALAL CERTIFICATION VERIFICATION THROUGH THE INTEGRATION OF BLOCKCHAIN AND QUICK-RESPONSE CODE TECHNOLOGY Heesong Koh1, Elif Kübra Övüt.....	258
(S-26) EXAMINATION OF TRACEABILITY SYSTEM IN HALAL QUALITY INFRASTRUCTURE BASED ON OIC/SMIIC STANDARDS Fatma Betül Telliöğlü.....	260
(S-27) THE SCALE OF HALAL CERTIFICATION IN OUR SOCIETY Muhammet Ali Bal, Bahadır Öztürk, Esranur Bal, Hüsamettin Vatansav, Muslu Kazım Körez	262

(S-28) THE ROLE OF DIGITAL MEDIA IN HALAL FOOD IN GERMANY: A REVIEW ON COMPANIES, CERTIFICATES AND MUSLIM CONSUMERS Dilara Sultan Faslak1.....	264
(S-29) CONSIDERATIONS FOR THE HALAL CERTIFICATION OF CULTIVATED MEAT: A SINGAPORE PERSPECTIVE Zalman Putra Ahmad Ali, Nurul Hidayah Abubakar, Izal Mustafa Kamar.....	266
(S-30) IMPLEMENTATION OF OIC/SMIIC HALAL STANDARDS IN AFRICA: CURRENT STATUS AND CHALLENGES Abdoul Fathi Sanogo.....	268
(S-31) HALAL-BASED HEALTHCARE SERVICE: PATIENTS' EXPERIENCES AND CHALLENGES IN PERFORMING SOLAH IN HOSPITAL Ratna Zuhairah Abdul Halim, Sanisah Saidi1, Mohamad Firdaus Mohamad Ismail, Nazri Mohd Yusof, Aminudin Che-Ahmad.....	270
(S-32) KOMBU TEA: FUNCTIONAL PROPERTIES AND HALAL DIMENSION Süleyman Gökmen, Hasan Yetim.....	279
(S-33) THE PLACE OF SUSTAINABLE ANIMAL PROTEIN SOURCES ALTERNATIVES FROM A HALAL FOOD PERSPECTIVE Sümeyra Şahin Bayram.....	281
(S-34) THE EFFECT OF NUTRITION ACCORDING TO TEMPERAMENT ON HEALTHY LIFE Tuğba Kundakçı, Hüsamettin Vatansev.....	287
(S-35) THE INFLUENCE OF BELIEF AND CULTURE ON MUSLIMS' DIETARY BEHAVIORS Hediye Gültekin.....	294
(S-36) THE RELATIONSHIP BETWEEN NUTRITION LABEL READING AWARENESS AND HEALTHY AND HALAL NUTRITIONAL ATTITUDES IN ADULTS Fadime Ovalı, Fatma Şengül, Hüsamettin Vatansev.....	302
(S-37) THE PERSPECTIVE OF HALAL NUTRITION: A HEALTHY AND SUSTAINABLE LIFESTYLE APPROACH Zeynep Erkoç, Solmaz Ece Yılmaz.....	304
(S-38) LEASING AND SUKUK PRACTICES IN THE CONTEXT OF RISK REDUCTION METHODS IN MODERN ISLAMIC FINANCE PRACTICES Yunus Araz.....	306
(S-39) COLLABORATION OF PARTICIPATION FINANCE AND HALAL VALUE CHAIN FROM THE PERSPECTIVE OF RESPONSIBLE INVESTMENT Mahmut Samar, Nafiye Aydın.....	312
(S-40) AN EXAMINATION OF HALAL FINANCE AND HALAL FOOD AS AN INTEGRATED ECOSYSTEM Ömer Faruk Güneşer, Eyyüp Yakup Gedikli.....	314

(S-41) THE ROLE OF FOUNDATIONS IN ISLAMIC SOCIAL FINANCE: ANALYSIS OF INTERACTIONS, CONTRIBUTIONS, AND RELATIONSHIPS WITH FINANCIAL INSTITUTIONS Mehmet Emin Karaaslan.....	316
(S-42) INVESTIGATION OF THE AWARENESS LEVEL OF THE CONCEPT OF HALAL IN PHARMACEUTICALS AMONG HEALTHCARE PROFESSIONALS Fatma Sengul, Fadime Ovali, Husamettin Vatansev.....	318
(S-43) BEAUTY THAT COMES WITH A SMALL BITE Fatma Çoruk, Hüseyin Ayhan	325
(S-44) NAVIGATING HALAL TALENT SUSTAINABILITY INSIGHTS AND STRATEGIES FOR HALAL ECOSYSTEM FROM MALAYSIA'S PERSPECTIVE Norhayati Rafida, Abdul Rahim., Muhammad Nizam, Awang@Ali	327
(S-45) EROSION OF THE CONCEPT OF TREATMENT IN IVF CENTERS AND VIOLATION OF HALAL LIFE LIMITS-THE CASE OF NORTHERN CYPRUS Ülfet Görgülü, Fatma Zehra Özaslan	335
(S-46) HALAL LIFE IN THE DIGITAL WORLD: SOCIAL AWARENESS AND ATTITUDE ANALYSIS Eissa Almaghrebi, Fatma Akat, Hakan Vatansev, Hüsamettin Vatansev.....	337
(S-47) UPDATING THE HALAL STANDARD IN LINE WITH THE GLOBAL BOYCOTT MOVEMENT Adnan A. m Oweida.....	339
(S-48) TRANSFORMATIONAL LEADERSHIP OF PROPHET MUHAMMAD (PBUH) Hasan Fehmi Atasağun, Yasemin Fındık, Ebru Gönülal, Ayça Gökkyer	354
(S-49) ENABLING THE PHILIPPINE HALAL INDUSTRY THROUGH SCIENCE, TECHNOLOGY, AND INNOVATION Sales, Anthony C., Parcon, Ma. Rachel V., Morales, Agnes G., Lamparas, Alma R., Domingo, Mirasol G., Catoera, Christine Esther Flor L.	356
(S-50) INVESTIGATION OF HEPATOTOXICITY IN CHILDREN WITH FATTY LIVER DISEASE Esratur Bal, Hakan Candan, Fuat Buğrul, Meltem Gümüş, Hüsamettin Vatansev, Muhammet Ali Bal.....	358
(S-51) COSMETIC USE AND HALAL PRODUCT PREFERENCES: ANALYSING PARTICIPANT OPINIONS Fatma Akat, Eissa Almaghrebi, Hakan Vatansev, Hüsamettin Vatansev	360
(S-52) COMPARATIVE STUDY OF KAOLIN AND BENTONITE CLAY AS POTENTIAL MATERIALS FOR HALAL SERTU IN HEALTHCARE APPLICATIONS Aminudin Che-Ahmad, Abdul Rahman Al-Azmi, Zuraida Ahmad, Noorasikin Samat, Norshahida Sarifuddin, Mohd Shukrimi Awang	362
(S-53) WHAT DO WE KNOW ABOUT AUTISM SPECTRUM DISORDER AND THE MICROBIOTA AND BRAIN-GUT RELATIONSHIP Behiye Nur Karakuş, Faik Özdengül.....	372

(S-54) HALAL MARKET APPROACHES IN AGRICULTURAL ACTIVITIES AND CONTRIBUTIONS TO THE ECONOMY Tuba Albayrak, Nevzat Artık.....	381
(S-55) HALAL LIVING SPACES IN SEARCH OF 21ST CENTURY PLANNING THEORY Fatiha Nur Terlemez, Rumeysa Yıldız	391
(S-56) HALAL PRACTICES IN ORAL-DENTAL HEALTH AND HYGIENE Hatice Feyza Akbulut	400
(S-57) GAPS AND OPPORTUNITIES IN DELIVERING HALAL EDUCATION AND TRAINING: CASE STUDY OF NEW HALAL SCIENCE DEGREE PROGRAM AT GOVERNMENT COLLEGE UNIVERSITY FAISALABAD, PAKISTAN Muhammad Umair Arshad	402

(S-52) COMPARATIVE STUDY OF KAOLIN AND BENTONITE CLAY AS POTENTIAL MATERIALS FOR HALAL SERTU IN HEALTHCARE APPLICATIONS

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Abstract

This study explores the suitability of kaolin and bentonite clays for halal Sertu solutions in healthcare applications, specifically for equipment cleansing using the spraying technique. Addressing challenges arising from dog and wild boar bites, the research emphasizes adherence to Islamic jurisprudence, utilizing water and specific soils for formulation. Structural properties of kaolin, with its ordered crystal lattice, and bentonite, known for its swelling capabilities, are analyzed through Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD). The study also investigates their morphology using Scanning Electron Microscopy (SEM). Results indicate that kaolin, with its higher crystallinity and organized structure, exhibits enhanced homogeneity and stability in healthcare-relevant solutions. In contrast, bentonite's more disordered structure may pose challenges in achieving uniform dispersion. The findings contribute crucial insights for developing a standardized, halal-compliant Sertu product, aligning with healthcare standards, equipment specifications, and regulatory guidelines for safe and quality industrial applications.

1. INTRODUCTION

The multifaceted issue of dog and wild boar bites requires careful attention in hospitals, addressing both wound treatment challenges and healthcare equipment decontamination. Saliva impurity (*mughallazah najis*) in Islamic jurisprudence necessitates adherence to Halal "Sertu" methods, incorporating healthcare principles. *Sertu* (ritual cleansing) means cleansing something from *mughallazah najis* such as dogs, pigs and their descendants. In Shafi'ie Mazhab, *mughallazah najis* should be cleansed by 7 times of washing which consists of using one time of clean water mixed with clay and followed by six times of clean water. Formulating a Halal *Sertu* involves water and specific soils, such as clay or earth, with considerations for soil type, purity, and the soil-to-water ratio to meet healthcare standards. [1]

There are, however, many negative effects of using soil in the *Sertu* process, especially when it involves cleaning machines or instruments that are sensitive to the soil. Therefore, several literature [2-4] explained the suitable soil used in the *Sertu* process. The use of clay has been proven effective as a tanning agent in this *Sertu* industry because clay is used as an active ingredient in cosmetics because of the high level of absorption of substances such as oil, toxins, and others [5] Four types of physic-chemical properties of clays that need to be considered before using the clay in the halal industry includes; First, the pH must be at an acidic at natural level. Second, the particle size distribution (PSD) of clay must be small and contain no other particles that can cause blockages or scratches to the equipment. Lastly, toxic metals and microbial load must be at a low level and meet the limits allowed in the Malaysian Food Regulations 1985 to ensure it is safe to use [6]. Apart from these properties, most importantly, it must comply with the safety and quality of the products manufactured as well as the regulations and guidelines practiced. Therefore, a specific *Sertu* clay standard for industrial application is needed to meet the

halal requirement as well as meet the specifications of the equipment and machines. The conditions of the soil must be free from *najis*; and not *mustakmal* (soil that had been used for dry ablution) [7]

Types of soil ordinarily used in *sertu* purification include Kaolin Clay, Bentonite Clay, Fuller's Earth, Red Clay, White Clay (China clay), and local clays based on traditions [8 – 10]. Among all, local clay, kaolin clay and bentonite clay are the three materials that are easily available. For commercialization purposes and controlling the properties of the *sertu* product to be produced, the focus of the study is only on kaolin and bentonite.

Kaolin, or China clay, is a soft and white clay mineral primarily composed of kaolinite, a type of alumina silicate. Its presence in various industrial sectors, such as paper, ceramics, and pharmaceuticals, highlights its versatility and safety profile. This type of clay, known for its distinctive white colour and fine particle size, is primarily composed of a composite of kaolinite. The crystal structure of kaolinite is a layered arrangement of tetrahedral silica and octahedral alumina sheets. These layers are held together by weak van der Waals forces and hydrogen bonding, resulting in a relatively low cation exchange capacity. The presence of hydroxyl groups on the surface of kaolinite provides sites for potential interactions with water and other molecules, making it an excellent adsorbent material. This unique structure contributes to its stable and non-swelling nature, making it particularly suitable for applications where controlled stability is required, such as in pharmaceutical formulations and cosmetic products [11].

On the other hand, Bentonite is a porous clay with a high percentage of montmorillonite, endowing it with exceptional swelling and absorbing capabilities. These properties make Bentonite an essential component in various applications, including drilling fluids, adsorbents, and even cosmetics. Bentonite, characterized by its high content of montmorillonite, exhibits a more complex and expandable crystal structure. Montmorillonite belongs to the smectite group of clay minerals, featuring a three-layered structure consisting of two tetrahedral silica sheets sandwiching an octahedral alumina sheet. The layered structure of montmorillonite is responsible for its exceptional swelling capacity when exposed to water, allowing it to expand several times its original volume. The interlayer spaces between the layers provide sites for the absorption of water molecules and other cations, resulting in a higher cation exchange capacity compared to Kaolin. This unique structural feature gives Bentonite its remarkable water-absorbing properties, making it valuable for applications requiring high moisture retention, such as in drilling fluids and cat litter [10].

In the context of the spraying technique for clay solutions, it is imperative to consider specific solution characteristics to prevent nozzle clogging and adhere to the *Sertu* standard, which stipulates a 2.5% composition of clay from the total mixture of clay and liquid. To ensure optimal performance, the solution should exhibit a homogeneous consistency that avoids the formation of clumps or blockages in the spraying mechanism. Furthermore, the selected clay concentration needs to align with the *Sertu* standard, striking a balance between effective cleansing properties and compliance with the specified percentage. This meticulous approach ensures that the sprayed clay solution remains uniform, user-friendly, and meets the stringent standards set by *Sertu* for healthcare applications.

Therefore, the research seeks to compare the suitability of kaolin and bentonite soils in a *sertu* process, specifically in a spraying application adhering to *sertu* standards. The primary goal is to formulate a *sertu* product that ensures effective equipment cleansing while prioritizing user-friendliness and compliance with halal standards. Given machinery sensitivity to soil, selecting an appropriate soil type is crucial. The proposed spraying application necessitates a comprehensive study of the homogeneity and stability of the solution. Additionally, it is imperative to maintain a clay composition of more than 2.5% in the solution to meet *sertu* standards. This research aims to contribute insights for developing a standardized, halal-compliant *sertu* product that aligns with equipment specifications and regulatory guidelines, ensuring safety and quality in its industrial application

2. MATERIALS

Kaolin and bentonite clays were obtained from Morning Prestige Trading. The clays were in the form of a fine powder, and its purity was verified using X-ray diffraction (XRD) analysis. Analytical grade solvents, such as Sodium Lauryl Ether Sulfate (SLES), paraben, deionized water and ethanol were also obtained from Morning Prestige Trading and were used for the preparation of clay pastes.

3. METHODOLOGY

3.1 Characterisation

The mineralogical composition and crystalline structure of both Kaolin and Bentonite clays were determined using an X-ray diffractometer (XRD) (D2 Phaser, Bruker). The clays were subjected to X-ray diffraction, and the resulting diffraction patterns were analyzed to identify the crystal phases present in each clay. Scanning Electron Microscopy (SEM) (JSM 5600, JEOL) was used to analyze the particle size distribution and surface morphology of the clays. Zeta potential measurements were carried out by the Nano-ZS model (Malvern) zetasizer instrument. Fourier Transform Infra-Red (FTIR) spectroscopy (Perkin Elmer 100 Series), characterized by a 4 cm^{-1} resolution and 32 scans within the spectral range of $1000 - 4000\text{ cm}^{-1}$.

3.2 Preparation

Kaolin and Bentonite clays were mixed with deionized water to form a homogenous paste. The water-to-clay ratio was optimized based on initial rheological studies to achieve a stable and workable consistency.

3.3 Paste Stability Evaluation

The homogeneity of each paste was visually inspected, looking for any signs of phase separation or agglomeration of particles and the consistency of the pastes. The stability of each paste was evaluated over a designated period, and changes in consistency and other physical properties were monitored at regular intervals.

4. RESULTS AND DISCUSSION

4.1 Physical Properties

The kaolin and bentonite clay in powder form. Upon visual inspection and tactile examination, bentonite and kaolin exhibit distinct physical properties discernible to the naked eye when it is touched. Bentonite typically presents itself in light grey, featuring a smooth and slightly slippery texture. In its dry form, bentonite manifests as a fine powder, while in a wet state, it transforms into a sticky, mouldable consistency. The visual appearance is granular and powdery, with a glossy sheen when wet. Conversely, kaolin is characterized by its pure white, offering a soft and silky texture akin to chalk. In its dry state, kaolin appears as a fine powder, transforming into a smooth paste when wet. The visual presentation of kaolin is velvety and smooth, providing a matte finish when wet.

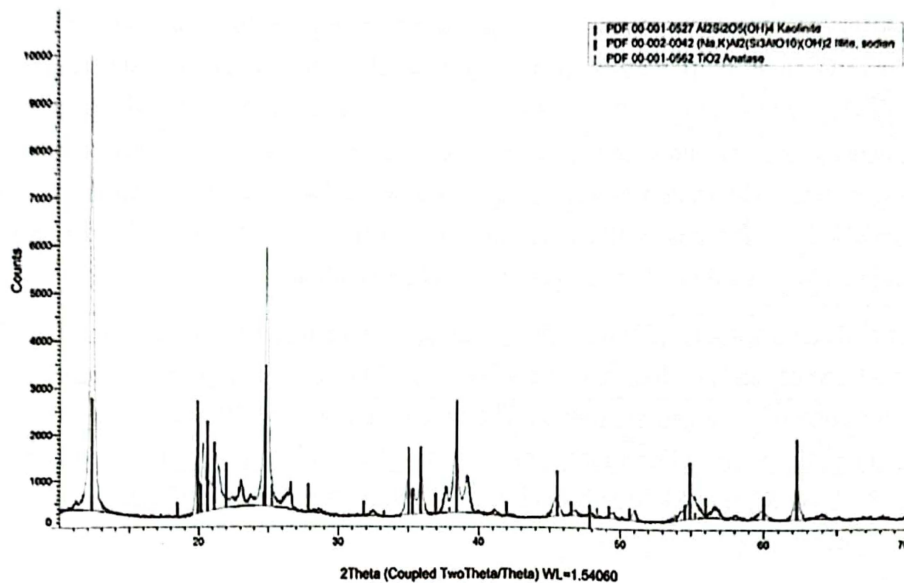
4.2 Characterisation

4.2.1 X-ray Diffraction (XRD) Analyses

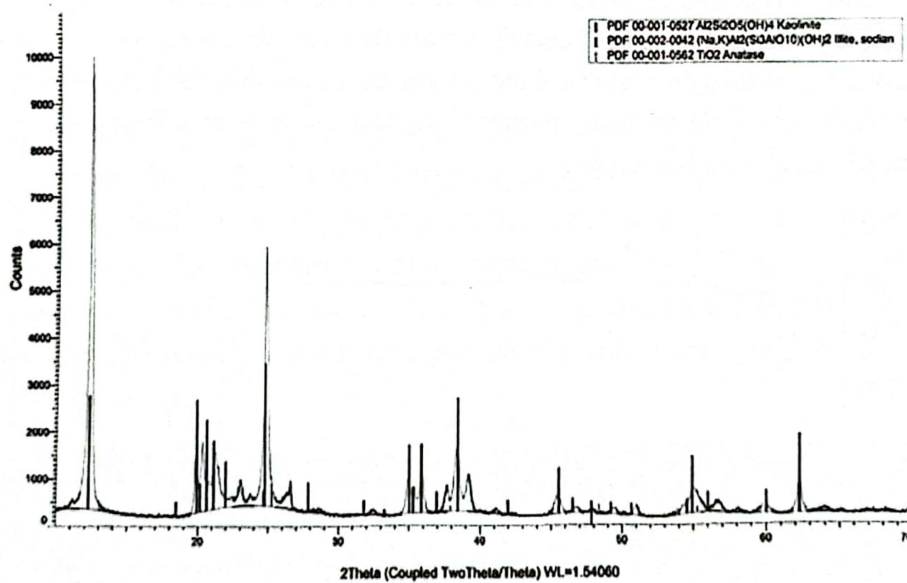
X-ray Diffraction (XRD) analysis unveils the distinct mineral composition of kaolin and bentonite by emphasizing critical peaks in their respective patterns. Figure 2(a) for the kaolin diffraction pattern exhibits a well-defined peak at specific angles, notably around 12.4° and 24.8° (2 θ). These peaks signify the presence of kaolinite, emphasizing the dominant mineral in kaolin. Conversely, bentonite, in Figure 2(b), enriched displays key peaks around 5.2° , 19.2° , and 29.6° (2 θ). These peaks highlight the mineral composition, especially the prevalence of montmorillonite. The broader and less intense nature of these peaks reflects the more disordered crystal structure inherent in bentonite. Variability in peak shapes and positions underscores the diverse minerals contributing to bentonite's composition. The XRD analyses provide insights into the mineral composition and crystalline

structure of kaolin and bentonite. This information is crucial in ensuring the absence of prohibited substances, as it allows for the identification and confirmation of the specific minerals present.

It can be seen from Figure 2(a), that the characteristic of the peak for kaolin is sharper, more intense, and narrower, suggesting a well-ordered crystal lattice compared to bentonite in Figure 2(b) signifying greater crystallinity. An increased number of symmetric peaks at specific angles, along with their distinct shapes add up to confirm it.



(a)



(b)

Figure 3: X-ray Diffraction pattern for (a) Kaolin (b) Bentonite

In general, kaolin tends to exhibit higher crystallinity compared to bentonite. Crystallinity refers to the degree of organization and order within the crystal lattice structure of a mineral. Kaolin, composed mainly of kaolinite, often features a well-organized, ordered crystal lattice, contributing to its high crystallinity [8-9]. Bentonite, on the other hand, is a group of clay minerals, primarily composed of montmorillonite, which has a more complex structure. Bentonite minerals can have variable crystallinity, but they generally exhibit a more disordered structure compared to kaolin. The presence of additional minerals and the unique layering characteristics of bentonite contribute to its lower overall crystallinity compared to kaolin [10].

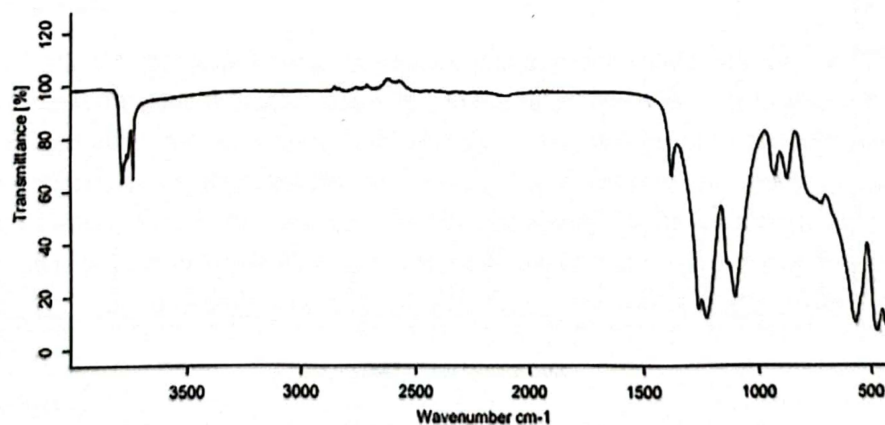
This high crystallinity in kaolin promotes uniform dispersion, enhancing homogeneity and solution stability over time. In contrast, bentonite, primarily composed of montmorillonite, exhibits lower crystallinity due to its complex and disordered structure. This structural variability can lead to less uniform dispersion, potentially impacting homogeneity and solution stability.

4.2.2 Fourier Transformation Infra-Red (FTIR)

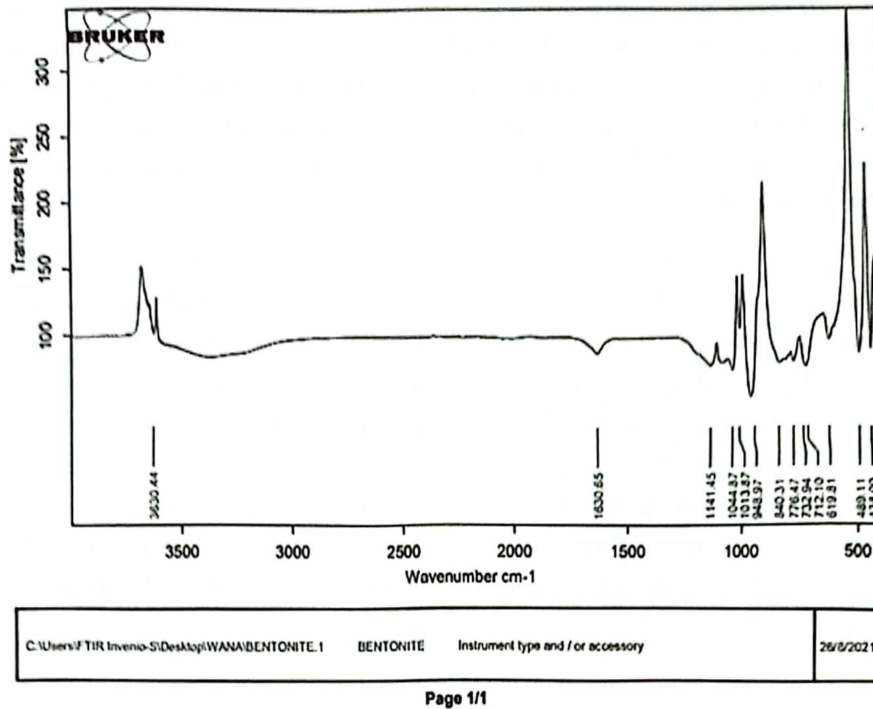
In the presented Fourier Transform Infrared (FTIR) spectrum (Figure 3(a)), characteristic absorption bands corresponding to OH (hydroxyl) groups in the kaolinite clay showed distinct appearance. Notably, four well-defined bands at 3700, 3670, 3650, and 3620 cm^{-1} indicate an ordered kaolinite structure. This ordered arrangement enhances stability and unique properties. Conversely, a disordered structure lacks the 3670 cm^{-1} band, suggesting higher dehydration susceptibility. P0 index calculations (3620 cm^{-1} to 3700 cm^{-1} ratio) confirm the ordered nature of the kaolinite structure ($P0 = 1.121 > 1$). This structural order promises enhanced homogeneity and solution stability when integrated into other solutions.

The FTIR spectra of raw bentonite (Figure 3(b)) reveal key mineral phases present in the clay. The absorption band at 3657 cm^{-1} corresponds to the stretching vibrations of structural OH groups coordinated to Al-Al pairs, indicating the presence of hydrated aluminum. The broad band around 1030 cm^{-1} signifies Si-O stretching vibrations, characteristic of the silica framework in bentonite. Additionally, bands at 520 and 468 cm^{-1} are related to Al-O-Si, Si-O-Si, and Si-O deformations, suggesting the presence of aluminum and silicon bonds within the clay structure.

Compared to kaolin, bentonite exhibits a different structural composition and arrangement. While kaolin typically features well-defined absorption bands indicating an ordered crystal lattice, bentonite tends to exhibit broader bands due to its more disordered structure. This structural difference affects the homogeneity and solution stability of bentonite-containing solutions. Bentonite's more disordered structure allows for greater surface area and porosity, enhancing its ability to absorb and retain water and other molecules. However, this can also result in less uniform dispersion within solutions, potentially impacting homogeneity. Therefore, for the purpose of producing Sertu solution, kaolin is preferable.



(a)

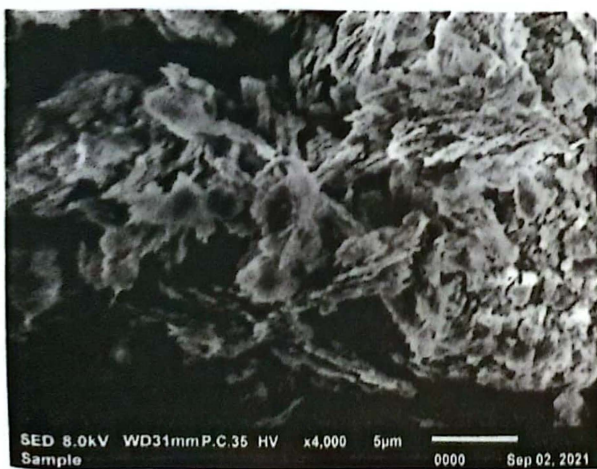


(b)

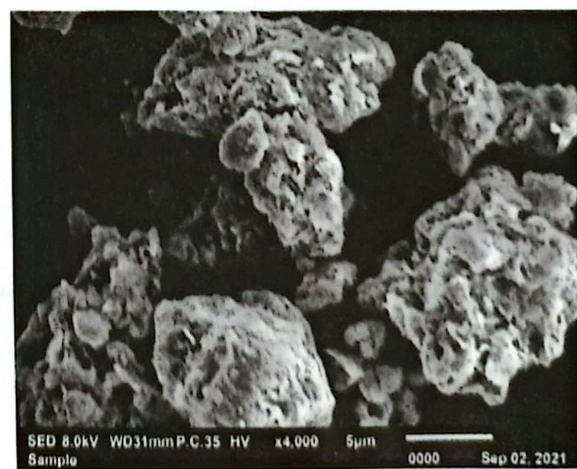
Figure 3: FTIR spectra of (a) Kaolin and (b) Bentonite

4.2.3 Scanning Electron Microscope

Scanning Electron Microscopy (SEM) serves as a valuable tool in corroborating and enhancing the characterization obtained through Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD) analyses. FTIR provides insights into molecular vibrations and chemical compositions, while XRD reveals crystalline structures within materials. SEM complements these techniques by offering a high-resolution visual examination of the surface morphology and microstructure to enables us to validate and further understand the physical attributes and arrangements of particles, confirming the outcomes derived from FTIR and XRD analyses.



(a)



(b)

Figure 4: Scanning Electron Micrograph for (a) Kaolin (b) Bentonite

Figures 4(a) and 4(b) reveal the microstructure of kaolin and bentonite showing intricate details that define their unique characteristics. Kaolin (Figure 4(a)) exhibits a smooth surface with fine particles, showcasing its well-ordered hexagonal crystal structure. The micrographs capture the organized arrangement layers, providing insights into its compact and uniform composition. In contrast, bentonite (Figure 4(b)) displays a more granular and layered appearance. The SEM images unveil the stacked, plate-like layers, showcasing the characteristic “house of cards” arrangement.

These visualizations allow for a closer examination of the microstructural intricacies that underlie the diverse properties and applications of kaolin and bentonite that affect the stability and homogeneity once they are in solution. The organized arrangement of particles in Kaolin allows for uniform dispersion, promoting stability over time. While the layered structure in bentonite enhances the material’s swelling and adsorption capacities, it can also lead to challenges in achieving uniform dispersion. The plate-like particles may tend to stack or aggregate, potentially influencing the stability and homogeneity of the solution. Therefore, the microstructural differences between kaolin and bentonite play a crucial role in dictating the behavior of these clays within the sertu solution. Since focus of the study is to produce sprayed sertu solution, stability and homogeneity of the solution is vital to ensure the percentage of clay in the solution is maintained to not less than 2.5% from the total mixture of soil and liquid.

4.2.4 Zeta Potential

The zeta potential is a key parameter in understanding the stability and behavior of colloidal particles, including clay minerals like kaolin and bentonite. Zeta potential represents the electric charge at the slipping plane of the particle and influences the particle’s dispersion and interactions in a solution. In the context of kaolin and bentonite, measuring their zeta potential provides insights into their stability, dispersibility, and potential agglomeration. For kaolin, a high negative zeta potential is often observed due to the presence of hydroxyl groups on its surface, contributing to repulsion between particles. This repulsion helps maintain the dispersion of kaolin particles, resulting in a more stable solution. Bentonite, on the other hand, may exhibit a more variable zeta potential depending on factors like pH and the presence of ions in the solution. The high surface area and charged sites on bentonite particles can lead to interactions that influence the zeta potential. Understanding the zeta potential of bentonite is crucial for predicting its behaviour in various applications, including sertu processes.

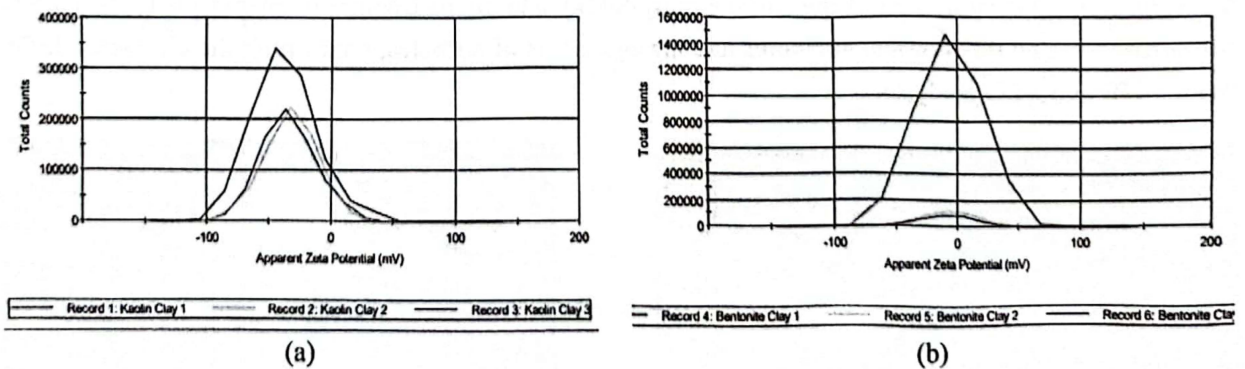


Figure 5: Zeta potential distribution of (a) Kaolin and (b) Bentonite

Zeta potential measurements offer valuable insights into the colloidal stability of kaolin and bentonite, aiding in the optimization of formulations and processes where these clay minerals are utilized. From Figures 5(a) and (b), the average zeta potential value for kaolin is -34.3 mV (-33.8 mV, -32.2 mV, and -37.3 mV for the red, green, and blue lines, respectively) and bentonite is -6.96 mV (-6.49 mV, -6.40 mV, and -8.00 mV for the red, green, and blue lines, respectively). According to Naval et al. (2019), [12], stable nanoparticles without the formation of aggregation in a colloidal suspension system could be achieved if the nanoparticles have a zeta potential of

more than +30 mV or less than -30 mV. In contrast, the nanoparticles that possess values between -30 mV and +30 mV will show flocculation, agglomeration, or aggregation. Therefore, from the zeta potential values, the kaolin exhibited better colloidal stability than the kaolin.

4.2.5 Solution Stability

We demonstrate the solution stability of kaolin and bentonite over six months. In the case of kaolin, the stability is evident, showcasing a consistent and uniform dispersion of particles without significant changes in properties. The well-ordered crystal lattice structure of kaolin contributes to this stability, preventing agglomeration or settling of particles. On the other hand, it indicates a less stable solution for bentonite after the same duration. The more disordered structure of bentonite, coupled with its higher swelling capacity, may lead to uneven dispersion and settling of plate-like particles. This difference in stability highlights the distinct behaviors of kaolin and bentonite in solutions over an extended period, emphasizing the importance of choosing the right clay for specific applications, such as Shariah-compliant *Sertu* solutions.

5. CONCLUSION

In summary, the study extensively compared kaolin and bentonite for potential use in halal *sertu* solutions for equipment cleansing in the healthcare industry. Physical examinations revealed distinct appearances, with bentonite presenting a light grey, smooth texture, and moldable consistency, while kaolin exhibited a pure white color and a soft, chalk-like texture. Advanced characterizations through FTIR, XRD, SEM, and zeta potential emphasized the ordered structure of kaolin (kaolinite) promoting stability, in contrast to bentonite's disordered structure affecting homogeneity differently. Kaolin demonstrated higher crystallinity, finer particle size distribution, and better solution stability over six months, showcasing its suitability for *sertu* applications. These findings offer crucial insights for selecting the appropriate clay for Shariah-compliant healthcare solutions, ensuring optimal performance and stability over time.

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