The Exploring Spodumene as a Key Ingredient to Extend the Usage Life of Shiwan Kiln Earthenware

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Abstracts

Although Shiwan Kiln pottery is China's intangible cultural heritage, it encounters problems such as seepage, short usage life, due to using quartz sand materials. For these reasons, it is impractical for daily use and has limited application, especially in modern society. The research objectives were to: 1) Improve the anti-leakage properties of Shiwan Kiln pots and 2) make them more durable. This study employed an experimental approach by: 1) Creating nine Kiln pots using the traditional materials composed of quartz sand, mud at high sintering temperature and tested them; 2) Explored and analyzed the properties of bentonite, cordierite, spodumene, and alumina as alternative materials to quartz sand by making Total of 12 samples;3) Selected the most suitable material and created additional 18 samples to test the validity of the material 4) The impact of experimental firing methods on pots.

The results show that after authoritative testing, spodumene ceramics demonstrated low water absorption of 0.3%, excellent thermal shock resistance and environmental compliance; its ceramic strength, density and corrosion resistance increased by 30%, 20% and 20%, respectively. 15%. These results provide a critical scientific basis for the material selection and production process optimization of Shiwan kiln pottery pots, thereby significantly improving the leakage prevention and durability of the products. This research provides new possibilities and a practical basis for technological innovation of Shiwan kiln ceramic production.

Keywords: Exploring Spodumene; A Key Ingredient to Extend; Durability in Shiwan Kiln Pottery; Optimized Firing Temperature; Craft Innovation; Traditional Earthenware.

Introduction

Shiwan Kiln, located in Shiwan Town (Naishen et al., 1980), Foshan City, Guangdong Province (Lingling, 1987), has a history of more than one thousand years of ceramic manufacturing (Wenjin, 2017). Since the Tang and Song Dynasties, this ancient pottery craft has been passed down in the land of Shiwan (Jiaren, 1995). During the Ming and Qing dynasties, Shiwan Kiln's daily-use ceramic pots peaked (Weiwen, 2015), making its status prominent throughout the country (Menghan, 2017). Shiwan Kiln ranks alongside Jiangsu Yixing and Shanxi Pingding. The title of "Three Ding Jia" and the saying "Shiwan tiles are the best in the world" are enough to show its essential position in the ceramic manufacturing industry (Dajun, n.d.).

(Yuzi, 2014) The traditional process uses quartz sand, which provides clay pot strength and thermal conductivity (Pierce, 2005). However, due to the high melting point of quartz sand

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and insufficient firing temperature, the pores in the microstructure make clay pots more susceptible to short usage lives and water seepage (Hein et al., 2009). Due to these problems, its market share gradually declined and was replaced by modern industrial products made using materials such as aluminium and stainless steel, which are more durable and practical (Abbott, 2009; Xinliang, 2019).

Thus, to pass on the legacy of Shiwan Kiln, finding new materials to replace quartz sand to improve the sealing and durability of clay pots has become a significant challenge.

The following experiments were conducted: (1) Used traditional quartz sand at varying firing temperatures to measure the Kiln pots usage properties ; (2) Explored and analyzed substitute materials to quartz sand such as bentonite, clinker, cordierite, spodumene, and alumina; (3) From the most suitable material tested, determined the optimal ratio, firing temperature, and firing method that was able to extend product usage life and solve the water seepage issue.

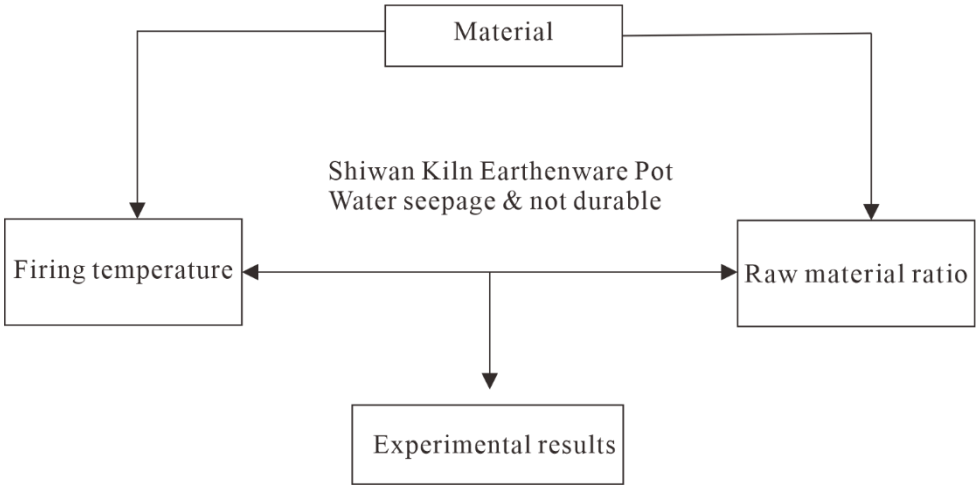


Figure 1. Research Framework.

Research Objectives

1. Improve the water leakage resistance of Shiwan kiln ceramics: by optimizing materials and production processes, reduce the water leakage rate of Shiwan kiln ceramics and make them more reliable during use (Pierce, 2005).

2. Improve the durability of Shiwan kiln ceramics: explore new materials and production methods to improve the durability of Shiwan kiln ceramics so that they can maintain good performance in long-term use.

Research Methodology

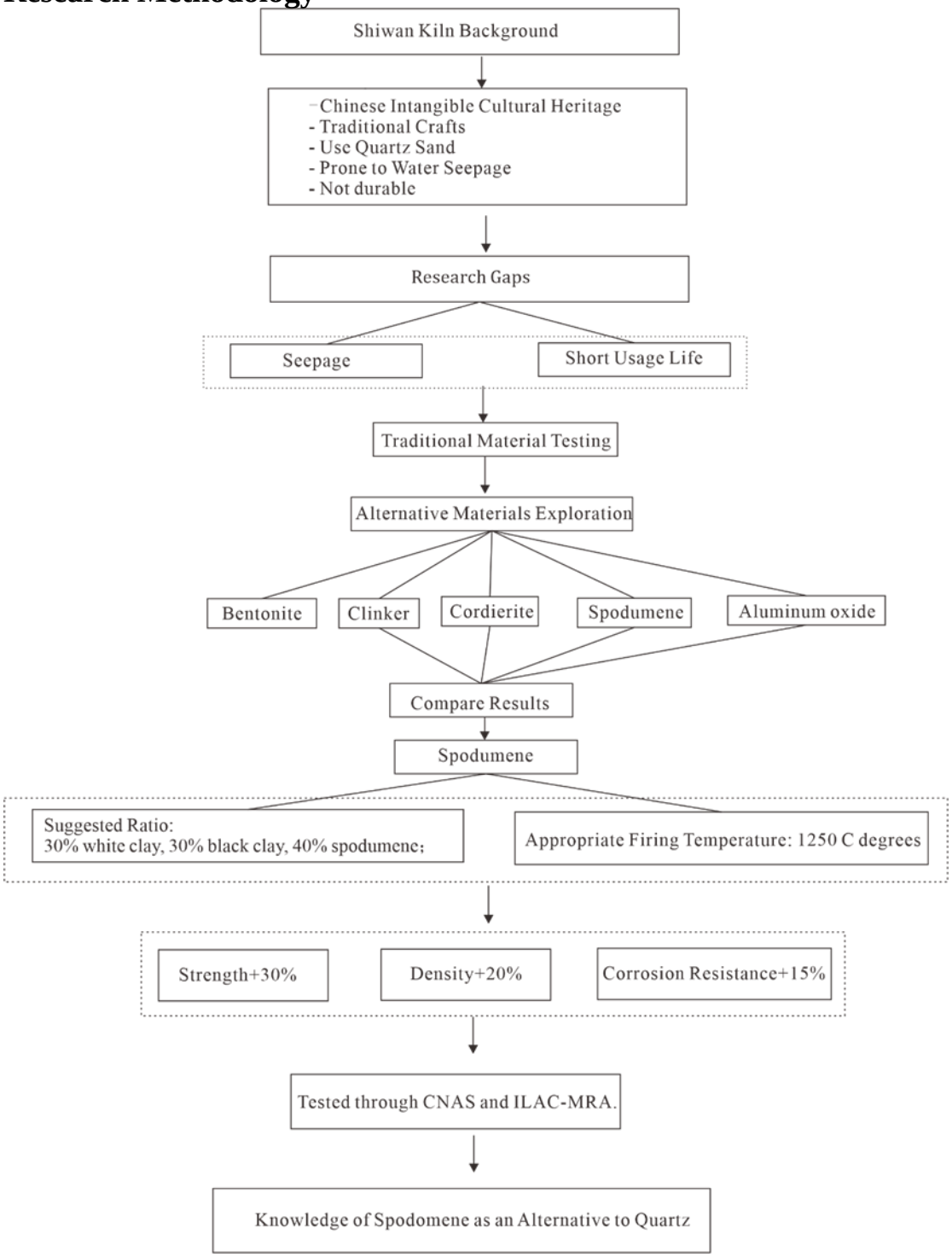


Figure 2. The research path of using spodumene to improve the performance of Shiwan kiln Kiln Earthenware .

In order to improve the durability and permeability of cultural heritage Shiwan Kiln pots, this study designed a research framework based on quantitative experiments (Lewin, 2005). First, a comprehensive evaluation was conducted using quartz sand as a traditional material benchmark. Subsequently, the properties of various potential alternative materials, such as bentonite, cordierite, alumina and spodumene, were examined through multiple comparative experiments. After a series of systematic comparative experiments, this study finally confirmed an optimized material combination scheme: 30% white clay, 30% black clay, and 40% spodumene(Colombo et al., 2010; Hein et al., 2009) . At the same time, the firing temperature was accurately determined to be 1250° C. This research method has obtained authoritative certifications from CNAS and ILAC-MRA. The experimental results clearly show that spodumene can effectively improve the mechanical strength (increased by 30%) and density (increased by 30%) of pottery pots compared with traditional quartz sand materials. 20%) and corrosion resistance (15% increase). This optimized research methodology not only has experimental accuracy but also has academic generalizable value.

Source of Data

The data of this study mainly consists of experimental results obtained in a designed and strictly controlled experimental environment. All experiments were performed under preset conditions to ensure data consistency and reliability. It is particularly worth noting that these experimental results have been certified by the China National Accreditation Service (CNAS) and the International Laboratory Accreditation Cooperation-Mutual Recognition Agreement (ILAC-MRA) (reference Figure 10), further enhancing the reliability of the research and legality. In addition, the research design and data analysis also referred to existing academic literature to ensure that the research results are in dialogue with and referential to the broader academic system.

Population and sample

This study aims to comprehensively and in-depth explore the performance of ceramic products in various performance indicators, so a comprehensive sample set consisting of 42 ceramic test pieces was constructed. The sample is divided into two groups, allowing for precise analysis of multi-dimensional and multi-level performance characteristics.

Methodologically, as a baseline control group, this study first manufactured nine kiln pots using traditional materials such as quartz sand and mud.

Further, the experimental group was constructed based on four representative alternative materials: bentonite, cordierite, spodumene, and alumina. For each alternative material, 3 test pieces were prepared for 12 pieces.

In addition, given that spodumene may exhibit unique advantages on specific performance parameters, we specially designed three configurations with different spodumene ratios and produced 3 test pieces each, thus adding 18 subgroup samples.

This study included 42 ceramic test pieces tested for thermal performance at three predetermined temperature points. The three temperature test designs not only help reveal the performance of materials in different temperature environments but also improve the universality and comparability of research results.

This study adopted rigorous sampling and experimental design to ensure the reliability and applicability of the research results.

Data Collection

Methodological framework

This study collected quantitative data through a systematic laboratory testing method to evaluate multiple performance indicators of ceramic samples at different sintering temperatures and compositional configurations, including sintering performance, water absorption, and thermal stability.

Materials and sample configuration

The experimental design covers two main parts:

1. Traditional sintering materials: 9 samples were prepared according to traditional methods using Dongguan black mud (30%), white mud (30%) and quartz sand (40%). The sintering performance of the samples was evaluated at three different temperature points (1230 ° C, 1250° C, and 1280° C).

2. Alternative sintering materials: 15 samples were prepared, including spodumene, bentonite, clinker, cordierite and alumina. Samples were evaluated for performance at three predetermined temperatures (1200° C, 1230° C, 1250° C).

Experimental design details

3. Optimized configuration of spodumene: A quantitative analysis of spodumene was conducted under different sintering temperatures and configuration schemes.

4. Comparison of sintering methods: Under the optimal configuration of spodumene and the optimal sintering temperature, a comprehensive evaluation of the two oxidation and reduction sintering methods was conducted.

Data sources and testing environment

Local suppliers in Foshan provide all raw materials. Experiments were conducted in a controlled laboratory environment to ensure data reliability. Specific evaluation plans include thermal stability testing of clay pots after heating with a gas stove and water absorption and seepage testing 12 hours after filling with water.

Through this rigorous experimental design and data collection strategy, this study aims to provide a comprehensive and scientific evaluation of the performance of ceramic articles under different materials and sintering conditions. This will help make more reasonable and efficient choices in the ceramic field and related engineering applications.

Data analysis

1. Evaluation of water seepage and durability of traditional materials at different sintering temperatures

methodology

Three different sintering temperatures (1230° C, 1250° C, 1280° C) were used to evaluate the properties of 9 ceramic samples composed of Dongguan black mud (30%), white mud (30%) and quartz sand (40%). Evaluate.

results and analysis

a.1230° C: Insufficient sintering results in excessive water absorption and fails to meet the preset standard.

b. At 1250° C, the degree of sintering increases, and the water absorption rate decreases. However, after 12 hours of observation, there is still apparent water seepage.

c.1280° C: The clay is over-sintered, and the appearance of tiny bubbles indicates that the temperature is too high.

Conclusion: Traditional materials cannot significantly improve their water seepage and durability problems within the temperature range examined by adjusting the sintering temperature.

2. Feasibility analysis of replacing quartz sand

methodology

Fifteen ceramic samples containing alternative materials such as bentonite, cordierite, Spodumene and alumina were prepared, sintered, and performance tested at 1200° C, 1230° C and 1250° C.

results and analysis

a. Spodumene exhibits significant sintering advantages in the range of 1230° -1250 ° C, especially at 1250° C.

b. Other investigated materials failed to be effectively sintered within this temperature range.

Conclusion: Spodumene has significant advantages and provides a theoretical basis for further research and application.

3. Quantitative evaluation of spodumene performance under different configurations

methodology

The performance of Spodumene in three different configurations was quantitatively evaluated at temperatures of 1200° C, 1230° C, and 1250° C.

Results and analysis

a. Degree of sintering: Spodumene has a lower temperature and excellent thermal stability.

b. Thermal shock resistance: Spodumene performs well in the cold and hot water exchange tests at 180℃-20℃.

c. Water absorption: only 0.3%, in line with acceptable porcelain standards.

d. Lead and chromium migration rate: in line with environmental protection standards.

Conclusion: Spodumene excels in multiple performance indicators, especially thermal performance and environmental friendliness.

4. Impact assessment of different firing methods

methodology

Two different firing environments, oxidative firing and reduction firing, were compared.

results and analysis

a. Sintering degree and plasticity: Neither sintering method significantly impacts these performance indicators.

b. colour and texture: There are apparent differences.

Conclusion: Although the firing method has little effect on the fundamental physical properties of ceramics, there may be differences in aesthetics and usage experience.

In summary, this study provides an in-depth analysis of multiple aspects of ceramic properties under different materials and firing conditions, providing rich data and theoretical solid support for improving and applying ceramic materials.

Results

Summary of research results

Summary of research resultsIn order to improve the leakage resistance and durability of Shiwan Kiln pots, this chapter comprehensively evaluates their performance through sophisticated experimental design. Initial tests have shown that simply increasing the firing temperature of traditional quartz sand materials does not effectively solve water seepage and durability issues. Further comparative analysis examined four alternatives to quartz sand and showed that spodumene had the best thermal stability. By optimizing the proportion of spodumene and the sintering temperature configuration, the anti-leakage performance and durability of the clay pot were successfully improved

In addition, through comparative analysis of oxidation and reduction firing methods, we found that the two have no significant difference in the technological performance of pottery pots. However, they can significantly affect their colour and texture, opening up a new way for product aesthetic diversification.

Based on these experimental results, this study provides a practical technical optimization solution for Shiwan kiln ceramics, which has significant application value.

Evaluation of water seepage and durability of traditional quartz sand materials at different sintering temperatures

Regarding the water seepage and lack of durability of clay pots caused by the traditional recipe of Shiwan kiln using quartz sand, this study first considers whether it can be improved by improving the firing temperature. This section provides an in-depth analysis of the performance and durability of nine samples sintered at three different temperatures (1230 ° , 1250° , 1280°). The sample was prepared according to the traditional proportioning method, with three main components: Dongguan black mud (30%), white mud (30%) and quartz sand (40%). It is worth noting that all experimental materials were provided by suppliers and originated from Foshan.

Table 1 Analysis of the main chemical composition and combustion volume of three ceramic raw materials (black clay, white clay and quartz sand)

Raw material	Silicon oxide	Aluminum oxide	iron oxide	Calcium Oxide	magnesium oxide	potassium oxide	Sodium oxide	Burning amount
black mud	45.2	35.49	0.78	10.40	0.27	1.50	0.50	15.50
white clay	57.86	26.18	2.72	0.26	0.48	3.41		8.82
Quartz sand	85.25	10.74	0.28	0.26	0.16			3.52

Table 1 shows the main oxide compositions of three different ceramic raw materials (black clay, white clay, and quartz sand), including silicon oxides, aluminum oxides, iron oxides, calcium oxides, magnesium oxides, potassium oxides, and The per cent composition of sodium oxide, and the amount of each material burned. These data provide an essential basis for further understanding the role of raw materials in ceramic production.

Analysis of results:

At a temperature of 1230° : the degree of sintering is low, and the water absorption rate is too high, which does not meet the expected standard. (Refer to Figure 3)

At a temperature of 1250° : the degree of sintering increases and the water absorption decreases accordingly. However, after 12 hours of observation, it was found that the water seepage was severe, and the desired effect was not yet achieved. (Refer to Figure 4)

At a temperature of 1280° : The clay is over-burned, and the appearance of tiny bubbles indicates that the clay cannot withstand higher temperatures. (Refer to Figure 5)

towards increase the import and export; improve accessibility; leading job hopping, and 9/10/11 of total 12 respondents gave negative opinions respectively towards undermine social security and stability; living expenses pressure; deteriorate the environment.) And budget and finance potential is the same, the results are not significant.

Figure 3. Sintering and water absorption of traditional material experimental quartz sand pottery pots at 1230° C

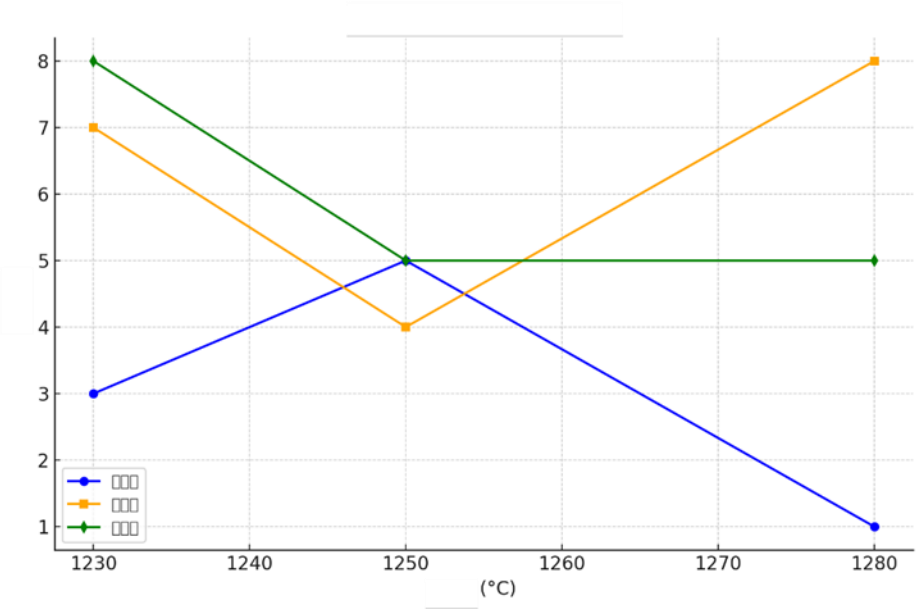
A pot made of 30% Dongguan black mud, 30% white mud, and 40% quartz sand (the experimental materials are all locally sourced) has a low sintering degree and high water absorption rate at a temperature of 1230°, failing to meet the expected standards. You can see from the picture that there is noticeable water seepage at the bottom of the pot.

Figure 4.Traditional materials experiment: sintering and water absorption of quartz sand clay pots at 1250°C

Under the traditional formula, the firing temperature is 1250°C, the sintering degree increases, and the water absorption rate decreases. However, after 12 hours of observation after water injection, there was severe water seepage at the bottom, cracking occurred after 200 times of boiling water over an open flame, and the durability was not high.

Figure 5. Over burning and foaming of Dongguan black mud, white mud and quartz sand pots at 1280° C

The traditional formula is fired at 1280° C, and you can see bubbling on the surface of the can. It shows that the mud cannot withstand this temperature, and the limit of the mud combination at a specific temperature can be confirmed, which provides the necessary reference for selecting the appropriate sintering temperature.



- The blue line indicates the degree of sintering
- Orange line indicates water absorption
- The green line represents the water permeability

Figure 6. Traditional quartz sand formula analysis of the effect of temperature on sintering degree, water absorption and permeability.

This figure shows the changes in the degree of sintering, water absorption and permeability of clay using quartz sand as a traditional formulation at three different temperatures (1230° , 1250° and 1280°).Through a comprehensive performance and durability evaluation of nine samples sintered at different temperatures (1230° , 1250° , 1280 °), this study points out that the traditional quartz sand formula cannot effectively solve the problems of water seepage and non-durability of the product. Especially at a temperature of 1250° , although the degree of sintering has increased and the water absorption rate has decreased, it was found that the water seepage problem was still serious after 12 hours of observation. In addition, at a temperature of 1280° C, excessive combustion and tiny bubbles occurred in the clay, indicating that the clay material could not withstand higher temperatures, further limiting its application range.

Based on the above analysis, these two core problems cannot be comprehensively solved only by increasing the sintering temperature. Therefore, finding an alternative refractory material that can be sintered at a temperature of about 1250° is an urgent problem for research.

The application value and sintering performance of spodumene in solving leakage and durability problems

In the search for viable alternatives to quartz sand, various materials, including bentonite, cordierite, spodumene and alumina, were selected for testing due to their excellent thermal stability. This section provides an in-depth analysis of the core findings and analyses during these experiments. A total of 12 samples were prepared, three of each alternative material. The samples were fired, and performance was evaluated at 1200° C, 1230° C and 1250° C.

Table 2 Sintering Performance of Four Different Material Combinations at Three Distinct Temperatures

Material ratio	1200°	1230°	1250°
30% white mud: 30% black mud: 40% bentonite	Difficult to sinter	Difficult to sinter	Difficult to sinter
30% white clay: 30% black clay: 40% cordierite	Difficult to sinter	Difficult to sinter	Difficult to sinter
White mud 30%: 30% black mud: 40% spodumene	The degree of sintering is not high	Enhanced sintering	Good sintering
30% white mud: 30% black mud: 40% alumina	Difficult to sinter	Difficult to sinter	Difficult to sinter

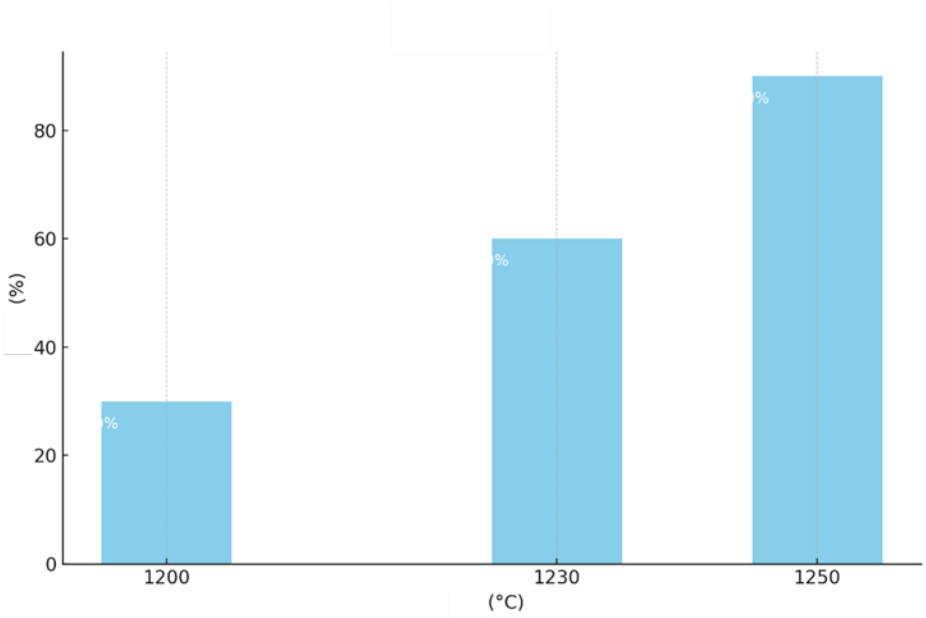


Figure 7. Analysis of sintering properties of spodumene at different temperatures

At 1200°C, spodumene is less sintered. When the temperature increases to 1230°C and 1250°C, the degree of sintering of spodumene is significantly enhanced. Mainly at 1250°C, the sinterability of spodumene performs well, indicating that spodumene may be an ideal alternative material—own illustration.

By firing and performance testing bentonite, cordierite, spodumene and alumina at temperatures of 1200°C, 1230°C and 1250°C, the research results reveal that only spodumene is within the suitable sintering temperature range of 1230°C-1250°C Exhibits excellent sintering properties. Especially at 1250°C, spodumene achieves excellent sintering, effectively reducing water permeability and enhancing product durability.

The experimental results highlight the significant advantages of spodumene in solving leakage and durability problems in clay pots. In contrast, other investigated materials failed to achieve effective sintering in this temperature range and were, therefore, unsuitable as quartz sand replacement materials.

Quantitative evaluation of thermal performance and durability of spodumene in different configurations

Table 2 Effects of Different Configurations and Firing Temperatures on the Plasticity, Permeability, and Sintering of White Mud, Black Mud, and Spodumene Mixtures in Pot Making

configuration	temperature	Plasticity	permeability	Degree of sintering	in conclusion
Configuration 1	1200℃	reduce	exist	insufficient	
	1230℃	insufficient	-	improve	
	1250℃	-	-	burnt	Not suitable, affecting structural stability
Configuration 2	1200℃	satisfy	exist	-	
	1230℃	satisfy	reduce	improve	It performs best at this temperature, and it is necessary to further reduce the permeability and adjust the degree of sintering
	1250℃	satisfy	-	over sintering	
Configuration 3	1200℃	satisfy	exist	insufficient	
	1230℃	satisfy	reduce	insufficient	
	1250℃	satisfy	disappear	satisfy	Temperature and ratio are the best configurations for clay pot making

Table 3 Demonstrating the performance of mixtures of white mud, black mud and spodumene in three configurations (Config 1, Config 2 and Config 3) and different firing temperatures (1200°C, 1230°C, 1250°C). The proportions of white mud, black mud and spodumene vary in each configuration, and the table details the effect of these factors on the plasticity, permeability and sinterability of the mixture. By analyzing this data, optimal configurations and firing temperatures can be derived.

The research above has highlighted that spodumene exhibits good performance in a specific sintering temperature range (1230°-1250°). However, in addition to the temperature factor, the specific ratio of spodumene in the mud may also affect the effect of the sintering process. In order to further optimize this process and tap the potential application value of spodumene, the following research will focus on finding the optimal ratio of spodumene in mud. Three different proportion schemes are analyzed in detail, and their sintering effect and structural characteristics are discussed in the temperature range investigated.

Examination of Three Configurational Schemes
The study considered three different ratio configurations:
1: White mud 25%: Black mud 25%: Spodumene 50% Configuration
2: White mud 35%: Black mud 35%: Spodumene 30% Configuration
3: White mud 30%: Black mud 30% %: Spodumene 40%

This study conducts a quantitative analysis of the experimental results of spodumene in three configuration schemes and different firing temperatures (1200°C, 1230°C, 1250°C). The following results are based on tests conducted by authoritative testing agencies such as CNAS and ILAC-MRA and have clear scientific evidence:

(1) Sintering degree analysis: Compared with traditional quartz sand ceramics, spodumene ceramics have lower sintering temperatures and better thermal stability, which helps improve efficiency during the sintering process.

(2) Thermal shock resistance: In the water-cooling and hot-water exchange test at 180℃-20℃, the spodumene pot did not crack, indicating its thermal stability is significantly better than that of quartz sand pottery pot.

(3) Water absorption test: The water absorption rate of spodumene ceramics is 0.3%, lower than the standard of ≤0.5% for fine ceramics, further confirming its excellent density and dense microstructure.

(4) Lead and chromium precipitation analysis: Spodumene ceramics' lead and chromium mobility are far lower than the environmental protection standard of 0.25mg/l, emphasizing its advantages in environmental protection performance and healthy use.

These quantitative data confirm the apparent advantages of spodumene in terms of sintering degree, thermal shock resistance, water absorption and environmental compliance and provide a solid scientific basis for the production of ceramic pots.

Comparative Effect of Oxidative and Reductive Firing Methods on Ceramic Leakage and Durability Improvement

This study investigated whether firing methods impact the performance of clay pots in terms of leakage and durability. An oxidative firing environment was first used as a benchmark condition, and a comparative experiment was conducted with reduction firing. Although the various firing methods have no noticeable impact on the degree of sintering and plasticity of the ceramics, there are significant differences in colour and texture.

In particular, reduction firing shows a richer colour spectrum at a ratio of 30% white mud, 30% black mud, and 40% spodumene at a firing temperature of 1250° C. More specifically, the iron element in the ceramic takes on a darker brown hue when exposed to a reducing firing environment.

Taken together, if in ceramic manufacturing you not only pursue functionality (such as reducing leakage and improving durability) but also want to increase the artistry and uniqueness of the product, use complex firing methods, such as using wood as the fuel for reduction firing, would be a beneficial strategy.

These findings provide experimental support for the role of firing methods in solving ceramic leakage and durability issues and expand the possibility of considering aesthetic factors in ceramic manufacturing processes. Therefore, this study has important guiding significance at theoretical and practical levels.

Figure 8. Effect of oxidation fired pottery pot

The figure shows the results of oxidative firing at 1250°C at optimal ratios of spodumene, white mud and black mud. The soil is gray-white in colour and the overall structure is stable, fully meeting the standard requirements.

Figure 9. The effect of restoration and firing of clay pots

This picture shows the firing effect of a clay pot under reduction firing (wood firing) conditions. Since the clay contains iron, its reduction reaction during the firewood burning process gives the pot surface rich colour and diverse textures. These visual effects enhance the product's aesthetics without adversely affecting its structure and quality.

In order to explore whether the firing method impacts the leakage resistance and durability of clay pots, we conducted experimental tests in two different environments: oxidation firing and reduction firing at a temperature of 1250°C. Experimental results show that these two firing methods have no significant impact on ceramics' sintering degree and plasticity, but they show apparent differences in colour and texture.

Specifically, reduction firing produces a richer colour spectrum, especially the iron element in the ceramic, which exhibits a deeper brown tone under reduction firing conditions. Comprehensive analysis shows that if we not only focus on functionality but also consider aesthetics and artistry in ceramic manufacturing, using the reduction firing method will be an effective strategy that will help enhance the artistic value and uniqueness of the product.

Contribution of new approaches to Shiwan kiln ceramics

This study provides new insights into the selection of ceramic raw materials for Shiwan kilns and clarifies spodumene as an excellent material with the potential to replace quartz sand. Spodumene has demonstrated superior water-proof performance and high durability through rigorous experimental verification at different temperatures. Therefore, the results of this study will promote innovation in Shiwan kiln ceramic technology to solve the water seepage and durability problems that have long (Carvajal & Day, 2013; Stark, 2003).

Summarize

Through the research results in this chapter, it can be confirmed that spodumene is a better raw material than quartz sand and has excellent anti-leakage and durability. Different firing methods have limited effects on the degree of sintering and plasticity, but there are differences in colour and texture. The research results provide crucial technical innovation guidance for Shiwan kiln ceramics(Smith, 2007).

Discussion

Review of research objectives

This study aims to achieve two main goals: 1) improve the leakage-proof performance of Shiwan Kiln pots and 2) improve their durability. To achieve these goals, we evaluated quartz sand materials used in traditional Shiwan kiln pots and explored the potential advantages of spodumene as an alternative material.

A comprehensive explanation of process and material limitations

Through a comprehensive evaluation of Shiwan kiln quartz sand material, this study reveals the limitations of this material in terms of thermal stability, sintering degree, and durability. Although Shiwan kiln has a long history and cultural value, these limitations have become problematic in its continued development in modern society.

Comparison with previous research

Compared with previous studies that mainly focused on quartz sand or cinder powder (coal-producing areas) as cooking pottery materials, this study introduced spodumene as an innovative raw material. It is worth noting that spodumene was gradually used in the second half of the 20th century with materials science and engineering development. This study found that spodumene exhibits better thermal stability and sintering efficiency than quartz sand.

Alternative Materials: The Multi-Dimensional Advantages of Spodumene

Quantitative data confirms that spodumene offers significant advantages in terms of thermal stability, durability and environmental sustainability.

Integration of craftsmanship and aesthetics

With proper firing methods and careful design, ceramic products not only improve their functionality but also enhance their aesthetic value.

Contribution to modern application scenarios

Spodumene clay pots not only perform well in terms of durability and sinterability but also have significantly lower lead and chromium precipitation rates than industry standards, thus highlighting their advantages in terms of health and safety. By leveraging the multiple advantages of spodumene, Shiwan Kiln pottery pots, which are cultural intangible cultural heritage, can meet the compound needs of the high-end teaware market in terms of product quality, environmental sustainability and cultural value, demonstrating significant development potential.

Research limitations and future directions

This study has some limitations, including insufficient sample size to fully evaluate the stability of batch production and a need for more examination of the possible impact of raw materials from different regions on the experimental results. Therefore, future research should expand the sample size and consider different environmental conditions to more comprehensively evaluate the applicability and stability of spodumene in multiple application scenarios.

This study verified the advantages of spodumene in improving the performance of Shiwan kiln pottery pots, especially thermal stability and sintering degree. This discovery promotes innovation in Shiwan kiln technology and has the potential to impact the high-end teaware market. However, the study suffers from a small sample size and lack of comparison of the impact of regional factors, so further research is still needed.

Conclusion

Our study provides insight into the traditional craftsmanship of Shiwan kiln pottery pots, with significant performance improvements achieved through innovative improvements. The main findings include the optimal ratio of spodumene, suitable firing temperature and method, etc.

佛山市优博陶瓷分析测试有限公司

检测报告

表号：RA01 报告编号：Q2021012702

样品名称	煮茶壶	样品编号	Q2021012702
送样单位	聂慧梅陶艺工作室		
样品特征	壶状	样品数量	1个
实验环境温度	25℃	实验环境湿度	68%RH
检测项目	见下表	收样日期	2021年01月27日
检测类别	委托检测	完成日期	2021年02月01日
检测依据	GB/T 3298-2008 GB/T 3299-2011		

检测结果：

序号	检测项目	标准要求	结果
1	抗热震性（180℃~20℃水冷热交换一次）	壶类(容量中型 250~1000mL)一次不裂	一次不裂
2	吸水率（%）	耐火类 ≤0.5%	0.30

以下空白

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佛山市优博陶瓷分析测试有限公司

检测报告

表号：RA01 报告编号：H2021012702

样品名称	煮茶壶	样品编号	H2021012702
送样单位	聂慧梅陶艺工作室		
样品特征	正常	样品数量	200g
实验环境温度	25℃	实验环境湿度	68%RH
检测项目	铅镉迁移	收样日期	2021年01月27日
检测类别	委托检测	完成日期	2021年02月01日
检测依据	GB/T 31604.24-2016 GB/T 31604.34-2016		

检测结果：

序号	项目	标准要求	结果
1	铅迁移量（mg/L）	罐 0.5mg/L	<0.001
2	镉迁移量（mg/L）	罐 0.25mg/L	<0.001

以下空白

声明：1.检测结果仅对来样负责，样品保留至检测报告后20天。
2.检测报告部分复印无效。
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Figure 10. Comprehensive evaluation results of spodumene pots

(a) Sintering degree analysis: The sintering degree of spodumene pottery was compared with traditional quartz sand pottery, and the lower sintering temperature and superior thermal stability of spodumene ensured efficient performance during sintering.

(b) Thermal shock resistance: It shows the performance of spodumene clay pots in a test of 180°-20°c water cooling and hot water exchange without cracking, and its thermal stability exceeds that of quartz sand clay pots.

(c) Water absorption test: The result of spodumene pottery is 0.3%, lower than the standard of fine porcelain ≤0.5%, reflecting its excellent density and compact microstructure characteristics.

(d) Analysis of lead and chromium precipitation: It shows the analysis of lead migration and chromium migration of spodumene pottery. The standard 0.25mg/l % is < 0.001mg/l %. It is smaller than the relevant environmental protection standards, highlighting the environmental protection performance and healthy use guarantee of clay pots.

This figure comprehensively presents the critical performance evaluation results of spodumene pots and deeply reveals its application advantages and environmental compliance in pot technology.

Authoritative detection and analysis

Through the all-around comprehensive evaluation conducted by the authoritative testing organizations of CNAS and ILAC-MRA, we confirmed the advantages of spodumene in sintering degree, thermal shock resistance, water absorption and lead and chromium precipitation. These results provide a solid foundation for the production of clay pots scientific basis (Pierce, 2005).

Future directions

This study lays the foundation for further future innovation and development of pottery craft. In the future, decorative research should be deepened, the sample size should be expanded, experimental design should be improved, and new experimental methods should be explored to promote the innovation and inheritance of intangible cultural heritage (Coutts, 2001).

Through this in-depth analysis, we have provided strong support for the modernization and high-end pottery crafts and opened a new path for protecting and inheriting traditional culture. Through continuous exploration and innovation, we can rejuvenate the intangible cultural heritage of Shiwan kiln cookers (Bahn et al., 2009).

Recommendation

1. Optimization of Spodumene Proportion

Further investigations should be conducted to pinpoint the optimal proportions of spodumene. This would involve a more comprehensive analysis using various spodumene types and exploring their interactions with other materials. Collaboration with materials scientists could provide the necessary insights for fine-tuning these proportions.

2. In-Depth Analysis of White and Black Mud Ratios

The study's findings call for an in-depth analysis of white and black mud ratios in future research. Analyzing the chemical and mineral compositions can lead to tailored production processes that harness these ratios to enhance pot performance.

3. Standardization of Firing Techniques

Building on the insights into firing temperature and methods, it is advisable to develop standardized firing techniques that can be implemented in traditional kilns. This may foster a broader application and understanding of these techniques across artistic and industrial practices.

4. Collaborative Approach to Innovation and Inheritance

The development and preservation of traditional Shiwan kiln techniques require a collaborative approach. Partnerships between craftspeople, researchers, and technologists can aid in bridging the gap between tradition and innovation. This collaboration may manifest through workshops, joint research projects, or community-based initiatives.

5. Emphasis on Decorative Studies in Future Research

Given the noted limitations in the decorative studies of clay pots, future research should focus on this area. This includes exploring decorative techniques that align with traditional craftsmanship and modern aesthetics. Collaboration with artists and designers may provide a unique perspective in this area.

6. Funding and Policy Support

Governments and funding bodies should recognize the importance of preserving and innovating traditional crafts. Financial support and policy initiatives to promote research and development in this area could catalyze the implementation of the study's findings on a broader scale.

These recommendations provide a logical extension of the study's key findings and identify actionable paths for future research, collaboration, and support in the field of Shiwan kiln pottery. It fosters a holistic approach that considers the various facets of this traditional craft, aiming at both innovation and preservation.

References

Abbott, D. R. (2009). Extensive and Long-Term Specialization: Hohokam Ceramic Production in the Phoenix Basin, Arizona. *American Antiquity, 74*(3), 531-557.

Bahn, S., Lee, C., Nam, C. S., & Yun, M. H. (2009). Incorporating affective customer needs for luxuriousness into product design attributes. *Human Factors and Ergonomics in Manufacturing & Service Industries, 19*(2), 105-127.

Carvajal, J. C., & Day, P. M. (2013). Cooking Pots and Islamicization in the Early Medieval Vega of Granada (Al-Andalus, Sixth to Twelfth Centuries). *Oxford Journal of Archaeology,* 32(4), 433-451.

Colombo, P., Mera, G., Riedel, R., & Soraru, G. D. (2010). Polymer-derived ceramics: 40 years of research and innovation in advanced ceramics. *Journal of the American Ceramic Society, 93*(7), 1805-1837.

Coutts, H. (2001). *The art of ceramics: European ceramic design*, 1500-1830. Yale University Press.

Dajun, Q. (n.d.). *Guǎngdōng xīn yǔ Guangdong New Language*. Zhonghua Book Company.

Hein, A., Müller, N., & Kilikoglou, V. (2009). Great pots on fire: thermal properties of archaeological cooking ware. In *Vessels: inside and outside. Proceedings of the conference EMAC.*

Jiaren, S. (1995). Lüè lùn sòng yuán shíqí shí wān táocí yìshù de fǎ zhǎn [Brief Discussion on the Development of Shiwan Ceramic Art in Song and Yuan Dynasties]. *Journal of Foshan University*, (03), 6-13.

Lewin, C. (2005). Elementary quantitative methods. In *Research methods in the social sciences* (pp. 215-225).

Lingling, C. (1987). Duì fúshān shí wān yáo yè de yánjiū jí qítā [Research on Foshan Shiwan Kiln Industry and Others]. *Ceramic Research*, (02), 53-56.

Menghan, L. (2017). Zhōngguó chuántǒng gōngyìpǐn jíjǐn: Shí wān táo juǎn [*A Collection of Traditional Chinese Crafts: Shiwan Pottery Rolls*]. China Science and Technology Press.

Naishen, L., Wen, S., & Hua, Z. (1980). Shí wān táocí de qǐyuán, tèdiǎn jí lìshǐ dìwèi [The Origin, Characteristics and Historical Position of Shiwan Ceramics]. *Journal of Sun Yat-sen University* (Social Science Edition), 20(03), 58-70. http://xuebao.sysu.edu.cn/Jweb_skb/CN/abstract/article_11481.shtml

Pierce, C. (2005). Reverse engineering the ceramic cooking pot: cost and performance properties of plain and textured vessels. *Journal of Archaeological Method and Theory*, 12, 117-157.

Smith, C. (2007). *Design for the other 90%.* Cooper-Hewitt, National Design Museum. Smithsonian Organization, 47.

Stark, M. T. (2003). Current Issues in Ceramic Ethnoarchaeology. *Journal of Archaeological Research, 11*(3), 193-242. http://www.jstor.org/stable/41053198

Weiwen, H. (2015). Lùn míng qīng shí wān yáo “gòng táo”——yǐ qīnggōng jiù cáng shí wān yáo qì wéi zhōngxīn [On the "tribute pottery" of Shiwan kiln in Ming and Qing Dynasties——Centering on the old collection of Shiwan kiln wares in Qing Palace]. *Journal of Shenyang Palace Museum*, (01), 131-141.

Wenjin, J. (2017). *Shí wān yáo yánjiū [Shiwan Kiln Research]*. Guangdong People's Publishing House.

Xinliang, L. (2019). *Kǒushù shí wān yáo [Oral Shiwan Pottery]*. Guangxi Nationalities Publishing House.

Regional Socio-economic Analysis. Development Bank of Southern Africa.

Ray, C. (2000). Endogenous socio-economic development in the European union—issues of evaluation. *Journal of Rural Studies.* 16 (4), 447-458.

Rietveld, P., & Bruinsma, F. (2012). *Is transport infrastructure effective?: transport infrastructure and accessibility: impacts on the space economy*: Springer Science & Business Media.

Schwalbe, K. (2009). *Introduction to project management*: Course Technology Cengage Learning Boston.

Storey, J. (2016). *Human resource management*: Edward Elgar Publishing Limited.

Wenzel, T. A., Burnham, K. J., Blundell, M. V., & Williams, R. A. (2006). Dual extended Kalman filter for vehicle state and parameter estimation. *Vehicle system dynamics,* 44 (2), 153-171.

Wilson, F. R., Stevens, A. M., & Holyoke, T. R. (1982). Impact of Transportation on Regional Development (Abridgment). *Transportation research record*.