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Developing Low Temperature Glazes for Omani Clay Artworks: Laboratory Investigation to Reduce Costs by Using Frits

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Abstract

The role of using frits in developing glazes for ceramics has increasingly received attention across a number of industrial ceramics fields in recent years. Over the past decade, the link between using frits for developing ceramics glazes and the reduction of financial costs has been at the center of much attention. Determining the impact of using frits in the local ceramics industry in Oman is important for the future study of this creative field. Using imported ready-made glazes, despite their long commercial success, is associated with a number of problems, including a shortage of suppliers, high costs, and logistical difficulties. Consequently, there is an urgent need to address the importance of developing glazes locally to help establish some workable solutions for the aforementioned problems. To date, no research studies have investigated using local Omani earthenware clays to make glazes by combining them with commercial frits using empirical laboratory methodologies. By developing low temperature chemical glaze recipes, the main aim of this study is to explore the possibilities of using Omani earthenware clays (OECs) and frits to create glazes that are suitable for local Omani ceramic works.

Keywords

Omani Earthenware Clays, Ceramics, Frits

1. Introduction

It is generally known that ready-made glazes are hugely expensive, in spite of their widespread availability in Oman. Most ceramic manufacturers and art creators, at various levels of education and the industry, depend on foreign rather than local materials, which have resulted in high production costs. One of the most significant current discussions in ceramics and pottery studies is developing ceramics glazing recipes in artists' laboratories for creative pottery. However, to date there has been little debate about introducing Omani clays in ceramics glazing recipes in Oman. This is because very little research has been conducted in this area of study, and the analysis of local pottery clays is costly, especially for independent artists and educational institutions.

To develop glazes in an independent laboratory at a lower cost, it is essential to reduce the number of materials included in ceramics glazing recipes, and to make the glazes applicable in ceramics art and industries, it important to use professional frits. The Oxford English Dictionary (OED) explains that the term "frit" was first used in 1662 to refer to "a calcinated mixture of sand and fluxes ready to be melted in a crucible to make glass" [1]. Frits, in fact, are ingredients in glaze recipes which are melted and reground prior to inclusion in the glaze slop [2]. A variety of definitions have been suggested for the term "frit," but this paper will use the definition of Dodd and Murfin, who defined frits as materials used in ceramic glazes that have been fused, quenched, and granulated. They are considered an important part of compounding enamels and ceramic glazes. Basically, frits are combined raw materials that are mixed, fired, melted, crushed, and ground into a powder. The use of frits can decrease the toxicity of raw materials such as lead, barium, and zinc; reduce the fusion point of glazes; and avoid the volatilization of unstable substances [3].

Frits are manufactured according to the following process. It is fused with silica, which is glass, so the producer can guarantee providing the most important ingredient to create glazes. At that point, the raw material is melted into glass, which has the property of being insoluble, and finally the frit is crushed to produce a powder for coating. Because the use of frits differs from one ceramics manufacturer to other, there are four categories of frits, which are lead frit, lead and boron frit, borax frit borosilicate clear coated (no lead), and borosilicate frit coated solid white (no lead). In fact, ceramicists use frits as alternative materials for any basic glaze recipes. In other words, any frit represents the original standard glaze components, including silica, alumina, and flux.

According to [4], although frits can be a bit of a mystery to ceramicists who frequently use raw glazes, it became necessary to take advantage of frits which potentially help to solve various difficulties and improve ceramic glazed products. Obviously, frits are more luxurious and expensive than raw glazing materials, but the advantages often outweigh the production costs [4].

Numerous reasons for using frits as an alternative for raw materials are similar to those for using commercial stains over raw metal oxides. Generally, greater percentages of frit allow for better fired quality and accuracy, lower melting temperature, fewer glaze defects, better clarity, smoother surface, brighter colors, faster firing, and lower thermal expansion [4]. Usually, for mass production ceramics manufacturers, glazes that include 85% of frit and 15% of clay are very costly, and the cost will be more expensive for independent artists and small and medium pottery enterprises.

Therefore, there is a crucial need to address the importance of developing glazes locally, which can help to establish some workable solutions for glazing cost problems. To date, no experimental investigation has been conducted using local Omani earthenware clays to make glazes by combining them with commercial frits. By developing low temperature chemical glaze recipes, the main aim of this study is to explore the possibilities of using as much as possible of Omani earthenware clays (OECs) and as little as possible of frits to create glazes that can be used by local Omani ceramic works.

2. Laboratory Experiments: Selection of Materials

The final ready and bisque-fired ceramics embrace the application of glazes, which in a firing process give value to the ceramics production by improving the strength, protection, and aesthetic appearance [5]. Chemical compositional techniques that focus on ceramic local clays have been used widely in provenance studies that have addressed questions about glazing materials' costs and availability. Less attention has been paid to the glazes applied externally to ceramics created using local Omani clays, although the analyses of general pottery hand building techniques have appeared in the literature in the past two decades, especially from an archeological perspective.

However, selecting and using appropriate methodologies to examine the quality of local clays to develop glazes is another matter. Best research practices on glazes and clays using experimental methodologies have relied on developing chemical glaze recipes in the laboratory and testing their qualities by firing the created samples in pottery kilns according to specific firing schedules. This research study attempted to examine local Omani clays when mixed with ready-made frits to create glazes that are physically and artistically suitable to apply to ceramic pots.

The current study utilizes a mixture of experimental and qualitative research methods to explore the possibilities of using OECs and frits to create glazes that suit local Omani ceramic works. It was decided that the best method to adopt for this investigation was a laboratory experimental method, where 36 experiments (glaze recipes) were tested in the laboratory. The research team also evaluated the results of tests from an artistic perspective, so a qualitative evaluation rubric was used in this stage of the research. The actual experiments were conducted in the ceramics glazing laboratory at Sultan Qaboos University.

To start this project, it was essential to understand the basic facts about the chemical composition and structure of ceramic glazes. According to Rye (1981), glazes are primarily composed of silica (SiO_2) which acts as a "network former", or primary constituent [6]. However, because the melting point of silica is 1700˚C, a "network modifier" or flux was added to lower the melting point of the silica and create a glass, thus giving the paint a luster. According to Henderson (2013), globally, appropriate flux materials are rich in sodium, potassium, calcium, manganese, and lead. These types of fluxes help to reduce the silica melting point to be between 950˚C (a low temperature for ceramics) to 1290˚C (a high temperature for ceramics) [7].

In this project, local Omani clays were introduced to each glazing recipe at different amounts, ranging between 30% and 50%. Two types of local Omani clays were used in this project. The first type of clay was extracted directly from nature, without any modifications or additions, and it named Bahla clay, based on the area of extraction in the north of Oman. The second type of clay is composed by gathering many clays from different territories in Oman and is used especially by the Alanwar Ceramic Tiles Plant (ACTP), so it is named Alanwar clay.

An earlier study conducted by Almamari (2020) mentioned that earthenware clays created by the ACTP are produced locally from six different raw materials with various chemical compositions [8]. The final clay recipe produced by the ACTP is mixed with dry raw materials in different ratios, ranging from 10% to 28%. This clay recipe contains different types of sands and pure red clays collected in various Omani districts. As is the case at all ceramic plants, the raw materials are first ground in large ball mills and then mixed homogenously in the main (and largest) ball mill. **Table 1** lists the materials and their percentages used to compose Alanwar clay.

As planned, each glazing recipe was composed of only two materials, namely clay and frit, to achieve the purpose of the research, that is to investigate whether the cost of glazes can be reduced by reducing the number of materials introduced in each glaze recipe. In this research study, nine frits manufactured by Pottery Crafts were used in 36 glaze tests, as presented in **Table 2** below.

To constitute the recipes, each frit was used to compose four recipes, as follows (**Figure 1**):

1) Recipe with 30% Bahla Clay;
2) Recipe with 50% Bahla Clay;
3) Recipe with 30% Alanwar Clay; and
4) Recipe with 50% Alanwar Clay.

3. Sample Preparation: Preparing Glaze Recipes

To start sample preparation, measuring laboratory cups and hats are all volumetric

Table 1. List of materials and percentages used to compose Alanwar Clay (Source: Alshams Ceramic Company, Oman).

Raw Material	Percentage
General sand	14%
Scrap (fired ceramic grogs)	10%
Wadi Ghul clay	18%
Mahadha clay	28%
Lawa sand	14%
Al Hamra clay	16%
100%	

Table 2. List of frits and their codes used in laboratory tests.

Frit	Code (Pottery Crafts)
Borax (E) frit	P2953
Frit 3110	P3110
White Zircon Borax frit	R1122
High Alkali frit	P2962
Frit 3195	P3195
Alkaline Standard frit	P2961
Borax frit (J)	P2995
Lead Basilicata frit	P2950
Frit 3124	P3124

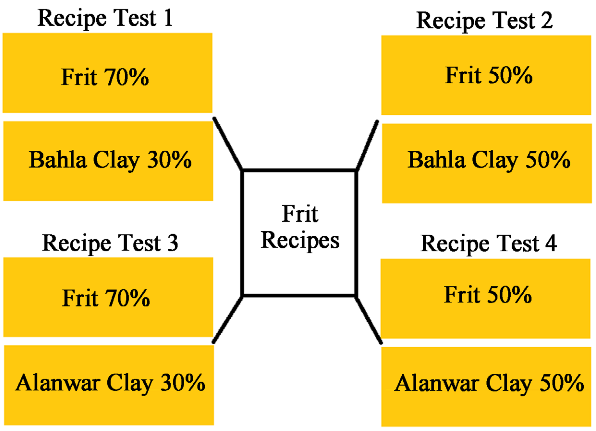

Figure 1. Above illustrates the standard structure of four tests for each frit used in this project.

measures. Also, accurate scales are required especially digital scales using grams as a unit of measurement. Because 100g test considered as a quantity that will enable the researchers to weigh the glaze correctly and apply it with confidence, all this project's tests composed no less than 100g. After weighing out the materials as dry powder according to the research plans and calculation tables (**Appendix 1**), each test recipe labeled with numbers and kept in plastic containers. Each recipe becomes ready in this stage for sieving through 120 mesh before moving to mixing stage.

There are many approaches to mixing and preparing glazes test recipes. In this project, the researchers used the most common and classic approach which is to use a pestle and mortar. Where a small amount of water is poured into the mortar, the ingredients are added and mixed with the pestle, and it possible to add extra water if required. Then each recipe sample sieved through 350 mesh to avoid lumps in each test sample. The researchers followed the procedures mentioned in Greg Daly book (developing glazes) [9], and in fact his method helped to avoid all technical problems usually effect glaze preparation in ceramic laboratory in art school. All glaze recipes are applied on ceramics fired pieces. The first application is the thin application, and the second coating was the 1 - 2 mm thickness. And for some test recipes, another third coating added between 2 - 3 mm thickness.

4. Firing Process

The laboratory steps include the preparation of low-fire earthenware ceramic, the investigation of glazes, and the preparation, coloring, and analysis of glaze qualities, including their defects. As described in **Appendix 1**, all recipes composed by the research team were constituted of quantities totaling 100%, with the colorant stains as added quantities (the colorant stains added for each glaze recipe mostly comprised 8 g). After the laboratory preparation and application to the fired ceramic pieces, all tests were then fired in an oxidation firing environment using the electric kiln. All tests were fired at 1020˚C, using a smooth, gradual firing circle according to chart in Figure 2.

5. Results of the Experimental Project

This section summarizes the findings and contributions made. Overall, our method was the one that obtained the most applicable results that help to develop ceramic artistic colors by using ceramic frits. The table entitled The Rubric Used to Assess the Final Results (**Appendix 2**) showed detailed evaluation of each test composed in the project. And the images of tests (**Appendix 3**) showed images of ceramic test objects with their final colors and textures.

6. Discussing Results

This research study set out to assess the efficacy of using between 50% and 70% of a single frit in glaze recipes. In this case, nine frits were used in glaze recipes at a concentration of 50% to 70%, combined with local Omani earthenware clay comprising between 30% and 50%. After firing the tests in an electric kiln, the

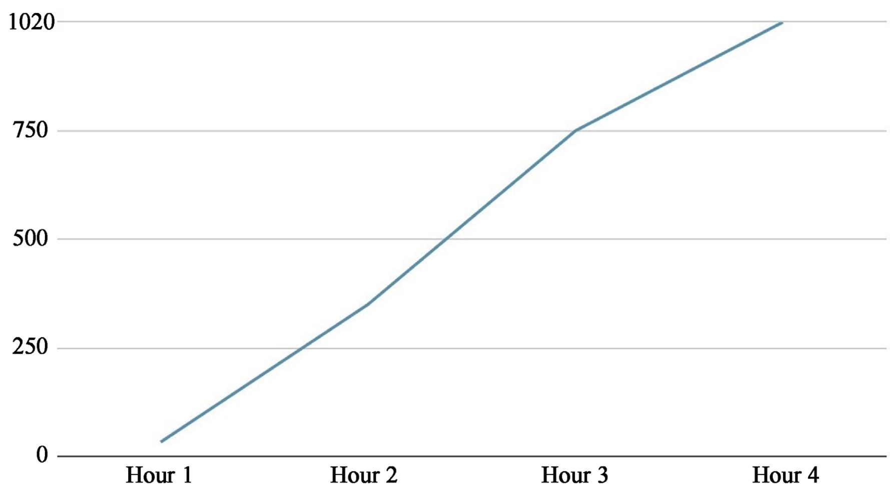

Figure 2. Standard firing circle used to fire all glazing tests in this study.

majority did not exhibit any glaze defects, including crazing, shivering, crawling, pin holing, or blistering. With respect to the first research question, it was found that using frits as the main ingredient in each glaze recipe helped to form an appropriate glaze for ceramics and pottery, especially for low- and mid-firing temperature ceramics. This finding has important implications for developing a simple color glaze recipe for industrial and educational ceramics. In addition, all experimental tests in this project revealed that all the stains worked very well with all the composed recipes, as demonstrated in **Appendix 1**. Overall, as illustrated in **Appendix 3**, all test samples were smooth, had accurate colors, and had no visible defects.

In summary, of the 36 tests (glaze recipes) completed in this study, more than 22 exhibited glossy textures and the rest were matt. Furthermore, regarding the level of smooth textures, the final results of this project indicated that most of the tests had satisfactory, marketable smooth textures, and were appropriate for tableware ceramics production. In fact, the matt glazes can also be used for special artistic production (sculptural and decorative ceramics). **Appendix 2** presents the rubric used to assess all the results, including the glossy and matt textures on the one hand, and the glaze defects (shivering, crawling and blisters) on the other.

7. Conclusion

By developing low temperature chemical glaze recipes, this study explored the possibilities of using as much as possible of Omani earthenware clays and as little frits as possible to create glazes that are suitable for local Omani ceramic works. One of the more important findings to emerge from this study is that many of the tested glazes are suitable for use in ceramic glazing in medium and small ceramics enterprises. This finding has significant implications for understanding how potters, ceramicists, and teachers in art schools can reduce the number of chemical materials in glaze recipes when using local clays and artificial frits. It is also worth noting that further experiments on other frits could help determine a greater degree of accuracy in the knowledge on this matter, especially in commercial ceramics production.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Weiner, E.S. and Simpson, J.A. (1989) The Oxford English Dictionary. Clarendon Press, Oxford.

[2] Hamer, F. and Hamer, J. (2016) The Potter's Dictionary: Of Materials and Techniques. Bloomsbury Academic, London.

[3] Dodd, A. and Murfin, D. (1994) Dictionary of Ceramics. The Institute of Materials, London.

[4] Hansen, T. (n.d.) Frit. https://digitalfire.com/glossary/frit

[5] Adelabu, O.S. (2012) Documentation, Application and Utilisation of Clay Minerals in Kaduna State (Nigeria). INTECH Open Access Publisher, Sankt Veit am Flaum.

[6] Rye, O.S. (1981) Pottery Technology: Principles and Reconstruction. Taraxacum.

[7] Henderson, J. (2013) The Science and Archaeology of Materials. Routledge, London. https://doi.org/10.4324/9780203630143

[8] Almamari, B. (2020) Examining the Quality of Local Omani Clays for Ceramic Slip Casting in Art Schools: Testing Deflocculant, Specific Gravity, and Viscosity. *International Journal of Sciences*: *Basic and Applied Research* (*IJSBAR*), **52**, 183-190.

[9] Daly, G. (2018) Developing Glazes. Bloomsbury Visual Arts.

Appendix 1. List of Glazes Recipes Composed in the Laboratory's Tests

Borax Frit (E)

Test (1)

Item	Percentage
Borax Frit (E)	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4129.5	8%

Test (2)

Item	Percentage
Borax Frit (E)	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4188.5	8%

Test (3)

Item	Percentage
Borax Frit (E)	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4185.5	8%

Test (4)

Item	Percentage
Borax Frit (E)	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4132.5	8%

Frit 3110

Test (5)

Item	Percentage
Frit 3110	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4179.5	8%

Test (6)

Item	Percentage
Frit 3110	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4187.5	8%

Test (7)

Item	Percentage
Frit 3110	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4108.5	8%

Test (8)

Item	Percentage
Frit 3110	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4140.5	8%

W.Z. Borax Frit

Test (9)

Item	Percentage
W.Z. Borax Frit	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4136.5	8%

Test (10)

Item	Percentage
W.Z. Borax Frit	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4182.5	8%

Test (11)

Item	Percentage
W.Z. Borax Frit	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4140.5	8%

Test (12)

Item	Percentage
W.Z. Borax Frit	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4108.5	8%

High Alkail Frit

Test (13)

Item	Percentage
High Alkail Frit	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4187.5	8%

Test (14)

Item	Percentage
High Alkail Frit	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4179.5	8%

Test (15)

Item	Percentage
High Alkail Frit	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4132.5	8%

Test (16)

Item	Percentage
High Alkail Frit	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4185.5	8%

Frit 3195

Test (17)

Item	Percentage
Frit 3195	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4188.5	8%

Test (18)

Item	Percentage
Frit 3195	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4185.5	8%

Test (19)

Item	Percentage
Frit 3195	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4132.5	8%

Test (20)

Item	Percentage
Frit 3195	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4179.5	8%

Alkaline Standard Frit

Test (21)

Item	Percentage
Alkaline Standard Frit	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4187.5	8%

Test (22)

Item	Percentage
Alkaline Standard Frit	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4108.5	8%

Test (23)

Item	Percentage
Alkaline Standard Frit	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4140.5	8%

Test (24)

Item	Percentage
Alkaline Standard Frit	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4182.5	8%

Borax Frit (J)

Test (25)

Item	Percentage
Borax Frit (J)	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4142.5	8%

Test (26)

Item	Percentage
Borax Frit (J)	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4136.5	8%

Test (27)

Item	Percentage
Borax Frit (J)	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4182.5	8%

Test (28)

Item	Percentage
Borax Frit (J)	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4140.5	8%

Lead Bisilicate Frit

Test (29)

Item	Percentage
Lead Bisilicate Frit	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4108.5	8%

Test (30)

Item	Percentage
Lead Bisilicate Frit	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4132.5	8%

Test (31)

Item	Percentage
Lead Bisilicate Frit	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4179.5	8%

Test (32)

Item	Percentage
Lead Bisilicate Frit	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4187.5	8%

Frit 3124

Test (33)

Item	Percentage
Frit 3124	70%
Earthenware Clay 1 (Oman)	30%
Total	100%
+Colorant: P4108.5	8 g

Test (34)

Item	Percentage
Frit 3124	50%
Earthenware Clay 1 (Oman)	50%
Total	100%
+Colorant: P4140.5	8 g

Test (35)

Item	Percentage
Frit 3124	70%
Earthenware Clay 2 (Oman)	30%
Total	100%
+Colorant: P4182.5	8 g

Test (36)

Item	Percentage
Frit 3124	50%
Earthenware Clay 2 (Oman)	50%
Total	100%
+Colorant: P4138.5	8 g

Appendix 2. The Rubric Used to Assess the Final Results

(YES = Y/NO = N)

Test No.	Texture		Common Ceramic glaze defects		
	Glossy	Matt	Shivering	Crawling	Blisters
1	Y	N	N	N	N
2	Y	N	N	N	N
3	Y	N	N	N	N
4	Y	N	N	N	N
5	Y	N	N	N	N
6	N	Y	N	N	N
7	Y	N	N	N	N
8	N	Y	N	N	N
9	N	Y	N	N	N
10	N	Y	N	N	N
11	N	Y	N	N	N
12	N	Y	N	N	N
13	Y	N	N	N	N
14	Y	N	N	Y	N
15	Y	N	N	N	N
16	N	Y	N	Y	N
17	Y	N	N	N	N
18	Y	N	N	N	N
19	Y	N	N	N	N
20	Y	N	N	N	N
21	Y	N	N	N	N
22	Y	N	N	N	N
23	Y	N	N	Y	N
24	Y	N	N	Y	N

Continued

25	Y	N	N	N	N
26	Y	N	N	N	N
27	Y	N	N	N	N
28	Y	N	N	N	N
29	Y	N	N	N	N
30	Y	N	N	N	N
31	Y	N	N	N	N
32	Y	N	N	N	N
33	Y	N	N	N	N
34	Y	N	N	N	N
35	Y	N	N	N	N
36	N	Y	N	N	N

Appendix 3. The images of Tests


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