

Characterisation of Local Bone Ash for Bone China Production

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Graphical abstract



Abstract

Clay body can be defined as a mixture of clay or other minerals to achieve a specific purpose in the production of ceramics. Among the types of clay that can produce white translucent ceramic products is porcelain. 'Porcelain' is derived from Italian word *porcelino* which means 'piglet'. It is said that the name was given based on a cowry shell which is small and plump like a piglet or *porcelino* and the shell also has shiny transparent finish like porcelain. Porcelain was produced in the 10th century during the reign of Emperor Hou Zhou Shi Zong, China. In 1748 a modification was carried out to the porcelain body by a British ceramic manufacturer Thomas Frye in Bow porcelain factory, London. The new body was known as 'fine porcelain'. He has formulated 45 % cattle bone ash in his porcelain mix to produce finer porcelain body, stronger, lower level of maturity during firing and its translucent effect was even greater. The term 'Bone China' was introduced by Josiah Spode in 1789 from Stoke after he successfully improved the formulation created by Frye. The beauty of bone china product in various forms is interesting enough for people to collect this exclusive product. However, bone china product has becoming an issue for Muslims who questions the materials used such as the permissible status of the bone used in its production. To solve this problem, a research has been carried out to identify the raw materials, the production methods and the way of detecting what type of bone used in the production of bone china.

Keywords: Bone China; clay body; bone ash; Islamic compliance

Abstrak

Jasad tanah liat boleh ditakrifkan sebagai campuran tanah liat dan lain-lain bahan mineral tanah yang dicampur untuk mencapai tujuan tertentu dalam penghasilan produk seramik. Antara jenis tanah yang boleh menghasilkan barangan seramik bersifat putih lut sinar ialah porselin. Perkataan porselin berasal daripada Itali iaitu *porcelino* bermaksud 'anak khinzir'. Nama ini diberi berdasarkan jasad porselin yang bersifat lut sinar seumpama kulit siput jenis cowry dan bentukannya seperti anak khinzir atau *porcelino*. Porselin dihasilkan pada kurun ke 10 ketika pemerintahan Maharaja Hou Zhou Shi Zong, China. Pada tahun 1748 telah berlaku pengubahsuaian jasad porselin yang dikenali sebagai 'porselin halus' oleh seorang pembuat seramik berbangsa Inggeris iaitu Thomas Frye di kilang porselin Bow, London. Beliau telah menggunakan formulasi 45% abu tulang lembu dalam campuran porselinnya untuk menghasilkan jasad porselin yang lebih putih, keras, tahap kematangan pembakaran yang lebih rendah dan kesan lut sinar yang lebih jelas. Istilah bone china telah diperkenalkan oleh Josiah Spode berasal Stoke pada tahun 1789 setelah beliau berjaya memperbaiki formulasi ciptaan Frye. Keindahan produk bone china dalam pelbagai bentuk cukup menarik minat kepada mereka yang gemar mengumpul koleksi eksklusif produk ini. Namun begitu, produk bone china telah menjadi satu isu kepada masyarakat Islam tentang bahan yang digunakan seperti yang nyatakan oleh beberapa pihak iaitu sejauh mana halalanya tulang yang digunakan dalam penghasilannya. Bagi menyelesaikan permasalahan ini, satu penyelidikan telah dilakukan bagi mengenal pasti kandungan bahan mentah, kaedah pembuatan dan cara mengesan jenis tulang apa yang digunakan sebagai bahan campuran dalam menghasilkan produk bone china.

Kata kunci: Bone China; jasad seramik; abu tulang; pematuhan Islam

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■1.0 INTRODUCTION

Research was conducted because Malaysian Muslims were concern about the permissible status of ceramic products using animal bones in its manufacturing process. The identified items were bone china products such as teapot sets, tableware, jewelry products and home decorative items.

It is hoped that from the results of this research, Malaysian Muslims will be informed about the contents in bone china products and it will help the Department of Islamic Development Malaysia (JAKIM) issuing a 'fatwa' or legal pronouncement on the permissible status of this product.

To achieve the objective, extensive research using the latest equipment was carried out to study various samples of bone china products and bone ashes of animals such as cattle, goat and swine.

■2.0 OBJECTIVES OF STUDY

To ensure this study has a clear justification, the objectives are:

1. To identify the general technique and manufacturing process of bone china products.
2. To review the material mixture/content of products made from swine bone ash or similar.
3. To carry out the process of characterization and testing of mineral properties in various samples of bone china products and animal bone ash.
4. To identify and detect the products made of swine bone ash or similar in local market.

In order to identify the raw materials suitable for the objectives above, the characterization of the properties of raw materials needs to be carried out. The most common characterization technique is the mineral content analysis techniques - XRD (X-ray Diffractometer). Through this technique, the phases of the raw material can be detected and it can be compared with the phases of the raw materials from abroad. Next is the chemical analysis technique - XRF (X-ray Fluorescence Spectrometer). This technique will provide the types of oxides present in a raw material. Then a comparison was carried out to get the right raw materials. Furthermore, several other materials characterization needs to be carried out such as the determination of particle size - PSD (Particle Size Distribution) and micro structural analysis techniques - SEM (Scanning Electron Microscope)

■3.0 HISTORY OF BONE CHINA

As known, the body of bone china was invented by Thomas Frye but the quality cannot rival the porcelain products from Europe's or China. Thus, his factory was not a commercial success at the time. However, improvement in bone china bodies had been done by Josiah Spode in Stoke between 1789 to 1793 by using formulation of porcelain body from China with addition of cattle bone ash. He formulated 50% bone ash, 25% Cornish Stone and 25% China Clay and named it bone china. This new formulation has succeeded in making the production of porcelain-bone china product competing against the existing outstanding porcelain production. From the earlier development and up to the end of 20th century, bone china has become English exclusive pottery products and the major manufacturers were localised to Stoke-on-Trent.

■4.0 DEFINITION OF BONE CHINA

Bone : bone

China : refers to porcelain based ceramic products (china ware)

Bone China is soft porcelain or soft-paste porcelain which the material essentially consists of bone ash, feldspar and kaolin. The body is designed for use in ceramic industry which produces ceramic products with porcelain-like quality, but at a lower cost.

■5.0 THE ADVANTAGES OF BONE CHINA

5.1 Strong

It is strong and tougher compared to porcelain. This is due to bone ash content in its formulations. When fired at high temperature, bone ash provides strong chemical bonds

5.2 White

The use of bone ash gives clean white finish to bone china products. This is because there is no impurities such as metal oxides in bone ash that can influence the color of a body. The whiteness of bone china allows decoration, decal and color application to it.

5.3 Translucent

Once the bone china product is fired at around 1250°C, the bone ash became vitreous, hence its translucency. Usually the bone china product is produced as thin as 1 - 2.5mm using slip casting technique just to make it more transparent.

5.4 Low Cost

Firing cost is reduced. Compared to porcelain, the firing temperature of bone china is lower, which is around 1250°C, whereas the firing temperature of porcelain is around 1400°C

■6.0 THE PRODUCTS OF BONE CHINA

6.1 Set of Tableware

The set includes rice plate, side plate, salad plate, soup bowl, casserole, set for cold drinks (jug and glasses) and set for hot drinks (teapot, cups, saucers, sugar and milk containers) (see Picture 1).

6.2 Decorative Products

Decorative products such as figurines, vases, sculpture etc. The whiteness of bone china allows color application which makes it more attractive (see Picture 2).

6.3 Lamp

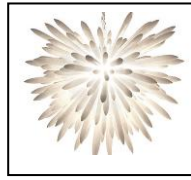
The type of lights such as wall lights, table lights and chandeliers. The transparent nature of bone china produce a beautiful beams of light and its strong body enables a longer lifespan for the lights products (see Picture 3)



Picture 1
Coffee set



Picture 2 Vases



Picture 3
Lights

7.0 ADVANTAGES OF BONE CHINA COMPARED TO OTHER PORCELAIN (TABLE 1)

Table 1 Comparison between bone china and porcelain

Bone China	Porcelain
Lower firing temperature at around 1250°C	Higher firing temperature at around 1400°C means higher cost for fuel.
Easily maintained compared to porcelain	Harder and more complicated to maintain
Clean white finish allows the decoration and color applied to it.	Inconsistency in the color, the shades of gray and blue. Color application and decoration is less interesting.
Strong in nature even though the product is as thin as 1-2.5mm	Less strong compared to <i>bone china</i> .

The advantages of bone china body caused its wide utilization in a number of ceramic factory in Liverpool, Minton, Derby Worcester, Wedgwood and Rockingham in the early 19th century.

8.0 COMPOSITE MATERIAL OF BONE CHINA

The composite materials commonly used to produce bone china body are as follows;

- Processed bone ash (calcined bone ash)
- Raw materials with high plasticity (china clay)
- Raw materials with low plasticity (feldspar)

8.1 Bone Ash (Ca₃(PO₄)₂)

Bone ash is the main ingredient, and used up to 50% in bone china body formulations. Usually the bones of animals such as cattle bone is used. Firstly, the flesh and cartilage bits attached to the bone is removed by boiling. The bone is burnt at temperatures around 100°C to eliminate organic waste as well as changing the mineral structure of the bone to suit the intended use for the formulation of bone china. The charred bones were grounded and sieved to get a fine particle size suitable for the mixture.

Bone ash is a composition of calcium and phosphorous (Ca₃(PO₄)₂), where in ceramic, calcium acts as stiff glass-former. This material will melt at temperatures above 1670°C. When bone ash is mixed with feldspar and china clay, it will produce a thin ceramic products, but strong and translucent in nature.

8.2 China Clay (Al₂O₃ 2 SiO₂ 2 H₂O)

China clay or kaolin is known as a material that contains elements of alumina and silica. These two elements are very important in the production of ceramic bodies, as it serves as a refractory material that provides resistance to high temperatures. It is white, and this criteria is suitable for producing porcelain and bone china body. In addition, it has a good level of plasticity. But it does not give the plasticity naturally because it has to be mixed with water and other materials. The use of kaolin also gives a moderate shrinkage to a fired ceramic products.

8.3 Feldspar ('R'₂O Al₂O₃ 6SiO₂)

Feldspar is a flux material, which can lower the melting temperature of refractory materials such as alumina and silica. It consists of a crystal structure, a combination of alumina silicate with potassium oxide, sodium oxide or calcium oxide. The importance of feldspar depends on the elements inside (the material represents the 'R' in the formula). Among the types of feldspar are as follows:

- Orthoclase (potash feldspar) - K₂O Al₂O₃ 6SiO₂
- Albite (soda feldspar) - Na₂O Al₂O₃ 6SiO₂
- Anorthite (lime feldspar) - CaO Al₂O₃ 6SiO₂

Different types of feldspar allows the diversity in the usage. For example, a feldspar with high potassium content is suitable for producing a ceramic body. Apart from that, the use of potash feldspar can reduce the drying time and shrinkage of clay, as well as providing strength before and after firing..

9.0 THE MANUFACTURING PROCESS OF BONE CHINA BODY

The manufacturing process of bone china body can be divided in two main ways, for plastic forming (containing 10% to 25% water) and slip casting (20% to 60% water content). Rajah 1 below shows the manufacturing process of bone china body commonly carried out by ceramics producer;

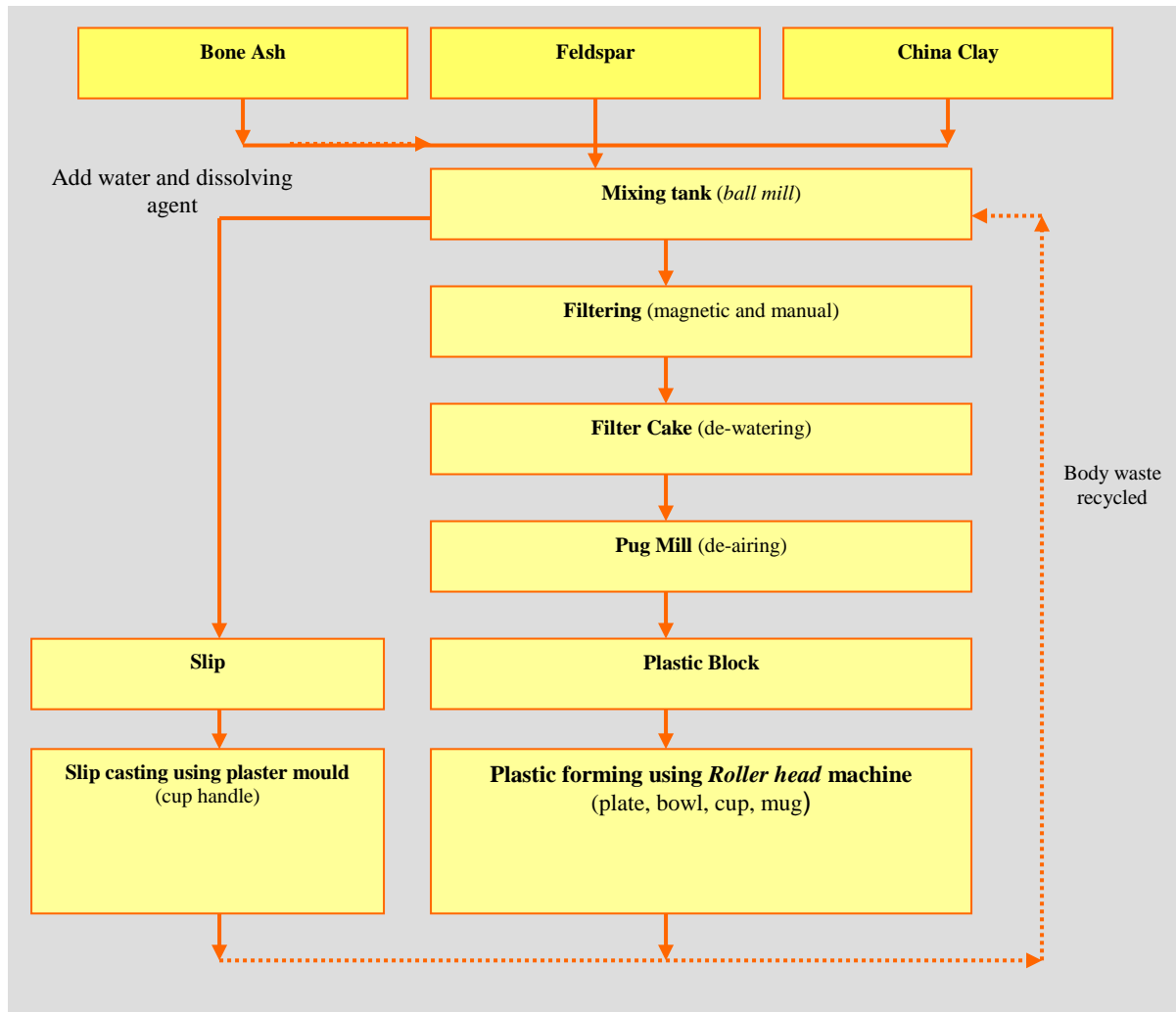
The production process of bone china body requires several stages and expertise in handling large machine. This process is done on a large scale to produce large quantities of products.

9.1 The Processes

Raw materials such as bone ash, feldspar and china clay are grounded and sieved to separate impurities. It is intended to ease the process of dissolving the raw materials.

9.1.1 Mixing Tank (ball mill)

The raw materials is weighed before it is fed into the mixing tank. Water is measured and added to the solution. This is to get the required density and fluidity of the clay solution. Deflocculants such as sodium silicate is added around 0.2 - 0.4% to the solution. It is to stabilize the thickness of the solution. The mixing process takes approximately 4 to 6 hours.



Rajah 1 Production process of bone china

9.1.2 Filtering (manual and magnetic)

The clay solution goes through a filtering process which is to eliminate impurities and insoluble substances. A magnetic separator is used to separate iron oxide. This process will produce a quality slip.

Slip

At this stage the slip formulation is achieved, and the slip can be used for the casting. Slip should be mixed regularly to maintain the quality.

9.1.3 Filter Cake

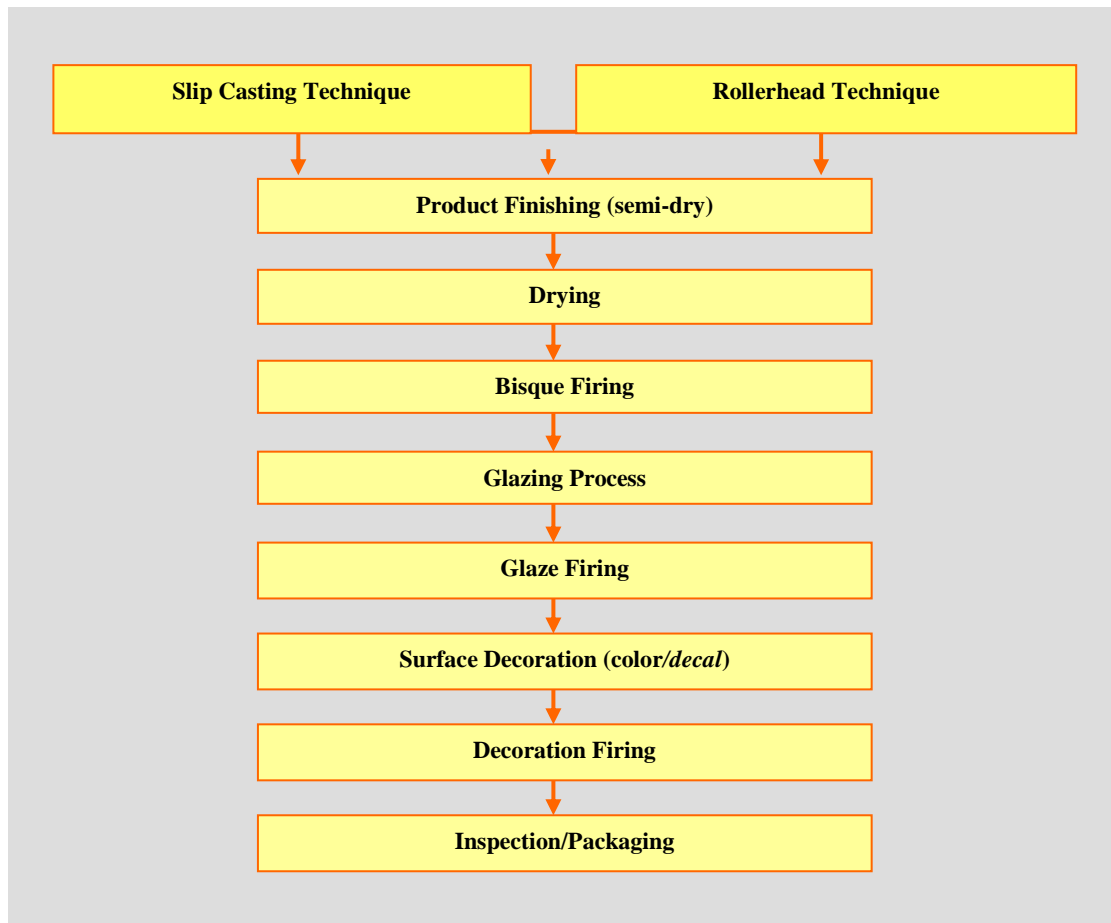
For plastic forming, the water from the slip should be removed by using a filter cake machine. The machine will pump the water away from the slip and this process will produce slabs of clay body.

9.1.4 Pug Mill

The clay slabs are fed inside the pug mill. It is to compress the clay and remove the trapped air. This process will form a block of clay (blanks). The plastic block is then covered with a piece of plastic to keep the clay moist.

9.1.5 The Forming Process of Bone China Products

The production of bone china products is not much different from other ceramic products. Rajah 3 below shows how the work production of bone china.



Rajah 3 Forming process of bone china product

10.0 THE FORMING METHOD OF BONE CHINA PRODUCT

10.1 Slip Casting

This method is used to produce complex shaped such as teapot (tea and coffee), sugar and milk containers, casserole, handle (for cups, mugs, teapot) etc. The processes are;

- Clay slip is poured into plaster mould which is designed specifically for slip casting. It is left a few minutes to get the desired thickness.
- Once the thickness is right, the excess slip is poured out of the mould. The plaster mould will absorb the moisture from the clay slip coating.
- After few more minutes, the mould is then opened, and the product is released slowly.

10.2 Plastic Forming

The process is using roller head machine which produces simple shape product such as plate, saucer, cup and mug. The machine is capable of producing large quantities of products in a very short time. The processes are;

- Clay plastic blocks cut at certain length are fed into a plaster mold of the roller head machine.
- The machine will form the product automatically. The product is then removed from the mold after a few minutes.

The advantage of this technique is that it requires little manpower because all processes are performed by machines. The products also are of high quality and similar in shape.

10.3 Products Finishing

The finishing process which removes clay edges is done while it is still in leather hard stage. The joining process such as attaching the handle of the cup is also done at this stage. This process is done manually by skilled workers.

10.4 Drying

Products are usually air dried naturally. But for large-scale production, a drying tunnel or a special oven is used. This can save time and the drying of products is uniformed.

10.5 Biscuit Firing

Once the product is completely dry, it is put inside the kiln either electric or gas kiln for firing process. Usually for biscuit firing, the product will be fired at temperatures around 1280°C. At this stage, the bone china is white, strong and translucent. The main purpose of this process is to expel the water in the product and to strengthen the chemical bonds of the particles in the body.

10.6 Glazing Process

The biscuit products are glazed with certain glazes. Usually the techniques used are dipping and spraying. The main purposes of glazing process are as follows:

- provides physical strength
- provides glossy effect
- eliminates the porosity of products

10.7 Glaze Firing

The process will melt the glaze and make it adhere to the product. It is usually fired at temperature around 1080°C using a kiln.

10.8 Surface Decoration

For decoration, the most common method is using decal paper with different surface patterns. It is attached on the surface of bone china products. Apart from that, gold lines is used to increase the exclusivity of the product.

10.9 Decoration Firing

This is a low temperature firing which is about 700°C depending on the type of decal and decoration used. The process will make decal patterns adhered to the surface of the products.

10.10 Inspection and Packaging

This stage is important before the product is marketed. Physical defects such as scratches, cracks, uneven color and form etc. is inspected and the defect products are separated. Quality products will be packaged following the customer and the dealer's order.

11.0 LIST OF MACHINES

11.1 Ball Mill (Picture 4)

The machine is for mixing and grinding raw materials into clay solution. There are thousands of hard balls inside the machine. When the machine is operating, the balls will collide and crush the raw materials to a finer size.

11.2 Blunger (Picture 5)

The machine is for mixing clay in large quantity. It is usually used for blending the clay slip to keep it in good quality.

11.3 Filter Cake (Picture 6)

The machine is used to remove as much water from the clay slip. Slip is pumped into a machine that has a special filter cloth. Strong pressure will force the liquid out of the filter cloth. This process will produce a plastic slabs of clay body.

11.4 Pug Mill (Picture 7)

The machine is used to compress the clay and to remove the trapped air inside the clay. Clay slabs are fed into the machine and this process will produce plastic clay blocks which will be used on the rollerhead machine.

11.5 Rollerhead (Picture 8)

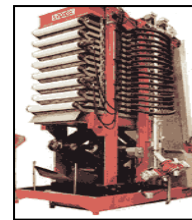
This machine is capable of producing products such as plates and cups in a short time, and in large quantities. Clay blocks cut to a certain length and then placed on the rollerhead mold. The pressure of the mold will form the product technically.



Picture 4 Ball mill



Picture 5 Blunger



Picture 6 Filter Cake



Picture 7 Pug Mill



Picture 8 Rollerhead

12.0 LABORATORY STUDIES

Laboratory studies include determining the characteristics of raw material inside bone china body based on a sample of identified bone china. The phases are:

- Phase 1. Sample study of bone china from United Kingdom, Japan and porcelain products.
- Phase 2. Sample study of bone ash from United Kingdom and Japan.
- Phase 3. Sample study of bone of local cattle, goat and swine.
- Phase 4. Study of bone china body following standard formula composition.

12.1 Studies Procedures

All the above studies were following these methods:

- i. Particle size analysis using Micromatics 5100 Particle Size Analyser. (Picture 9)
- ii. Chemical composition analysis using Shimadzu XRF-1700 X-ray Fluorescence Spectrometer. (Picture 10)
- iii. Microstructure materials analysis using HITACHI S-2500 Scanning Electro Microscope. (Picture 11)
- iv. Phase composition analysis using Bruker AXS D8 X-ray Diffractometer. (Picture 12)



Picture 9 Analysing the mass size bunber using *Micromatics 5100 Particle Size Analyser*



Picture 10 Analysing phased composition using *Bruker AXS D8 X-ray Diffractometer*



Picture 11 Analysing chemical composition using *Shimadzu XRF-1700 X-ray Fluorescence Spectrometer*



Picture 12 Analysing material micro-structure composition using *HITACHI S-2500 Scanning Electro Microscope*

12.1.1 Phase 1 and Phase 2 Study

This study is focused on samples of bone china products from United Kingdom, Japan and porcelain products. The two countries are the country founder of manufacturing bone china products. Porcelain products is used to compare the content between the two products.

A total of 5 samples were labeled:

- UKB - Bone china body from United Kingdom
- JB - Bone china body from Japan
- SP - Standard Porcelain Body
- UKA - Bone Ash from United Kingdom
- JA - Bone Ash from Japan

12.1.2 Results and Discussion

Table 2 shows the two bone china bodies (UKB & JB) have a particle size distribution pattern almost similar which is around 7 μ m. Meanwhile, the bone china body from Japan (JB) produced twice the ratio of fine particle under 1.0 μ m (32%) and 0.5 μ m (20%) in size compared to bone china body from United Kingdom (UKB). Bone ash from United Kingdom (UKA) is coarser than Japan (JA), the mean particle size is 14 μ m and 11 μ m. The particle size is refined, a result of the grinding process. Concurrently, the standard porcelain body (SP) has a finer particle size, the mean size is 2.6 μ m.

Table 3 shows the bone china body from United Kingdom (UKB) contains high percentage of bone ash, based on the CaO and P₂O₅ contents compared with bone china from Japan (JB). This affects body composition of bone china from Japan (JB) in terms of higher Al₂O₃ content that gives more strength to bone

china products. Both bone ash from the United Kingdom (UKA) and Japan (JA) contain similar chemical composition. Meanwhile, Cao and P₂O₅ chemical composition of standard porcelain is low.

The study of microstructure and phase composition of the materials is shown in the SEM and XRD spectral micro image. The two bodies of bone china show uneven shape and flaky. Part of bone china body from UK has particle shaped like needles and fibers. Micro image of standard porcelain body is flaky and more consistent as shown in the particle size analysis. Bone ash from Japan (JA) is finer than bone ash from United Kingdom.

From this phase composition analysis, the results show bone china body from United Kingdom and Japan is almost similar, except from the additional muscovite material in the bone china body from United Kingdom. The two bodies have similar phase of mineral composition, consists of calcium phosphate, kaolinite, feldspar and quartz. All these minerals are also found on standard porcelain body. The two bone ash from United Kingdom and Japan consists of fully calcium phosphate material.

12.1.3 Summary of Laboratory Studies

The study shows a similarity in samples of bone china body from United Kingdom and Japan. But the bone china body from Japan is finer with a higher alumina content (Al₂O₃), and this gives more strength to bone china products from Japan. Both bone ash from United Kingdom and Japan have only calcium phosphate. This means that the ashes is not from original bones but of synthetic materials.

Table 2 Particle size analysis of bone china materials

Diameter, (µm)	Cumulative Mass Finer, (%)				
	UKB	JB	SP	UKA	JA
60	95.70	98.30	99.30	85.70	79.40
20	83.20	84.70	98.10	57.80	59.20
10	66.10	70.70	96.30	48.40	53.10
1.0	15.50	32.10	55.10	6.30	8.30
0.5	8.40	20.10	37.50	5.70	7.60
Mean	7.25	6.70	2.62	13.71	11.18
Median	4.64	1.80	0.63	8.84	6.18

Table 3 The chemical composition of bone china materials

Oxide	UKB	JB	SP	UKA	JA
CaO	25.9	23.3	0.21	41.7	41.1
P ₂ O ₅	22.7	19.2	0.24	57.1	55.9
SiO ₂	33.7	34.9	58.8	0.55	1.38
Al ₂ O ₃	14.1	19.5	36.9	0.33	1.30
Fe ₂ O ₃	0.31	0.19	0.82	0.09	0.10
TiO ₂	0.05	0.07	0.05	0.01	0.01
Na ₂ O	0.32	0.27	0.12	0.03	0.04
K ₂ O	2.26	2.06	2.21	0.03	0.04
MgO	0.68	0.52	0.73	0.20	0.21

12.1.4 Phase 3 And Phase 4 Study

This study using bone from the market, consists of bones of cattle, goat and swine. Only three types of bone normally used in bone china products because of its larger size and available in large quantity. All bones are burnt at temperature of 1000°C to remove the organic materials of the bone. Charred bones were grounded into a powder and then sieved before being labeled as OX (cattle bone ash), GA (goat bone ash) and SA (swine bone ash). Comparisons will be carried out between the three local bone ash and bone ash from United Kingdom (UKA) and Japan (JA).

12.1.5 Results and Discussion

50% of each bone ash is mixed with 25% kaolin and 25% feldspar to produce bone china body. The mixture is grounded and pressed to produce a pallet. All pallets are dried and labeled as BS1 (cattle bone ash composition), BS2 (goat bone ash composition) and BS3 (swine bone ash composition), as shown in Table 4. The dried pallet is fired at temperature of 1270°C and labeled as BS1-F, BS2-F, and BS3-F.

All samples consist of five bone ash labelled as OA,GA,SA,UKA dan JA. Bone china body composition is dried and fired at temperature of 1270°C for chemical composition analysis, micro structural analysis and phases material composition analysis.

Table 5 and 6 shows the differences in the composition of calcium and phosphate in the bones. Cattle bone contains the highest phosphate followed by goat bone and swine bone. The highest calcium content is swine bone, followed by goat bone and cattle bone. Overall, the oxide percentage in the dry composition is reduced after firing. Except for calcium content in bone china body mixed with swine bone (BS3-F), it shows a slight increase after firing.

12.1.6 Summary of Laboratory Studies

Based on the results and preliminary discussions of laboratory studies, the researchers concluded that bone china products have almost similar physical properties (particle size, chemical composition and chemical structure) even though the bones were of different origins (cattle, goat and swine bone ash). Oxide content in all bodies is the same and the oxide percentage differences was almost the same as shown in Table 3 and 5.

Although the XRD research showed the peak of spectra hydroxylapite on bone china body of swine bones is rather high, the hydroxylapite was actually evaporated at high temperature firing around 1270°C. The results on Table 4 and 5 shows the trends (cattle bone contains highest phosphate followed by goat and swine. For calcium, the highest content is in swine bones followed by goat and cattle), but the percentage differences is too small to be measured. Micro image also shows almost similar result on the surface of bone china body even though the bone ash content is different.

The study shows that in the preparation of bone ash from natural bone, the organic materials such as flesh, blood and cartilage were burnt off at high temperatures, above 1000°C. All that left is only

oxide material $\text{Ca}_3(\text{PO}_4)_2$ - calcium phosphate, and when blended with ceramic body, it is fused into a bone china body.

Table 4 Composition of studied material

Body No.	BS1	BS2	BS3
	50% OA	50% GA	50% SA
Materials Composition		25% Cheras Kaolin 25% Potash Feldspar	

Table 5 Chemical composition of bone ash using XRF

Oxide	OA	GA	SA	UKA	JA
P_2O_5	44.7	43.9	43.3	57.1	55.9
CaO	51.7	53.6	55.4	41.7	41.1
SiO_2	1.08	0.19	0.24	0.55	1.38
Al_2O_3	0.44	0.15	0.15	0.33	1.30
Fe_2O_3	0.19	0.06	0.03	0.09	0.10
TiO_2	0.01	0.004	0.001	0.01	0.01
Na_2O	0.61	0.97	0.13	0.03	0.04
K_2O	0.08	0.03	0.03	0.03	0.04
MgO	1.15	1.07	0.63	0.20	0.21

Table 6 Bone china chemical composition before and after firing

Oxide	BS1	BS2	BS3	BS1-F	BS2-F	BS3-F
P_2O_5	21.9	20.5	18.9	20.8	20.2	19.4
CaO	23.5	25.4	26.0	22.2	25.3	26.8
SiO_2	34.5	34.3	34.4	35.7	34.1	33.8
Al_2O_3	14.9	15.9	15.2	16.0	15.7	15.0
Fe_2O_3	0.51	0.52	0.42	0.48	0.42	0.48
TiO_2	0.11	0.09	0.10	0.10	0.09	0.08
Na_2O	0.20	0.16	0.22	0.33	0.28	0.25
K_2O	4.04	3.65	4.57	4.06	3.79	4.05
MgO	0.22	0.43	0.17	0.14	0.17	0.16

13.0 CONCLUSION

Based on the results of the research, it is proven that the determination of the types of bone used in the content of bone china product should be reviewed and monitored continuously to ensure the spiritual welfare of Malaysian Muslims is guarded. In the future through this research we are always be able to identify the content of material used to make the bone china products regardless of whether the product is produced locally or abroad. It

is hoped that from the results of this research, Malaysian Muslims will be informed about the contents in bone china products which further helps Selangor Mufti Department issuing a legal pronouncement on the permissible status of any product in the market soon.

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