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DEVELOPMENT OF BONE-CHINA FROM INDIGENOUS RAW MATERIALS

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Bone-china has been developed from indigenous raw materials. The results are encouraging. Major difficulties encountered have been discussed and their remedies are suggested.

INTRODUCTION

Bone-china was developed in U.K., at the end of 18th century. Due to its pleasing characteristics like translucency and whiteness, it soon became very popular. Its general composition as given by Searle [1] is bone-ash 42–50%, ball clay, 4–23%, china clay, 23–30% and cornish-stone, 7–30%.

Recently, Franklin and Forester [2] while working on the development of bone-china, have drawn a relationship of its composition with its properties. In the literature so far available, bone-china has always been developed with the addition of cornish stone besides other ingredients.

The present studies were undertaken with a view to replace the cornish-stone absolutely by indigenous clays, quartz and feldspar, since the availability of cornish-stone is not reported so far [3] in Pakistan.

EXPERIMENTAL

Preparation of Bone-Ash. Leg bones were boiled with $N/10$ caustic soda solution so that all the greasy materials were removed from the bones. The remains were then washed with water and dried. Dried bones were calcined at 1250° in a gas furnace, so that these were completely burnt to ashes, and ground to –200 mesh.

Cornish-stone was substituted by a mixture of china clay, quartz and feldspar. The chemical analysis of various raw materials used in the preparation of bodies is given in Table 1.

Different bodies were made by mixing bone-ash, quartz feldspar, china clay and KD–10 as given in Table 2. In some bodies, ball clay was totally or partially replaced by KD(P) or KD–10 clay. The deflocculant used in all the bodies was 0.5% solution of sodium carbonate and sodium silicate in equal proportions. All the bodies were dried at 110°. The dried bodies were fired to $1230–1250^{\circ}$ in a KANTHAL super furnacee of SM-12 type. The temperature of the furnace was measured with Pt/Pt-Rh thermocouple Only the translucent pieces having porosity of 2-4% were glazed with a thick paste of glaze having 1.3 g/cm^3 density.

The composition of the glaze is given in Table 4. The glazed pieces were fired to 1000°. The result of various bodies after glaze application are reported in Table 5. The bodies number 12 and 13 was further ground in the pot mill for 4 hr. The slips thus made were cast. The bodies so prepared were dried at 110°. They were fired to $1230–1250^{\circ}$. Bodies reported were then glazed with the thick paste of glaze and fired at 1000°.

RESULTS AND DISCUSSION

The major difficulties generally encountered in the

Table 1

No	Name	L/I	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	+ K_2O	
1.	Quartz	0.5	98.00	1.5	–	–	–	–	–	
2.	Feldspar	1.96	67.81	20.51	0.93	0.37		6.95	1.47	
3.	KD (pottery)	14.00	50.00	35.00	0.30	Traces	–	–	–	
4.	English China clay	12.67	46.02	39.43	0.08	0.23	–	0.63	0.36	
5.	English ball clay	14.01	64.31	18.21	0.38	0.42	0.31	1.41	0.78	
6.	Cornish stone	1.25	71.10	16.82	9.16	1.60	0.50 0.50	0.05	2.29	6.57

Table 2. Compositions of different bodies

Sl. No.	Bone ash	Ball clay	Feldspar	Quartz	Kaolin	KD-10	KD9P	Bentonite
1	35	10.00	10.00	30.00	15.00	–	Nil	–
2	35	10.00	10.00	30.00	10.00	–	05.00	–
3	35	–	10.00	30.00	10.00	–	15.00	–
4	40	–	10.00	30.00	5.00	–	15.00	–
5	40	–	10.00	30.00	10.00	–	10.00	–
6	40	–	10.00	30.00	10.00	10.00	–	–
7	40	10.00	10.00	30.00	5.00	–	–	5.00
8	45	12.2	23.00	16.8	3.00	–	–	–
9	45	10.5	23.00	17.00	4.50	–	–	–
10	45	10.00	23.00	10.00	7.00	–	–	5.00
11	45	8.00	23.00	12.00	5.00	–	–	7.00
12	50	10.00	19.00	15.00	6.00	–	–	–
13	50	15.00	20.5	6.7	7.8	–	–	–
14	50	8.00	25.00	13.00	4.00	–	–	–
15	50	10.00	19.00	15.00	6.00	–	–	–

Table 3. Casting behaviour of various compositions

Body No.	
1	Well casted
2	Well casted
3	Cracked
4	Cracked
5	Cracked
6	Cracked
7	Well casted
8	Well casted
9	Well casted
10	Well casted
11	Well casted
12	Well casted
13	Well casted
14	Well casted
15	Well casted

Table 4. Composition of glaze used.

Feldspar	55.00
Limestone	15.00
Kaolin	3.00
Quartz	15.5
ZnO	10.5

Table 4. Body characteristics regarding translucencies of various compositions after glaze application.

Body No.	
1	The body is not translucent, but instead body develops colour
2	Negligible translucency
3	Nil
4	Nil
5	Nil
6	Nil
7	Possesses translucency but slightly coloured
8	Translucency is more than No. 7
9	Translucent
10	The body is translucent but colour development is noticed
11	The body is translucent but colour development is slightly more than No. 10
12	Translucency is more than previous compositions
13	Translucency less than Body No. 12 but more than Body No. 1 to 11
14	Translucency is more than the previous 1–13 bodies
15	Translucency is miximum of all

making of bone-china bodies [12] were: (i) Lack of plasticity; (ii) Short firing range and large firing shrinkage; and (iii) Tendency for the body to develop blue or brown colour.

Lack of plasticity was cured by the addition of ball clay which, of course, has adverse effects on translucency and colour. Another way of getting rid off this difficulty is to add 5–7% of bentonite. Mellor [13] while working on bone-china bodies using feldspar, cornish-stone and bone-ash has also shown that for the development of maximum plasticity of the body, feldspar, cornish-stone and bone-ash react gradually with water when in prolonged contact with it, whereby feldspar releases alkali silicates which make the water alkaline. Bone-ash reacts more quickly giving soluble acidic calcium phosphate or even phosphoric acid, which increases plasticity of the body.

Body Nos. 1 and 2 did not develop translucency due to the presence of iron in the pottery clay used. Bodies Nos. 3,4,5, and 6 cracked due to various reasons, major being the absence of ball clay. Body No. 7 shows translucency since reasonable quantities of bone-ash and plastic clays were used. The colour development in the body was due to the presence of bentonite. Body No. 8 showed greater translucency because of the absence of bentonite in the body. Translucency in Body No. 9 was more than 7 and 8 since smaller quantities of ball clay were used. Body No. 10 and 11 did not indicate much translucency due to the presence of 5–7% of bentonite. Body No. 12 was found to be more translucent than all the compositions. Body No. 13 was also found to be translucent, but translucency was less than Body No. 12 because more quantity of ball clays, at the cost of china clay, made the body less translucent. No. 14 and 15 were more translucent and 15 possessed maximum translucency because of the fine grinding of the composition No. 12 and 13.

The second cause of the heavy losses in bone-china is due to short firing range and large firing shrinkage, which results into large warpage. St. Pierre [14] while working on constitution of bone-china has propounded a hypothesis that a fully crystallised bon-china would consist of tricalcium phophate, anorthite, mullite and silica. Anorthite and tricalcium phosphate are to the expected as crystallised phases in normal bodies, since mullite and silica with samll amounts of soda-potash and magnesia forms a stable glass. Free silica, however, may be present as an unreacted constituent of the body in a very small quantity. The composition of the bone-china falls close to the eutectic between tri-calcium phosphate, anorthite and silica which accounts for its very short firing range. As soon as bodies reach eutectic temperature, substantial quantities of liquids are formed rapidly, which cause the body to deform. The only way in which this quantity of liquid forming at the eutectic temperature, substantial quantities of liquids are formed rapidly, which cause the body to deform. The only way in which this quantity of liquid forming at the eutectic temperature can be reduced, is to increase one of the components so that the composition of the body falls away from eutectic. In order to obtain a longer firing range, without losing bone china characteristics, it would be necessary to used proportionately more bone-ash at the expense of china clay. Our results very much tally with the above facts as composition Nos. 6, 7,8, 9, 10, 11, 12 contain more bone-ash at the expense of china-clay are more translucent.

Our results also correspond with that of Mellor [13] and we safely conclude that the tendency of turning the body blue or brown and to blister is due to the presence of iron, which reacts with calcium phosphate under certain firing conditions, whereby iron phosphate is formed. If the kiln atmosphere is reducing and if steam or carbonaceous matter is given off by the body then bone-china body will be turned coloured. Bodies Nos. 2, 3, 4, 5 developed blue or brown colour since they contain pottery clay.

Conclusion

(1) In the manufacture of bone-china ball clay cannot be substituted by the local clays known so far.

(2) The translucency of the bone-china body is inversely proportional to the thickness of the body.

(3) Relative translucency also decreases with the increase of china clay keeping the other components constant.

(4) Finer the grinding of the body, the greater the translucency developed.

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