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Original Research Article

Evaluation of *Gallus gallus domesticus* Eggshell and Glass as an Alternative to Dental Pumice

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ABSTRACT

The major purpose of the dental pumice is to clean and make tooth surfaces smooth, it is a highly siliceous material derived primarily from volcanic activity. In a quest to make pumice readily available, an alternative material to pumice was developed. 100 µm particle sizes of both powdered eggshell and glass were mixed, in ratios of 1.5:8.5, 2:8, 1:9, and 0:10 to obtain J85, J90, J95, and J100 respectively. A scanning electron microscope with energy dispersive spectroscopy (EDS) was used for morphological characterization and elemental composition. The research questionnaire was structured for dental practitioners for quality assessment purpose. The results showed that J100 had more porosity, with a smaller pore diameter than J95, J90, and J85 respectively. EDS revealed the presence of 16 elements in the fabricated pumice. J85, J90, J95, and J100 of particle sizes 100, 80, and 50 µm were set at different magnifications (500×, 1000×, and 1500×) respectively. This revealed that the fabricated polishing materials (FPMs) have porous structures, thus making them good for polishing and cleaning tooth surfaces.

Keywords: *Gallus gallus domesticus*, Eggshell, Spectroscopy, Pumice, FPM, and EDS

Introduction

In dental practice, pumice is a stone with a small particle size employed as a cleaning and polishing agent which also aids in finishing acrylic denture moulds.[1,2] It is derived from glassy igneous rock of volcanic origin, with characteristics such as high porosity and low density. It floats on water as its specific gravity is lower than that of water, possessing a cream white or occasionally grey color.[3-5] Pumice smoothens the surface of scratched enamel by removing the plaque, biofilm, stains, and preventing bacteria from clinging to a rougher surface of the teeth.[6,7] It is utilized as an abrasive in polishing compounds, natural teeth polishing, and oral hygiene pastes in the course of prophylactic care for the teeth.[8]
In Nigeria the cost of pumice is relatively high, consequently, it has made the abrasive material used in polishing heat-cured acrylic dentures to be limited in supply. The relative scarcity of pumice has made dental technicians' to resort to mixing powdered pumice with water while polishing and repairing acrylic dentures. This is not advisable, as it exposes the pumice to various contaminants. To this end, there is need to develop an alternative material to pumice from eggshells and glass.
The general objective of this study is to produce locally a dental pumice from a mixture of glass and eggshells and to investigate its efficacy.

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Materials and Methods

Materials and equipment
The raw materials used were eggshells collected in October, 2019 from the bakery at Shoprite, Enugu State, Nigeria. Wine bottles (glass) were collected from family refuse in Enugu State in October, 2019. The equipment used includes a mixing bowl, spatula, muslin cloth, hand gloves, petri dish, pot, sieve, ball miller, Gentalab hot-air oven (MNO/50), stove, denture polishing machine, weighing balance (Ohaus, China), grinding machine, and scanning electron microscope (SEM/EDS) (Phenom ProX, Netherlands).

Preparation of eggshells
The eggshells were washed in a large amount of clean water to remove dust particles and debris. They were subsequently spread on a large tray and sun dried. To reduce the microbial load, the sun-dried eggshell were desiccated. The eggshells were then carefully crushed with a pestle and mortar, after which they were ground into a fine powder using a coffee mixer. The eggshell powder was then sieved to separate the coarse particles from the fine powder; after which the fine eggshell powder was stored in a clean, dried, and properly covered container.

Preparation of the glass
The bottles were washed thoroughly, using distilled hot water to remove dust particles and dirt. It was sun-dried for 48 hours and pulverized into powdered form.

Preparation of formulated pumice material (FPM)
The powdered glass and eggshells were sieved separately with muslin cloth of pore size 50 – 80 µm to obtain the finest particle. The sieved eggshell and glass were mixed at 100 g in the ratios of 1.5:8.5; 2:8, 1:9, and 0:10 to obtain J85, J90, J95, and J100 respectively. 35, 40, 45, and 50 ml of tap water were added into the different mixtures J85, J90, J95, and J100 respectively. The wet mixtures were dried for 24 h at 105ºC using hot air oven. Afterward, the dried material was grounded

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using a mortar and pestle. The FPMs were fired at the final temperature (450ºC) for 2 h and allowed to cool at room temperature.

Scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS)

The SEM-EDS was performed to examine the physical/structural change of samples using the SEM model Phenom ProX, by PhenomWorld Eindhoven, The Netherlands. The samples were placed on double-adhesive which was on a sample stub, and was coated with a sputter coater by quorum technologies model Q150R, with 5nm of gold. Thereafter they were taken into the chamber of the SEM machine where they were viewed via Navcam for *focusing and adjustments*. Subsequently, they were transferred to SEM mode, focusing, and brightness contrasting were automatically adjusted after which the morphologies at different magnifications were stored on a USB stick/drive. Also, electron dispersive X-ray spectroscopy (EDS) analysis was carried out on individual samples to determine the elemental composition.

Quality assessment

Some dental technologists in the Federal College of Dental Technology and Therapy, Enugu were given the finished product for assessment. Production of the eggshell polishing agents can be achieved, provided it is produced in large quantity and readily available.

Results and Discussion

The result of this study showed that the morphology of locally FPMs that were observable using a scanning electron microscope (SEM); and are presented in Figure 1. SEM images were obtained at constant magnifications of the FPMs to prevent inaccurate comparisons. The morphological analyses of four different FPMs were shown. Figure 1a-l illustrates the SEM images of FPMs with three different magnifications (×500, ×1000, and ×1500). The images revealed that the FPMs have a porous structure, thus making them useful as good support for polishing of dentures.[9-11] Besides, it can be seen on the SEM images of FPM - J95 (Figure 1g-i), that the five percent (5%) eggshell added to the FPM decreased its porosity and also decreased the shining ability of the FPM. This could be alluded to the silicon content decrease from 55.73 for J100 to 54.12.[9] Furthermore, it can be viewed on the SEM images of J90 (Figure 1d-f), that the ten percent (10%) eggshells added, made the porosity level of the J90 to decrease further. This also reduced the sparkling of the FPM, which could also be as a result of gradual decrease of silicon content to 51.20. The same trend is seen for J85 (Figure 1a-c). It was also observed that the addition of more eggshells to the FPMs gradually decreased the porosity, and made the FPMs to appear less lustrous. The J100 had more porosity, with a smaller pore diameter than J95, J90, and J85 respectively; which is a result of a gradual increase in the composition of eggshells.

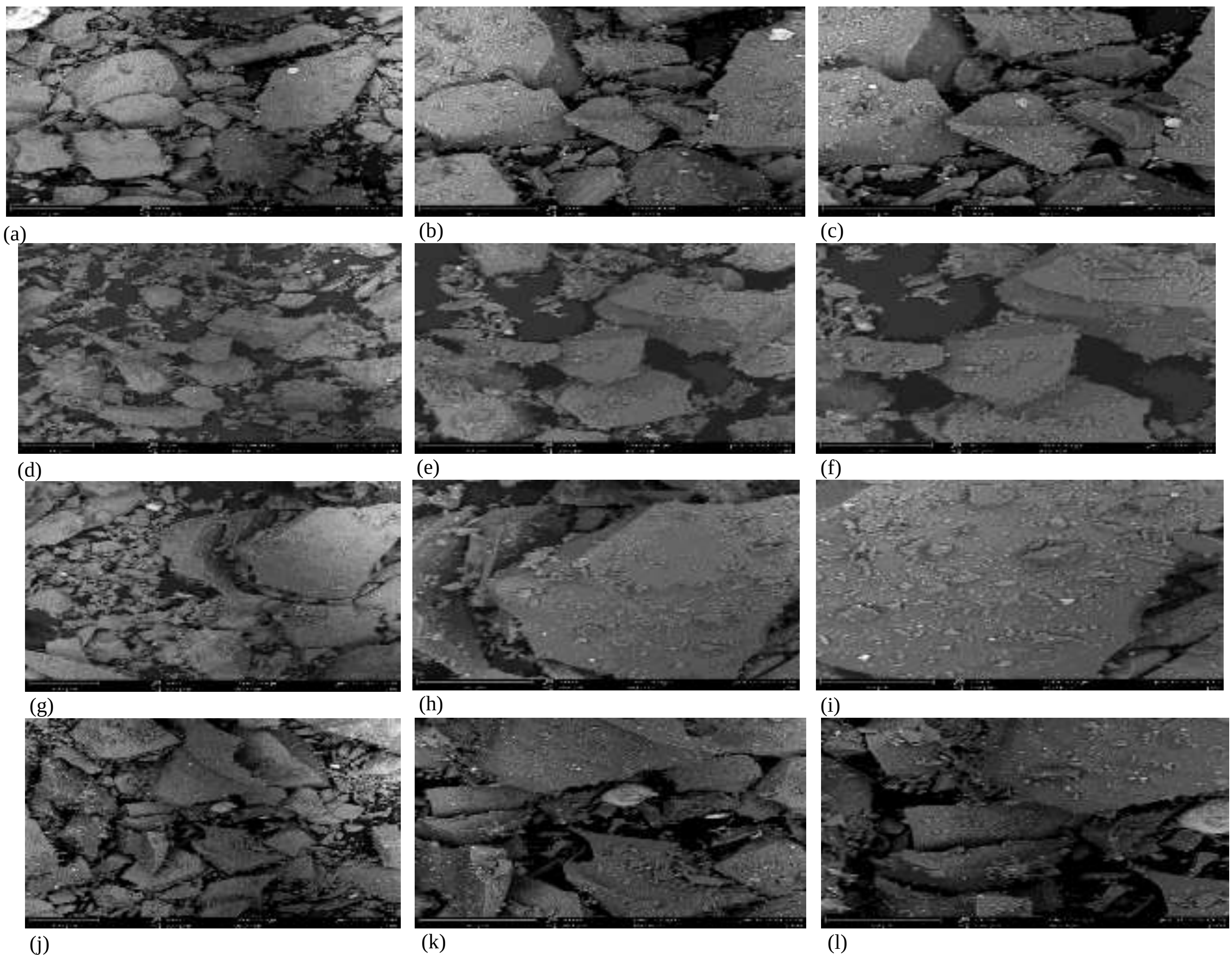

Figure 1: SEM images (a) – (c) 85% formulated pumice material of the particle size of 100 µm —500X; 80 µm —1000X; 50 µm —1500X respectively; (d)-(f) 90% formulated pumice material of the particle size of 100 µm —500X; 80 µm —1000X; 50 µm —1500X respectively; (g)-(i) 95% formulated pumice material of the particle size of 100 µm —500X; 80 µm —1000X; 50 µm —1500X respectively; (j)-(l) 100% formulated pumice material of the particle size of 100 µm —500X; 80 µm —1000X; 50 µm —1500X respectively.

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Analysis of the elemental composition revealed that peaks were recorded and J100 had the largest quantity of silicon which made it more lustrous than other FPMs. This result is supported by Ersoy *et al*.[12]

EDS analysis conducted on the FPMs to ascertain the elemental composition are presented in Table 1-2, Figure S1 and Figure 2. The result revealed the presence of Si, Ca, Na, Fe, K, Al, Mg, Ag, Y, Nb, S, P, Ti, Zr, Cu, and W, and the result is in line with research the conducted previously.[13,14]

Table 1 shows the elemental data obtained by the EDS and the percentage weight concentration of individual elements present in each FPM. From these results, the silicon content of the J100, J95, J85, and J90 samples were 55.73%, 54.12%, 52.74%, and 51.20% respectively. This indicates that there was a reduction in the percentage weight of the silicon as eggshells were added. This same trend is seen across the elements in Table 1.

The chemical constituents, especially SiO_2 content (Table 2) are an important material since their high value will elevate the hardness and resistance to chemical degradation, and also gives the samples their abrasiveness.[15-18] The SiO_2 values range from 60.55 – 64.47% in the FPMs with an average of 62.77% (Table 2). This is comparable with the SiO_2 contents in standard pumice samples.[18-20] The aluminum oxide (Al_2O_3) which is responsible for the resistance of pumice samples to heat and fire[15,16,18] was also present in a considerable quantity in the FPMs. The potassium oxide present in the FPMs was within the range of 1.33 – 2.12%, with a mean value of 1.76%. These values are similar to what we have in the standard pumice samples.[18-20] The percentages of sodium oxide and iron oxide in the FPMs which ranged from 6.49 – 7.29% and 4.15 – 6.14% (Table 2) with an average value of 7.02% and 5.23% (Table 2) were even higher than the standard pumice sample with the mean values of 4.67% and 2.05% respectively.[18-20] The high percentages of silica in these FPMs indicate that the samples constitute silica. The iron percentage value indicates the presence of pyroxene minerals in the FPMs; sodium, aluminum, and potassium oxide values indicate the feldspar minerals – potash and plagioclase feldspar.[15,18] The chemical evaluation of the FPMs in comparison with the standard pumice standard has similar values.

Table 1: Elemental composition of the formulated pumice materials

Element (%)	Sample				
	J85	J90	J95	J100	Average
Silicon	52.74	51.20	54.12	55.73	53.45
Calcium	16.04	18.65	17.32	18.32	17.58
Sodium	9.79	9.54	9.83	8.91	9.52
Iron	7.29	7.82	6.18	5.38	6.67
Potassium	3.19	2.80	2.01	2.65	2.66
Aluminum	3.02	3.13	1.91	2.65	2.68
Magnesium	1.73	1.57	1.47	1.47	1.56
Silver	1.44	0.99	0.82	0.81	1.02
Yttrium	1.44	1.28	1.15	nd	1.29
Niobium	0.97	0.98	0.64	0.70	0.82
Sulphur	0.92	1.39	1.25	1.55	1.28
Phosphorus	0.68	0.39	0.39	1.59	0.76
Titanium	0.37	0.31	0.26	nd	0.31
Zirconium	0.37	0.25	nd	0.24	0.29
Copper	nd	nd	1.63	nd	1.63
Tungsten	nd	nd	1.01	nd	1.01
Total (%)	**99.99**	**100.3**	**99.99**	**100**	**102.53**

Table 2: Oxides composition of the formulated pumice materials

Oxides	Sample				
	J85	J90	J95	J100	Average
SiO_2%	62.31	60.55	63.75	64.47	62.77
CaO%	12.39	14.42	13.34	13.86	13.50
Na_2O%	7.24	7.06	7.29	6.49	7.02
Fe_2O_3%	5.75	6.14	4.86	4.15	5.23
K_2O%	2.12	1.85	1.33	1.72	1.76
Al_2O_3%	3.15	3.24	1.98	2.70	2.77
MgO%	1.58	1.43	1.34	1.31	1.42
AgO%	0.85	0.58	0.48	0.47	0.59
Y_2O_3%	1.01	0.89	0.80	nd	0.90
NbO%	0.76	0.77	0.50	0.54	0.64
SO_2%	1.26	1.90	1.71	2.09	1.74
P_2O_5%	0.86	0.49	0.49	1.97	0.95
TiO%	0.34	0.28	0.23	nd	0.28
ZrO_2%	0.27	0.18	nd	0.17	0.21
CuO%	nd	nd	1.12	nd	1.12
WO_3%	nd	nd	0.70	nd	0.70
Total (%)	**99.89**	**100**	**100**	**100**	**101.6**

Table 3: Demographic data of the dental technologists

Variables	Frequency	Percentage
Sex		
Male	12	60
Female	8	40
Age		
<25	1	5
25 – 34	4	20
35 – 44	7	35
45 – 54	4	20
>54	4	20
Marital status		
Single	4	20
Married	16	80
Level of education		
HND/BSc	8	40
PGD	6	30
MSc	6	30
PhD	0	0
Years of experience		
<10	3	15
10 – 14	8	40
15 – 19	2	10
20 – 24	5	25
>24	2	10

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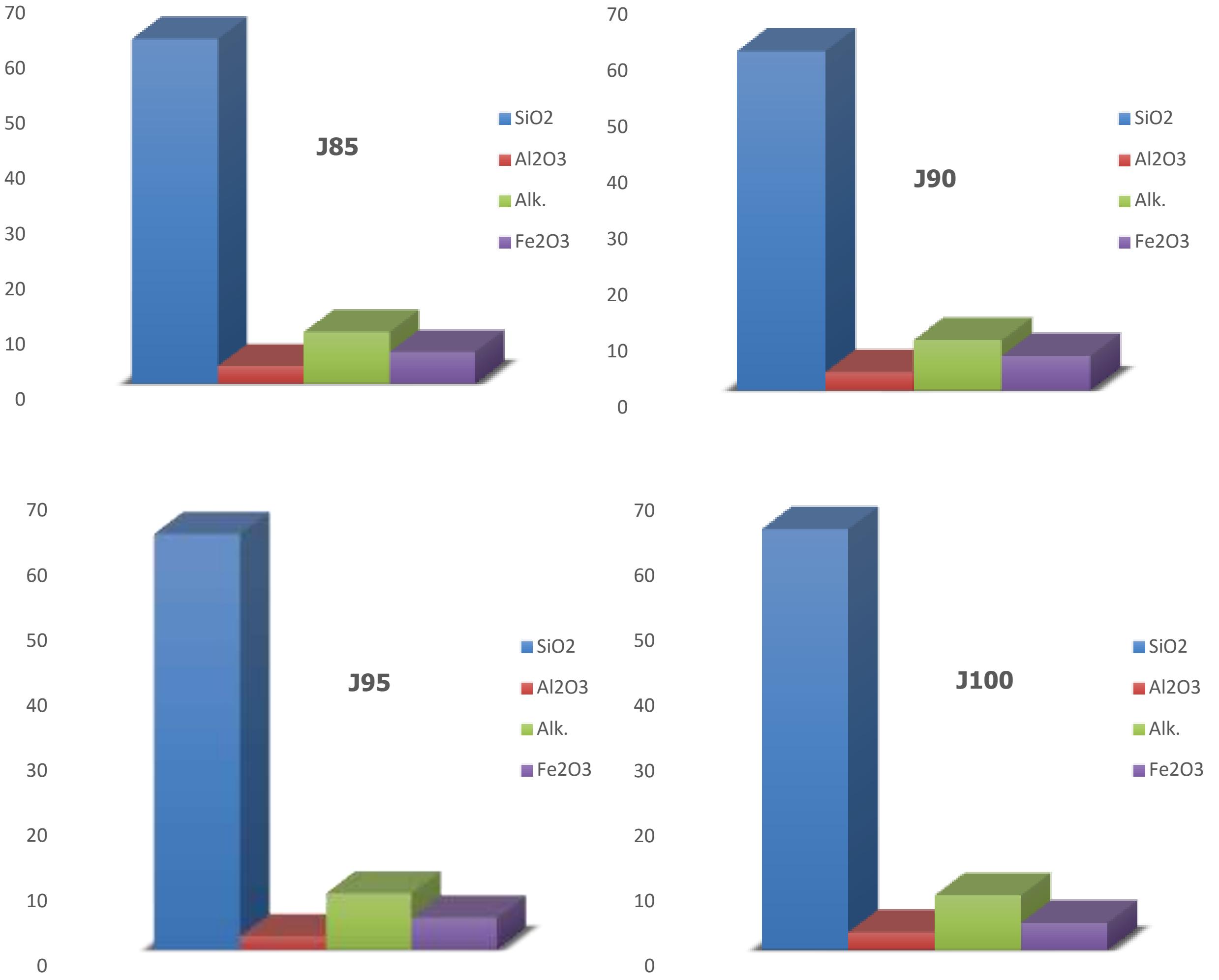

Figure 2: Relationships of SiO_2, Al_2O_3, Alkaline ($Na_2O + K_2O$) and Fe_2O_3

Table 4: Quality assessment of the formulated pumice materials

	Frequency (%)				
Variables	**Excellent**	**Very good**	**Good**	**Average**	**Poor**
Colour evaluation	2 (10)	4 (20)	8 (40)	5 (25)	1 (5)
Aromatic evaluation	3 (15)	9 (45)	7 (35)	1 (5)	0 (0)
Effectiveness	2 (10)	8 (40)	7 (35)	2 (10)	1 (5)
Acceptability	2 (10)	7 (35)	5 (25)	4 (20)	2 (10)

Quality assessments of FPMs (Table 3-4) were conducted at the Federal College of Dental Technology and Therapy, Enugu by dental technologists. Two dental technologists - 10% indicated the color of the material is excellent, four technologists - 20% indicated very well, eight technologists - 40% indicated good, five respondents - 25% indicated average, while one - 5% indicated poor. For the aromatic evaluation of the FPMs, three practitioners - 15% indicated that the odour of the materials was excellent, nine technologists - 45% indicated very good, seven respondents - 35% indicated good, and one respondent - 5% indicated average. Two respondents - 10% indicated the effectiveness of the material is excellent, eight respondents - 40% indicated very good, seven respondents - 35% indicated good, two respondents - 10% indicated average while one - 5% indicated poor. For the acceptability of the material, 10% of the practitioners indicated the acceptability of the material is excellent, 35% indicated very good, 25% indicated good, 20% indicated average and 10% indicated poor. Therefore, the new FPM is a suitable alternative to pumice as it effectively reduces the surface roughness of dentures. The practitioners believed that the new FPMs will definitely reduce the high cost of dental material.

Conclusion

From this study, SEM techniques revealed the presence of 16 elements in locally FPM and the surface of the FPM became more lustrous and porous due to different mesh sizes and the amount of silicon present. Quality control was done on the new local dental polishing agent, the dental practitioners believed that it will not only bring the cost of foreign pumice down but it will also replace the foreign pumice. From this study, it can be concluded that the FPM is a suitable alternative to pumice as it effectively reduces the surface roughness of dentures.

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Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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