Research Progress in Mechanical and Manufacturing Engineering Vol. 2 No. 2 (2021) 912-921
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Performance Comparison of Mussel and Clam Shell Wastes as an AbrasiveAgent Under Different Tooth Brushing Parameter

Irna Syafika Hassan[1], Shahmir Hayyan Sanusi[1]*

[1] Faculty of Mechanical Engineering and Manufacturing,
Universiti Tun HusseinOnn Malaysia (UTHM), 86400 Batu Pahat, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2021.02.02.098
Received 25 July 2021; Accepted 25 Nov. 2021; Available online 25 December 2021

Abstract: There are various types of abrasive particles used in toothpaste which contributes to the second-highest particle composition in a toothpaste. Around 10%-40% of the toothpaste consist of abrasive ingredient that is used to mechanically remove the extrinsic stain from the tooth surface. Calcium carbonate has been used for a decade as an abrasive agent in toothpaste. In regards to calcium carbonate, mussel shell and clamshell showed a high calcium carbonate content, which has the potential to be used in the formulation of medicine and toothpaste ingredients. Therefore, this study investigates the potential and performance of calcium carbonate obtained from mussel shell and clamshell as an abrasive agent in toothpaste and explore its efficiency under different toothbrushing parameters. The mussel shell and clamshell were milled and sieved to a maximum particle size of 63 µm. The powder obtained from mussel shell and clamshell were mixed with glycerol and water to form slurries. The brushing test was performed on the acrylic (PMMA) surface since it has good properties similar to artificial teeth by using Reciprocating Tooth Brushing Test Rig. The experimental result of scratch produced from mussel shell and clamshell abrasive particle was analyzed in terms ofscratch pattern, scratch factor, and drag factor to identify the effective toothbrushing parameter. The experimental analysis highlighted that teeth cleaning efficiency can be achieved by using the shell waste particles under optimum brushing load (1.5 N) and high brushing cycle (50 cycles). Technically, it is possible to replace the commercial calcium carbonate (extracted from limestone) with calcium carbonate obtained from mussel and clamshells as an abrasive agent in toothpaste. .

Keywords: Seashell Waste, Calcium Carbonate, Abrasive Particle

**Corresponding author: shahmir@uthm.edu.my*
2021 UTHM Publisher. All rights reserved.

1. Introduction

Tooth brushing and toothpaste plays a pivotal role in keeping gums and teeth clean as it is an important aspect of health and attractive appearance. It is worth noting that toothpaste contain complex formulations with often eight components that must be compatible to be effective; abrasive, humectant, water, binder, detergent, flavourings agent, preservative sweetener, therapeutic agent [1]. Around 10%-40% of the toothpaste consist of abrasive ingredient that is used to mechanically remove the extrinsic stain from the tooth surface.

In general, most abrasive particles in toothpaste were extracted from natural resources such as limestones. Improper control of harvesting natural resources would affect the balance of ecosystem. There is a necessity to investigate alternative material such as waste product to overcome this issue. According to Department of Fisheries Malaysia [2], the annual production of mussels and clams had reached 1220.63 tonnes and 111.77 tonnes respectively in 2019. Thus, shell waste disposal could result in environmental issue where if the dumped shell waste left untreated, it would lead to eyesore, strong nasty smells and pollution of local environment [3]. In order to minimize the shell waste issues,abundant research had been conducted on the way to utilize this waste as a resource by exploiting its advantages. Essentially, sea shell contains >95% chemical composition of calcium carbonate (CaCO3) and 1-5% remaining of organic material by weight [4], [5]. This provide new opportunities for sustainable development through the treatment of the shell waste materials by utilizing it to become useful material for various type of application. Many research applications of mussels and clams have been conducted in various field. Utilization of mussel shell and clam shell mainly focused on replacement material in a cement product for mansory and plastering [6]. Other application of seashell waste includes synthetic mussel-inspired adhesives [7], mussel-inspired hydrogels [8], and dentin bonding [9].

In this study, mussel shell and clam shell waste has been selected as one of the alternatives materials for abrasive agents along with its effective toothbrushing parameter in order to highlight the potential of mussel shell and clam shell waste to be used as an abrasive agent. Due to its availability and high composition of $CaCO_3$, mussels and clams shell waste might play a vital role as an alternative material for abrasive agent in the toothpaste.

2. Experimental Methods

2.1 Preparation of Mussel Shell and Clam Shell samples

Waste mussel shell and clam shell that used in this experiment were taken from a stall in Parit Raja. The shells were washed with tap water to remove dirt and been dried using industrial oven. It was crushed using crusher which was then been ground into the powder formusing Rotor mill machine. The powder was sieved in the shaker sieve.

2.2 Scratch Experiments

Scratch experiments was conducted to determine two important factors which were the toothbrush scratch factor and toothbrush drag factor. Toothbrush scratch factors indicates how many abrasive particles that the filaments can hold during brushing process while the toothbrush drag factor indicates how long the filaments can hold the abrasive particles throughout the brushing motion using the equation below:

$$Toothbrush\, scratch\, factor = \frac{Number\, of\, scratches}{Number\, of\, filaments} \qquad \text{Eq. 1}$$

$$Toothbrush\, drag\, factor = \frac{Scratch\, length}{Stroke\, length} \qquad \text{Eq. 2}$$

In order to obtain the number of scratches and the length of the scratches produced, the reciprocating tooth brushing test rig was used as the main tools for scratching test. The toothbrush head was attached to the connecting rod and secured with a screw to hold it tightly during scratch / wear process (Figure 1). Oscillating movements of the toothbrush against the fixed lower specimen (acrylic plate) takes place mechanically. A mixture of toothpaste was created by adding the mussel and clamshell powder into glycerol solution with an equal mass ratio. A small amount of abrasive particle material that enough to cover the brush filament area will be apply to the surface of theacrylic plate.

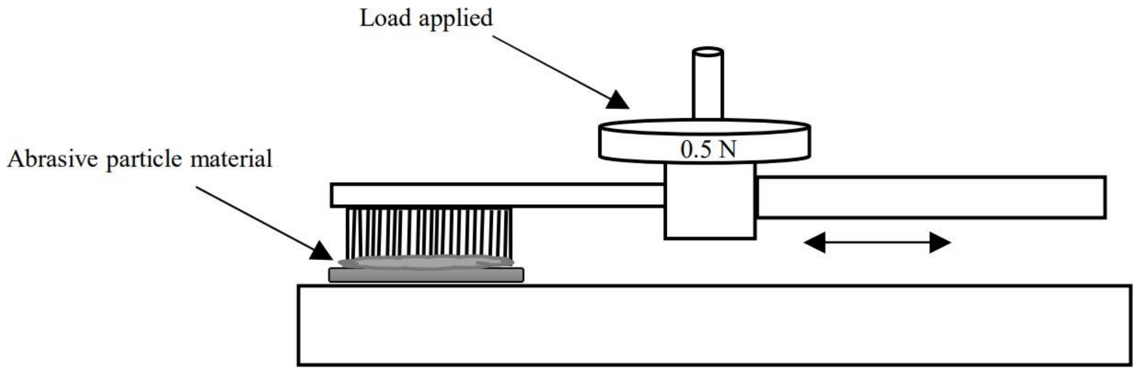

Figure 1: Tooth brushing visualisation test set-up Table

Table 1: Parameter setup during the toothbrushing test

Load applied on the toothbrush	0N, 0.5N, 1.0N, 1.5N, 2.0N
Abrasive particle material	Mussel shell particle Clam shell particle
Substances use as medium contact	Glycerol
Number of cycles for every load	0.5, 1, 5, 25, and 50 cycles

3. Results and Discussion

This section presents data and analysis from the experimental work of the overall study todetermine the effectiveness of mussel shell and clam shell waste as abrasive agents under different toothbrushing parameters.

3.1 Scratch Analysis

Scratch analysis was conducted to determine the number of scratches and the length of the scratch likely to occur on the acrylic plate (PMMA) surface by mussel shell and clam shell particle. This analysis shows how brushing load contribute to efficient tooth brushing cleaning.

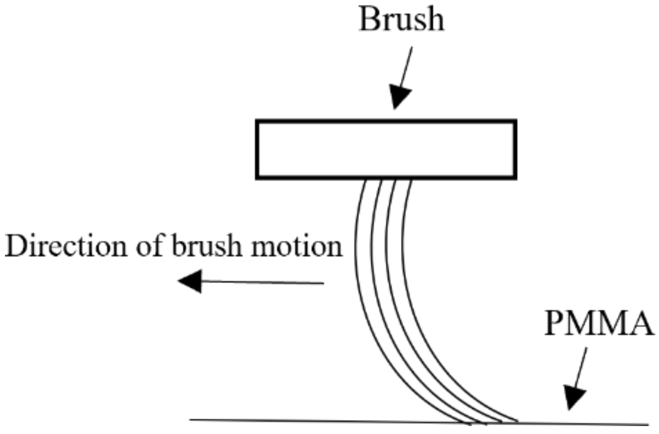

Figure 4: Deflected filament under high brushing load

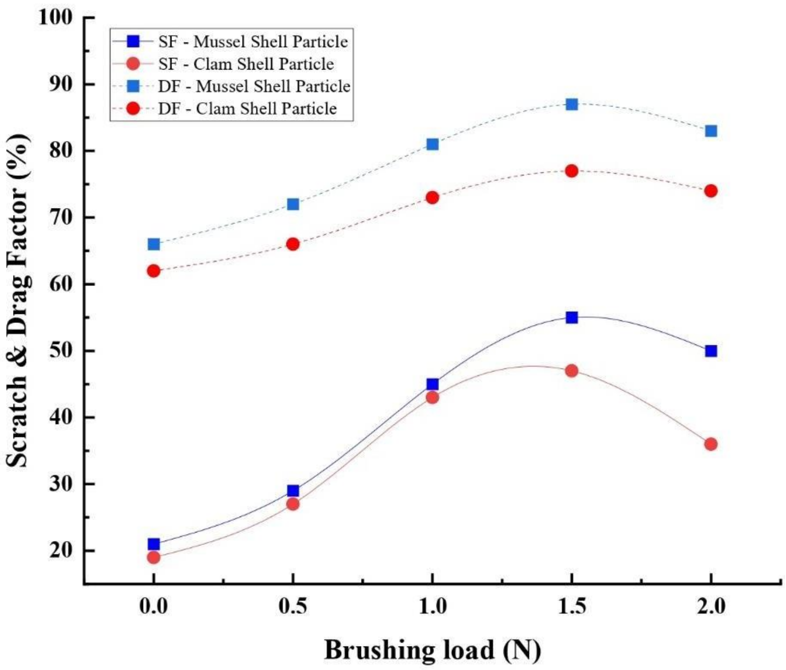

Figure 5: Scratch Factor and Drag Factor produced by Mussel Shell and Clam Shell under 0.5 brushing cycle

The scratch factor and drag factor produced under 0.5 brushing cycle (Figure 5) shows a non-monotonic trend for both abrasive particle. Increased brushing load significantly affected the scratch factor and drag factor of mussel shell and clam shell abrasive particle. As the scratch factor rate constantly increased with an increased in brushing load, the trend start to decreased once it passed 1.5 N brushing load. A similar trend can be observed in comparison to the drag factor. The peak of scratch factor and drag factor was obtained under 1.5 N brushing load for mussel shell and clam shell particle since it exceeded the optimum brushing load. However, mussel shell particles produced a significant scratch and drag factor compared to the clamshell particles under any loading conditions.

It was observed that significant scratch factor obtained by mussel shell particle was due to the particle shape and particle size since the maximum size of the particle is 63 µm. Mussel shell particle tends to have irregular shape (angular and cylindrical) with a high concentration of larger particles and lesser finer particles compared to the clam shell particle resulting in higher number of scratches produced. Other than that, under higher brushing load more scratches produces was observed during the experimental work, and this shows brushing load contributing to an efficient tooth cleaning process. But the filaments start to deflect as the brushing load exceeded 1.5 N due to the fact that the toothbrush's filaments deflected once it reach the maximum sustainable load (1.5N) and will not be able to hold the particle firmly and cause the particles to splayed out resulting to a reduction on number of scratches under 2.0 N brushing load (Figure 4). This finding agrees with previous studies which reported that few particles are trapped, and some do not stay trapped at the tip of filaments under excessive brushing load to produce scratch [14]. Hence, this trend line highlighted that more scratches could be produced under higher load until the toothbrush's filaments exceeded its optimum brushing load (1.5 N) which reduce the number of scratches produced.

Similar observation can be observed on drag factor, where the mussel shell particles obtained the highest drag factor value compared to clam shell particle under any loading conditions. Other than that, it can be seen that that the length of the scratch does not equal the length of the brush stroke (20mm). As the brushing load increases, the drag factor increases. The longer scratch was produced under 1.5 N because the filaments start to deflect as the brushing load exceeded 1.5 N brushing load and resulted in filaments fails to hold the abrasive particle throughout the brushing motions to produce continuous scratch per stroke under 2.0 N. It was observed that not all of the particles remain entrapped under the filament. It was thought to be that the particles would either move to another filament's tip or trapped between the filaments during the toothbrush's motion. Thus, it can be concluded that both scratch factor and the drag factor are significantly affected by the 1.5 N brushing load for efficient toothbrush cleaning using mussel shell abrasive particle.

3.2 Scratch Pattern

Technically, the amount of abrasion to the enamel rises as the brushing load and brushing cycle increased. Brushing load and brushing cycle significantly affect plaque and stain removal during toothbrushing [1]. These can be seen from the changes in the scratch pattern from each sample. Scratch patterns were crucial to understands the material removal process and the particle entrainment's effect on different toothbrushing parameters applied for this study.

Figure 6 show the comparison of the scratch pattern produced by different abrasive particle material under different loading condition. It can be observed that mussel shell particle would produce high number of scratches at any loading condition compared to clam shell. However, as the load exceeded 1.5 N brushing load, low intensity of scratch pattern can be observed resulting in less number of scratches produced.

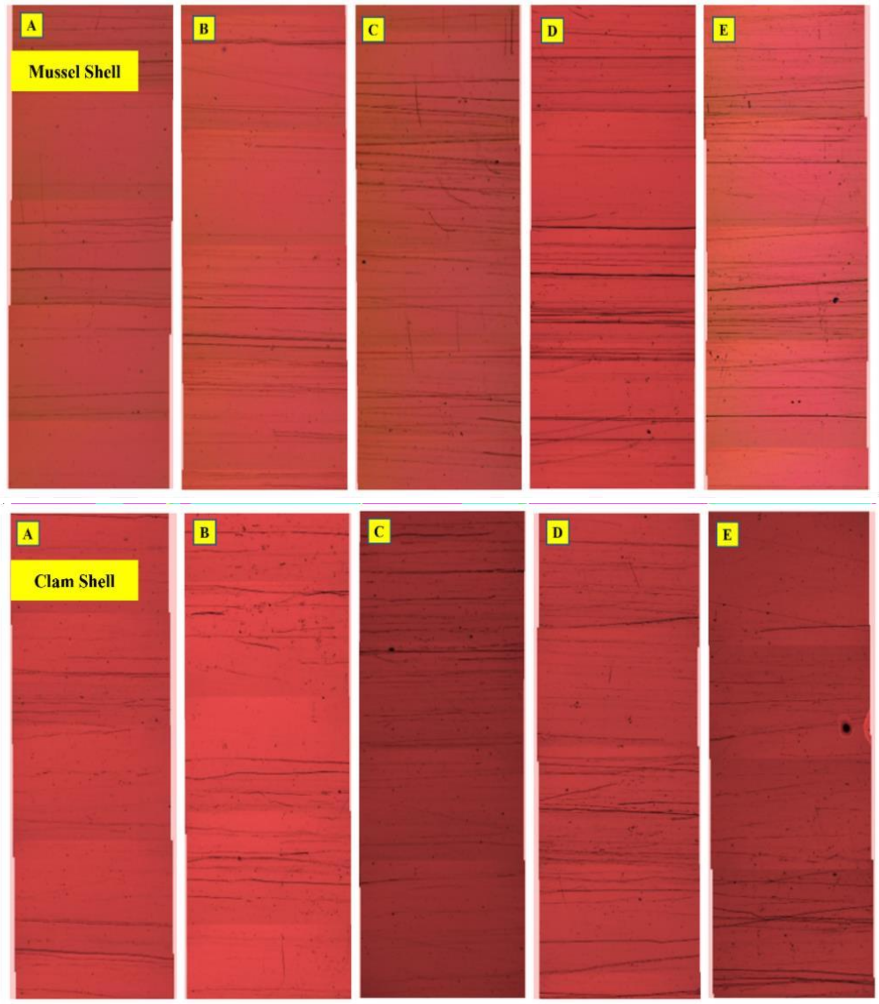

Figure 6: Scratch patterns produced by Mussel Shell and Clam Shell particle under 0.5 cycle; A) 0.0 N, B) 0.5 N, C) 1.0 N, D) 1.5 N, E) 2.0 N

As for the brushing cycle, higher scratch intensity was observed under high brushing cycle (50 cycles) for both abrasive particle material as shown in Figure 7. High brushing cycles produced more scratches than lower brushing cycles under similar loading condition. It denotes that only a few particles trapped and cause scratches under lowest brushing cycles (one forward movement of toothbrush head). As the toothbrush head moved back and forth, more scratches were produced but not all scratches were continuous, and some of them were intermittent and short in length indicating that some particle trapped and dislodged to another filament during reverse motion. This suggest that when brushing was conducted up to 50 cycles, more scratches will be formed and some of the initial scratches will getting deeper since some of the smaller particles might already trapped within the scratch mouth.

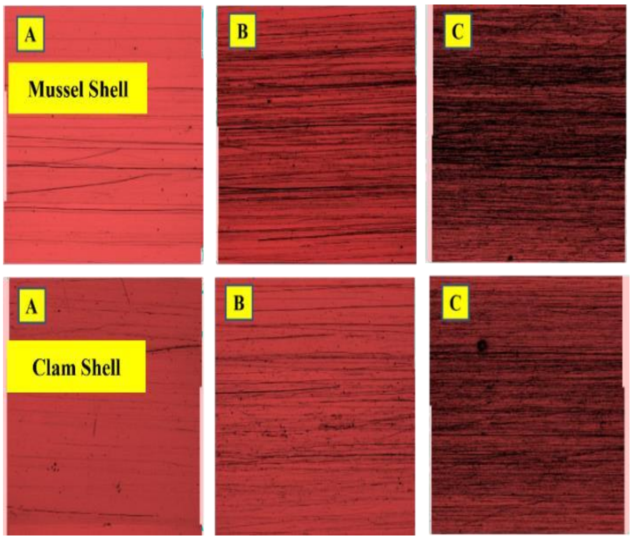

Figure 7: Scratch patterns produced by Mussel Shell and Clam Shell particle under 1.5 N; A) 0.5 cycle, B) 5 cycle, C) 50 cycle

4. Conclusion

This study aimed to investigate the abrasion and scratch characteristic produced by the mussel shell and clamshell slurry due to their high content of calcium carbonate. Thus, mussel shell has a high potential to be commercialized as an abrasive agent in the toothpaste since it shows a significant result in validation test of an artificial stain removal. Furthermore, the overall results from this study suggest that an effective tooth brushing can be obtained using an effectivetooth brushing parameter consisting of a 1.5 N brushing load, which was considered as the average normal brushing load and 50 brushing cycles. This study not only demonstrated the potential of the seashell waste, but it was also highlighting the effective parameters for efficient tooth brushing cleaning. By utilizing the seashell waste, many manufacturers could conduct further study and assess its suitability for toothpaste purpose aligned with 13th Sustainable Development Goal which to ensure sustainable consumption.

Acknowledgement

The authors gratefully acknowledge the financial support by Universiti Tun Hussein Onn Malaysia (UTHM) through the research grant Vot. H239. The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] M. L. Darby and M. Walsh, *Dental Hygiene: Theory and Practice*. 2014.

[2] “FAO Fisheries & Aquaculture - National Aquaculture Sector Overview - Malaysia.” http://www.fao.org/fishery/countrysector/naso_malaysia/en#tcN7002D (accessed Dec. 26,2020).

[3] M. C. Barros, P. M. Bello, M. Bao, and J. J. Torrado, “From waste to commodity: transforming shells into high purity calcium carbonate,” *Journal of Cleaner Production*, vol.17, no. 3. pp. 400–407, 2009, doi: 10.1016/j.jclepro.2008.08.013.

[4] M. Mohamed, S. Yousuf, and S. Maitra, “Decomposition study of calcium carbonate in cockleshell,” *J. Eng. Sci. Technol.*, vol. 7, no. 1, pp. 1–10, 2012.

[5] J. N. Murphy, K. Hawboldt, and F. M. Kerton, “Enzymatic processing of mussel shells toproduce biorenewable calcium carbonate in seawater,” *Green Chem.*, vol. 20, no. 12, pp. 2913–2920, 2018, doi: 10.1039/c8gc01274a.

[6] P. Lertwattanaruk, N. Makul, and C. Siripattarapravat, “Utilization of ground waste seashellsin cement mortars for masonry and plastering,” *J. Environ. Manage.*, vol. 111, pp. 133–141, 2012, doi: 10.1016/j.jenvman.2012.06.032.

[7] Q. Guo, J. Chen, J. Wang, H. Zeng, and J. Yu, “Recent progress in synthesis and application ofmussel-inspired adhesives,” *Nanoscale*, vol. 12, no. 3, pp. 1307–1324, Jan. 2020, doi: 10.1039/C9NR09780E.

[8] C. Zhang, B. Wu, Y. Zhou, F. Zhou, W. Liu, and Z. Wang, “Mussel-inspired hydrogels: Fromdesign principles to promising applications,” *Chemical Society Reviews*, vol. 49, no. 11. Royal Society of Chemistry, pp. 3605–3637, Jun. 07, 2020, doi: 10.1039/c9cs00849g.

[9] K. Li, Y. Sun, J. K. H. Tsoi, and C. K. Y. Yiu, “The application of mussel-inspired molecule indentin bonding,” *J. Dent.*, vol. 99, p. 103404, Aug. 2020, doi: 10.1016/j.jdent.2020.103404.

[10] W. Siriprom, J. Kaewkhao, K. Phachana, and P. Limsuwan, “Crystal structure and

morphologydependence of the phase of mollusc shell: A case study of XRD, SEM and ESR," *J. Phys. Conf. Ser.*, vol. 266, no. 1, 2011, doi: 10.1088/1742-6596/266/1/012124.

[11] S. Widyastuti and I. A. K. P., "Synthesis and characterization of CaCO3 (calcite) nanoparticles from cockle shells (Anadara granosa Linn) by precipitation method," in *AIP Conference Proceedings*, 2017, vol. 1855, p. 030018, doi: 10.1063/1.4985488.

[12] C. Martínez-García, B. González-Fonteboa, F. Martínez-Abella, and D. Carro-López, "Performance of mussel shell as aggregate in plain concrete," *Constr. Build. Mater.*, vol. 139,pp. 570–583, May 2017, doi: 10.1016/j.conbuildmat.2016.09.091.

[13] M. R. R. Hamester, P. S. Balzer, and D. Becker, "Characterization of calcium carbonate obtained from oyster and mussel shells and incorporation in polypropylene," *Mater. Res.*, vol.15, no. 2, pp. 204–208, 2012, doi: 10.1590/S1516-14392012005000014.

[14] R. Lewis and R. S. Dwyer-Joyce, "Interactions between toothbrush and toothpaste particlesduring simulated abrasive cleaning," *Proc. Inst. Mech. Eng. Part J J. Eng. Tribol.*, vol. 220,no. 8, pp. 755–765, 2006, doi: 10.1243/13506501JET96.