

**FORMULATION AND CHARACTERIZATION OF PORCELAIN BALLS  
FROM MALAYSIA CLAYS**

**by**

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## TABLE OF CONTENTS

	<b>Page</b>
<b>ACKNOWLEDGEMENTS</b>	ii
<b>TABLE OF CONTENTS</b>	iii
<b>LIST OF TABLES</b>	viii
<b>LIST OF FIGURES</b>	ix
<b>LIST OF SYMBOLS</b>	xv
<b>LIST OF ABBREVIATIONS</b>	xvi
<b>ABSTRAK</b>	xix
<b>ABSTRACT</b>	xxi
<b>CHAPTER ONE : INTRODUCTION</b>	
1.1 Research background	1
1.2 Problem statement	9
1.3 Research objectives	12
1.4 Research scopes	12
<b>CHAPTER TWO : LITERATURE REVIEW</b>	
2.1 Grinding technology	14
2.1.1 Introduction	14
2.1.2 Types of grinding mill	14
2.1.2.1 Tumbling grinding mill	15
2.1.2.2 Attritor grinding mill	19
2.1.2.3 Vibratory mill	20
2.1.2.4 Planetary mill	20
2.2 Types of grinding media balls	21

2.2.1	Metal balls	22
2.2.2	Ceramic balls	25
2.3	Types of ceramic balls	27
2.3.1	Advanced ceramics	27
2.3.1.1	Tungsten carbide balls	28
2.3.1.2	Zirconium oxide balls	30
2.3.1.3	Aluminium oxide balls	32
2.3.2	Conventional ceramic	34
2.3.2.1	Porcelain balls	35
2.4	Fabrication of porcelain balls	36
2.4.1	Raw materials for fabrication of porcelain balls	37
2.4.1.1	Clay	37
2.4.1.2	Silica	40
2.4.1.3	Feldspar	42
2.4.2	Methods of fabrication	44
2.4.2.1	Plastic forming	44
2.4.2.2	Powder pressing	45
2.5	Effect of sintering temperature on porcelain balls fabrication	47
2.5.1	Reactions occurring during firing	47
2.5.2	Factors influencing the maturing behaviour porcelain balls	51

### **CHAPTER THREE : METHODOLOGY**

3.1	Introduction	54
3.2	Experimental Part I – Characterization of raw materials	54
3.2.1	Sample collection and preparation	54
3.2.2	Physical properties	56

3.2.2.1	Particle size distribution	57
3.2.2.2	Particle morphology	58
3.2.2.3	Density and specific surface area	58
3.2.2.4	Consistency limits	59
3.2.3	Chemical properties	62
3.2.4	Mineralogical analysis	63
3.2.4.1	Qualitative analysis	63
3.2.4.2	Quantitative analysis	63
3.2.5	Thermal analysis	63
3.3	Experimental Part II – Properties and microstructure analyses of porcelain body formulation samples	64
3.3.1	Formulation of porcelain bodies	65
3.3.2	Sample preparation for the formulation of porcelain ball bodies	66
3.3.2.1	Physical properties	67
3.3.2.2	Chemical properties	67
3.3.2.3	Ceramic body colour	67
3.3.2.4	Phase transformation after firing	69
3.3.2.5	Microstructure	69
3.3.2.6	Thermal analysis	69
3.3.2.7	Firing properties	69
3.4	Experimental Part III – Fabrication and milling performance of porcelain grinding ball	73
3.4.1	Sample preparation and fabrication of grinding media	74
3.4.2	Wear and tear test	75

## CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1	Part I – Characterization of raw materials	77
4.1.1	General information of clay samples	77
4.1.2	Physical properties	78
4.1.2.1	Particle size distribution	78
4.1.2.2	Particle morphology	80
4.1.2.3	Density and specific surface area	82
4.1.2.4	Plasticity	83
4.1.3	Chemical composition	84
4.1.4	Phase analyses	85
4.1.4.1	Qualitative analysis of clay minerals	85
4.1.4.2	Quantitative analysis of clay minerals	87
4.1.5	Thermal property	88
4.1.6	Evaluation on clay suitability for industrial application	90
4.2	Part II: Properties and microstructure analyses of porcelain body formulation samples	91
4.2.1	Particle size distribution	91
4.2.2	Chemical composition analyses	92
4.2.3	Colour of ceramic bodies	93
4.2.4	Phase changes of fired samples	97
4.2.5	Microstructures of fired body formulation samples	102
4.2.6	Thermal property	109
4.2.7	Firing properties	111
4.2.7.1	Relationship between firing shrinkage, water absorption, bulk density and apparent porosity	111
4.2.7.2	Micro hardness and compressive strength	115

4.2.8	Evaluation on suitability for porcelain balls fabrication	117
4.3	Part III – Fabrication of porcelain balls and milling performance	117
4.3.1	Preparation and fabrication porcelain balls	118
4.3.2	Wear and tear test	120
<b>CHAPTER FIVE: CONCLUSION AND RECOMMENDATION</b>		
5.1	Conclusion	123
5.2	Recommendation	124
<b>REFERENCES</b>		125
<b>LIST OF PUBLICATIONS</b>		

## LIST OF TABLES

		<b>Page</b>
Table 1.1	Current EMA and USP limits for metals impurities in Pharmaceuticals (Figueiredo et al., 2016)	4
Table 2.1	Properties of grinding media (Kwade and Schwedes, 2007)	34
Table 2.2	Properties of commercial porcelain ball (UOP LLC, 2004)	35
Table 2.3	Commercial clay (Carter and Norton, 2013)	38
Table 2.4	Types of clay minerals (Dondi et al., 2014)	39
Table 3.1	Detailed specification of cold isostatic press (CIP) machine	75
Table 4.1	Particle size distribution of the samples	79
Table 4.2	Density and specific surface area of processed Malaysian clays	82
Table 4.3	Plasticity of processed Malaysian clays	83
Table 4.4	Chemical composition of the processed Malaysian clays, feldspar and silica	85
Table 4.5	Quantitative analysis of clay samples through Rietveld refinement method	87
Table 4.6	Chemical composition of the porcelain bodies	93
Table 4.7	Quantitative analysis of fired PBT, PBC, PBP, PBS and PBB through Rietveld refinement method	101

## LIST OF FIGURES

		<b>Page</b>
Figure 1.1	Location of clay and kaolin mines in Perak, Malaysia (Lian Marto et al., 2014)	8
Figure 2.1	Cascading and cataracting action in tumbling mill (McKeen, 2006)	16
Figure 2.2	Schematic diagram possible operating regime of a tumbling mill (McKeen, 2006)	16
Figure 2.3	Schematic of a tumbling ball mill (Lynch and Rowland, 2005)	18
Figure 2.4	Schematic of a rod mill (Vermeulen et al., 1984)	18
Figure 2.5	Attritor ball mill (El-Eskandarany, 2001)	19
Figure 2.6	Diagrammatic view of the vibratory ball mill (Gock and Kurrer, 1999)	20
Figure 2.7	Schematic drawing of a high-energy planetary ball mill (El-Eskandarany, 2001)	21
Figure 2.8	Shape of grinding media used by tumbling mill such as (a) spherical, (b) cylinder and (c) eclipsoids	22
Figure 2.9	Types of steel balls as grinding media available in the market such as (a) steel ball, (b) chrome steel ball and (c) forged ball	25
Figure 2.10	Tungsten carbide balls as grinding media (Ma, 2016)	28
Figure 2.11	Zirconia balls as grinding media (Ma, 2016)	30

Figure 2.12	Isostatic pressing versus uniaxial pressing (American Isostatic Presses Inc, 2003)	46
Figure 2.13	Wet bag isostatic pressing (a) the powder to be compacted is loaded into a bag mold (b) sealed the bag (c) the sealed bag is placed inside the pressure chamber (d) hydraulic pressure is applied and (e) compaction completed and removed part from chamber	47
Figure 3.1	Location of clays in Perak	55
Figure 3.2	Location of Selendang clays in Pahang	55
Figure 3.3	Flow chart of the Experiment Part I	57
Figure 3.4	(a) Liquid limit device and grooving tool and (b) diagrams illustrating liquid limit test (ASTM D4318-00, 2005)	60
Figure 3.5	Diagrams illustrating plastic limit test (Sack, 2015)	61
Figure 3.6	Flow chart of the Experiment Part II	65
Figure 3.7	Load and diagonals of the indentation hardness Vickers method (Al-Hilli and Al-Rasoul, 2013; ASTM C1327,2015)	72
Figure 3.8	Flow chart of the Experiment Part III	73
Figure 3.9	Sphere rubber mould for fabricated porcelain balls	75
Figure 3.10	Laboratory ball mill	76

Figure 4.1	Photographs of clay samples (a) Trong clay, (b)Kg. Coldstream clay, (c)Simpang Pulai clay, (d) Selendang clay and (e) Bidor clay	78
Figure 4.2	Cumulative particle size distribution of Malaysian clay	79
Figure 4.3	SEM micrographs of processed Malaysian clays: (a) TC, (b) KC, (c) SP, (d) SC and (e) BC (a) TC, (b) KC and (c) SP	81
Figure 4.4	Position of the processed Malaysian clay on the Holtz and Kovacs diagram (Boussen et al., 2016)	83
Figure 4.5	XRD pattern of the clay samples (a) TC, (b) KC, (c) SP, (d) SC and (e) BC	86
Figure 4.6	DTA/TG curves of the processed Malaysian clays (a) TC clay, (b) KC clay, (c) SP clay, (d) SC clay and (e) BC clay	89
Figure 4.7	Cumulative particle size distribution of porcelain mixture bodies	92
Figure 4.8	Coordinate of (a) the lightness colour L*, (b) red colour a* and (c) yellow colour b* of processed Malaysian clays	94
Figure 4.9	Coordinate of (a) the lightness colour L*, (b) red colour a* and (c) yellow colour b* of green body and fired porcelain body samples	96
Figure 4.10	XRD patterns of the PBT before and after fired at various temperature. (a) unfired, (b) 1200 °C, (c) 1230 °C, (d)1250 °C, (e) 1270 °C and (f) 1300 °C	98

Figure 4.11	XRD patterns of the PBC before and after fired at various temperature (a) unfired, (b) 1200 °C, (c) 1230 °C, (d) 1250 °C, (e) 1270 °C and (f) 1300 °C	98
Figure 4.12	XRD patterns of the PBP before and after fired at various temperature (a) unfired, (b) 1200 °C, (c) 1230 °C, (d) 1250 °C, (e) 1270 °C and (f) 1300 °C	99
Figure 4.13	XRD patterns of the PBS before and after fired at various temperature (a) unfired, (b) 1200 °C, (c) 1230 °C, (d) 1250 °C, (e) 1270 °C and (f) 1300 °C	99
Figure 4.14	XRD patterns of the PBB before and after fired at various temperature (a) unfired, (b) 1200 °C, (c) 1230 °C, (d) 1250 °C, (e) 1270 °C and (f) 1300 °C	100
Figure 4.15	Percentage of mullite of fired PBT, PBC, PBP, PBS and PBB through Rietveld refinement method	102
Figure 4.16	The FESEM images of the fractured surfaces of PBT fired at (a) 1200 °C, (b) 1230 °C, (c) 1250 °C, (d)1270 °C and (e) 1300 °C	103
Figure 4.17	The FESEM images of the fractured surfaces of PBC fired at (a) 1200 °C, (b) 1230 °C, (c) 1250 °C, (d) 1270 °C and (e) 1300 °C	104
Figure 4.18	The FESEM images of the fractured surfaces of PBP fired at (a) 1200 °C, (b) 1230 °C, (c) 1250 °C, (d) 1270 °C and (e) 1300 °C	105
Figure 4.19	The FESEM images of the fractured surfaces of PBS fired at (a) 1200 °C, (b) 1230 °C, (c) 1250 °C, (d) 1270 °C and (e) 1300 °C	106

Figure 4.20	The FESEM images of the fractured surfaces of PBB fired at (a) 1200 °C, (b) 1230 °C, (c) 1250 °C, (d) 1270 °C and (e) 1300 °C	107
Figure 4.21	DTA/TG curves of the porcelain ball bodies (a) PBT, (b) PBC, (c) PBP, (d) PBS and (e) PBB	110
Figure 4.22	Firing shrinkage of the fired porcelain body formulation samples	112
Figure 4.23	Relationship between (a) water absorption and (b) apparent porosity of the fired porcelain body formulation samples	113
Figure 4.24	Bulk density of the fired porcelain body formulation samples	114
Figure 4.25	Vickers hardness of the fired porcelain body formulation samples	116
Figure 4.26	Compressive strength of the fired porcelain body formulation samples	117
Figure 4.27	Green product porcelain balls after pressing with CIP (a) powder is not enough and (b) too much powder used	119
Figure 4.28	Porcelain balls PBT before and after fired at 1270 °C	119
Figure 4.29	Wear and tear test of porcelain ball PBT and commercial porcelain ball (CPB)	120
Figure 4.30	Cumulative particle size distribution of silica sand being milled by porcelain balls PBT from 0 to 25 hours	121

Figure 4.31 Cumulative particle size distribution of silica sand being milled by commercial porcelain balls (CPB) from 0 to 25 hours

122

## LIST OF SYMBOLS

~	approximately
Å	Angstrom
a*	Degree of reddish
b*	Degree of yellowish
D <sub>v</sub>	Volume distribution particle size
GoF	Goodness of fit
H <sub>v</sub>	Hardness Vickers
L*	Degree of lightness
Mt	million tonne
N <sub>c</sub>	Critical speed
R <sub>Exp.</sub>	R expected (error factor)
R <sub>P</sub>	R profile (reliability factor)
R <sub>WP</sub>	Weighted R profile
S <sub>BET</sub>	Specific surface area
wt. %	weight percent
W <sub>D</sub>	Dry weight
W <sub>I</sub>	Immersed weight
W <sub>S</sub>	Soaked weight
λ	Wave length

## LIST OF ABBREVIATIONS

AP	Apparent density
API	Active pharmaceutical ingredients
ASTM	American Society for Testing and Materials
BC	Bidor clay
BD	Bulk density
BET	Brunauer-Emmett-Teller method
CDSCO	Central Drugs Standard Control Organization
CE	Current era
CFDA	China Food and Drug Administration
CIE	International Commission on Illumination
CIP	Cold Isostatic Press
CVD	Chemical vapour deposition
DCA	Drug Control Authority
DTA	Differential thermal analysis
EMA	European Medicines Agency
FESEM	Field Emission Scanning Electron Microscopy
GPa	Giga Pascal
HK	High grade kaolin
ICDD	International Centre for Diffraction Data
ICH	International Conference on Harmonization
ISO	International Organization for Standardization
KC	Kg. Coldstream clay
KFDA	Korea Food and Drug Administration
kgf	kilogram force

LK	Low grade kaolin
LL	Liquid limit
LOI	Loss of ignition
MCAZ	Medicines Control Authority of Zimbabwe
MHRA	Medicines and Healthcare Products Regulatory Agency
MLCC	Multilayer ceramic condenser
MPa	Mega Pascal
PAHO	Pan American Health Organization
PBB	Porcelain Ball Bidor
PBC	Porcelain Ball Coldstream
PBP	Porcelain Ball Simpang Pulai
PBS	Porcelain Ball Selendang
PBT	Porcelain Ball Trong
PI	Plastic index
PKKMCP	Perbadanan Kemajuan Kraftangan Malaysia Cawangan Perak
PL	Plastic limit
PSZ	Partially stabilized zirconia
QPA	Quantitative phase analysis
RM	Ringgit Malaysia
rpm	rotation per minute
SAG	Semi-autogenous
SC	Selendang clay
SP	Simpang Pulai clay
TC	Trong clay
TEOS	tetraethyl orthosilicate
TGA	Thermogravimetric analysis

TZP	Tetragonal zirconia polycrystal
UOP	Universal Oil Product
USFDA	United State Food and Drug Administration
USP	United State Pharmacopeia
VHN	Vickers hardness number
WA	Water absorption
WHO	World Health Organization
WI	Whiteness Index
WIC	Whiteness index CIE
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
XRD	X-ray diffraction
XRF	X-ray fluorescence
Y-TZP	Yttria stabilized tetragonal zirconia polycrystal

# **FORMULASI DAN PENCIRIAN BEBOLA PORSELIN MENGGUNAKAN LEMPUNG-LEMPUNG DARI MALAYSIA**

## **ABSTRAK**

Kajian yang dijalankan ini adalah bertujuan untuk menghasilkan bebola seramik sebagai media pengisar pada suhu pensinteran rendah yang mempunyai sifat-sifat mekanikal dan fizikal yang unggul berbanding media pengisar sama yang didapati secara komersil. Kebanyakan media pengisar yang digunakan ialah bebola keluli terutamanya untuk pemprosesan mineral bagi pengurangan saiz partikel, walau bagaimanapun ia tidak sesuai untuk industri farmaseutikal dan kosmetik kerana pencemaran besi. Oleh itu, bebola seramik adalah salah satu media alternatif yang boleh menggantikan media pengisar daripada keluli disebabkan kestabilan kimia dan ketahanan haus yang tinggi. Walau bagaimanapun, industri-industri di Malaysia adalah semata-mata bergantung kepada bebola seramik yang diimport. Oleh itu, kajian ke atas penghasilan bebola seramik tempatan menggunakan tanah liat Malaysia yang siap proses dimulakan. Kajian ini dibahagikan kepada tiga bahagian iaitu Bahagian I adalah pencirian ke atas lima tanah liat Malaysia yang siap proses terpilih, Bahagian II adalah penilaian lima formulasi jasad porselin tempatan iaitu PBT, PBC, PBP, PBS dan PBB yang masing-masing menggunakan lempung-lempung dari Trong, Kg. Coldstream, Simpang Pulai, Selendang dan Bidor. Bahagian III berkenaan dengan sifat-sifat pengisaran bebola porselin tempatan terpilih (PBT) untuk ujian haus dan lusuh bagi menentukan prestasi pengisarannya dan dibandingkan dengan bebola porselin komersil. Keputusan menunjukkan bahawa sifat-sifat fizikal dan mekanikal jasad porselin tempatan meningkat dengan suhu pensinteran di mana jasad porselin PBT yang disinter pada 1270 °C menunjukkan kekerasan (7.32 GPa) dan kekuatan mampatan (381.6 MPa) yang paling tinggi. Keputusan prestasi pengisaran menunjukkan bahawa bebola PBT mempunyai lima kali lebih hebat rintangan haus

iaitu hanya 2.44% kehilangan berat berbanding 13.49% bagi CPB (bebola porselin komersil) dan 10% lebih baik prestasi pengisarannya bagi pengurangan saiz partikel berbanding CPB. Kajian ini membuktikan bahawa bebola porselin yang dihasilkan secara tempatan mempunyai sifat-sifat unggul berbanding bebola porselin yang terdapat di pasaran.

# **FORMULATION AND CHARACTERIZATION OF PORCELAIN BALLS FROM MALAYSIA CLAYS**

## **ABSTRACT**

The aim of this research is to fabricate locally produced low sintering temperature porcelain balls as grinding media with superior mechanical and physical properties than the similar commercially available grinding media. The mostly used grinding media is steel balls especially for mineral processing for reduction of particles sizes; however, it is not suitable for pharmaceutical and cosmetic industries due to contamination of iron. Therefore, porcelain balls are one of the alternative media that can substitute this steel grinding media due to its high chemical stability and wear resistant. However, Malaysian industries are solely dependent on the imported ceramic balls. Therefore, this research on locally produced ceramic balls using processed Malaysian clays was initiated. The research is divided into three parts i.e. Part I is on characterization of the five selected processed Malaysian clays, Part II deals on the evaluation the five formulated local porcelain bodies based on PBT, PBC, PBP, PBS and PBB, which used clays from Trong, Kg. Coldstream, Simpang Pulai, Selendang and Bidor, respectively. Part III deals with the grinding properties of the selected local porcelain body formulation (PBT) which was tested for wear and tear tests for milling performance and compared to the commercial porcelain balls. Results showed that physical and mechanical properties of local porcelain bodies were increased with sintering temperature whereby PBT body sintered at 1270 °C shows the highest hardness (7.32 GPa) and compressive strength (381.6 MPa). The milling performance results showed that PBT balls has five times greater wear resistance is only at 2.44% whereas 13.49% for CPB (commercial porcelain balls) and 10% better milling performance of particles size reduction than CPB. This research proves that locally

produced porcelain balls have superior properties than the commercially available porcelain balls.

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Research background

Grinding is crucial industrial operation that is used to reduce the size of the materials and release of valuable minerals from their matrices. Size reduction is critical step in many of the procedures by which raw materials are transformed into finished product. In mineral beneficiation, size reduction materials by grinding process is also use the most energy (Ozkan et al., 2009). Grinding cost is approximated 30-50% of common mining operating expenditures (Aldrich, 2013). Therefore, research efforts have been conducted continuously to reduce the costs. Costing during grinding process can be reduce by using suitable grinding media balls. Two types of grinding media balls in the market are metals and non-metals (Aldrich, 2013). Non-metal balls are made of ceramic materials such as alumina, silicon carbide, zirconium oxide and porcelain. Metal balls that commonly used are steel, stainless steel, carbon steel and chrome steel.

Metal balls such as steel-based grinding media ball are widely used in mineral processing industry for reduces ore mineral particles and others industry such as paper, paint, pharmaceutical and cosmetic manufactures. Steel balls are possess great impact toughness although less hardness. This make them more relevant to milling environments where large impact and rough grinding is needed, such as milled of hard gold ores (Aldrich, 2013). However, high wear and iron (Fe) contamination during grinding for long times, usage of steel-based grinding balls have been restricted in the production of sensitive products such as pharmaceuticals and cosmetics.

Currently, the operating benefits of grinding with fully inert ceramic media at plant scale has been termed as (i) improved selectivity against sulphide gangue mineral components, (ii) increased recovery of fine value mineral particles, and (iii) reduced collector consumption, amongst other benefits (Pease et al., 2006). The development of milling technology, utilising fully inert grinding media, efficiently avoids contamination of mineral surfaces from grinding media sources. Others field, pharmaceutical and cosmetics manufactures also used ceramic ball as grinding media to prevent contamination occurs.

Pharmaceutical and cosmetic manufacturers are very sensitive areas which involve human health and the most highly regulated industries worldwide. Every country has its own regulatory authority, which is responsible to enforce the rules and regulations and issue the guidelines to regulate drug development process, registration, manufacturing, licensing, marketing and labelling of pharmaceutical products. The regulatory authority of pharmaceutical products such as United States Food and Drug Administration (USFDA), China Food and Drug Administration (CFDA), Medicines Control Authority Zimbabwe (MCAZ), Medicines and Healthcare Products Regulatory (MHRA, UK), Central Drugs Standard Control Organization (CDSCO, India), Korea Food and Drug Administration (KFDA) and Drug Control Authority (DCA, Malaysia) are the few regulatory agencies and organizations established in respective countries (Fahmi et al.,2015; Hussain et al., 2015; Flick et al.,2016). World Health Organization (WHO), International Conference on Harmonization (ICH), World Intellectual Property Organization (WIPO), Pan American Health Organization (PAHO) and World Trade Organization (WTO) are some of the international regulatory agencies and organizations which also play an important role in all aspects of pharmaceutical regulations (Khanam et al., 2013; Simopoulos et al., 2000;