DEVELOPMENT OF NITROCELLULOSE AS A PROPELLANT IN ROUNDS 5.56MM BALL

FARIZHA BIN IBRAHIM

MASTER OF SCIENCE
(DEFENCE TECHNOLOGY)

UNIVERSITI PERTAHANAN NASIONAL MALAYSIA

2019

DEVELOPMENT OF NITROCELLULOSE AS A PROPELLANT IN ROUNDS 5.56 MM BALL

FARIZHA BIN IBRAHIM

Thesis submitted to Centre for Graduate Studies, Universiti Pertahanan Nasional Malaysia, in fulfillment of the requirements for the Degree of Master of Science (Defence Technology)

2019

ABSTRACT

Nitrocellulose also known as a gun cotton is produced through nitrating process. Currently, Malaysia is still buying gunpowder from other countries for our small arms industry. This scenario does not give a good strategic effect on our defence policy. Malaysia's survival when facing a prolonged crisis will not be at its optimal defensive capacity. Malaysia will face the possibility of running out of ammunition due to supply blockades from enemies and their possible allies. However, Malaysia has a lot of resources that can be used as a defence lifeline. In Malaysia, there are a lot of farm wastes, trees and other fibres that can be processed as nitrocellulose through the process of pulping, bleaching and nitrating. Through this process, a propellant grade nitrocellulose can be produced. This study is mainly done to investigate the powder or propellant charge effect in terms of kinetic energy and calorific value of the small arms bullet using Nitrocellulose, extracted from *Rhizophora Apiculata*, Kenaf Bast and Palm Oil Empty Fruit Bunches (EFB). After nitrocellulose was successfully produced, it was tested through firing test. The in-house nitrocellulose produced was then compared with Rounds 5.56mm Ball (M193) Gunpowder in terms of muzzle velocity and kinetic energy produced. The findings revealed that raw nitrocellulose with nitrogen content 10.8% to 11.4% can be produced through this study. The nitrocellulose surprisingly produced the average reading of 39% higher for muzzle velocity and 63% higher for kinetic energy when tested at Ballistic Lab of STRIDE Batu Arang, Selangor. Thermo Gravimetric Analysis (TGA) and Differential Scanning Calorimetric (DSC) measurement were also carried out to further investigate the properties and purity of nitrocellulose. This shows a great opportunity for Malaysian defence industry to develop new sources for the most important part of weapon, which is the propellant itself.

ABSTRAK

Nitroselulosa yang juga dikenali sebagai “gun cotton” dihasilkan melalui proses *nitrating*. Pada masa ini, Malaysia masih mengimport serbuk letupan dari luar dalam industri peluru senjata kecil. Kebergantungan ini secara strategik tidak memberi kesan yang baik kepada dasar pertahanan kita. Yang membuat kemandirian pertahanan kita tidak berada pada tahap yang tertinggi jika sebarang krisis tercetus. Kita berhadapan dengan risiko kehabisan peluru disebabkan oleh sekatan bekalan dari musuh dan sekutunya. Walau bagaimanapun, kita mempunyai sumber-sumber yang banyak dan boleh digunakan sebagai talian hayat kita setelah melalui beberapa proses. Walau bagaimanapun. Malaysia mempunyai banyak sisa pertanian, pokok dan serat lain yang boleh diproses sebagai nitroselulosa melalui proses pulpa, pelunturan dan penitratan. Melalui proses ini nitroselulosa gred bahan peledak boleh dihasilkan. Kajian ini dilakukan terutamanya untuk menentukan kesan pengisian serbuk atau propelan dari segi tenaga kinetik dan nilai kalori peluru senjata kecil menggunakan Nitrocellulose, yang diekstrak dari *Rhizophora Apiculata*, Kenaf Bast dan Tandan Buah Kelapa Sawit (EFB). Selepas nitroselulosa berjaya dihasilkan, ia akan melalui ujian tembakan. Nitroselulosa akan dibandingkan dengan serbuk letupan *Rounds 5.56mm Ball* (M193) dari segi halaju dan tenaga kinetik yang dihasilkan. Penemuan mendapati nitroselulosa mentah dengan kandungan nitrogen 10.8% kepada 11.4% dapat dihasilkan melalui kajian ini. Amat mengejutkan apabila nitroselulosa mentah yang diproses menghasilkan purata 39% halaju lebih tinggi dan 63% tenaga kinetik lebih tinggi daripada serbuk letupan *Rounds 5.56mm Ball* . Pengukuran Analisis Thermografimetrik (TGA) dan Kalorimeter Pengimbas Kebedaan (DSC) juga dilakukan untuk menentukan sifat-sifat dan keaslian unsur nitroselulosa. Ini menunjukkan peluang yang besar kepada industri pertahanan untuk membangunkan sumber baru bagi bahagian yang paling penting dalam senjata iaitu bahan dorongan dan peledak itu sendiri

ACKNOWLEDGEMENT

In the Name of Allah, the Beneficent, the Merciful

First, praise be to Allah, the Almighty, on whom ultimately we depend for sustenance and guidance. Second, my sincere appreciation goes to my supervisor Major Prof Dr Muhd Zu Azhan bin Yahya and Lt Kdr (B) Mohd Najib bin Abdul Ghani Yolhamid TLDM for the continuous support of my Master Degree research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my study.

Besides my advisor, I would like to thank Dr. Rushdan Ibrahim, and the rest of the team from Pulp and Paper Programme, Forest Products Division in Forest Reaseach Institute Malaysia (FRIM) for the full support and commitment that they have given me through my research. Last but not least, Mrs Raynee Ramliza bt Raybayi, Mrs Mastizah bt Saruji and their team from Ballistic Department, Weapon Technology Division at Science and Technology Research Institute for Defence (STRIDE) for excellent support and cooperation.

Most importantly, none of this would have been possible without the love and patience of my family. My immediate family, to whom this dissertation is dedicated to, has been a constant source of love, concern, support and strength all these years. I would like to express my heart-felt gratitude to my family. My extended family has aided and encouraged me throughout this endeavour.

APPROVAL

The Examination Committee has met on **18th March 2019** to conduct the final examination of **Farizha bin Ibrahim** on his degree thesis entitled **'Development Of Nitrocellulose As A Propellant In Rounds 5.56mm Ball'**

The committee recommends that the student be awarded the Master of Science (Defence Technology)

Members of the Examination Committee were as follows.

Prof Madya Dr. Norhana bt Abdul Halim
Centre for Defence Foundation Studies
Universiti Pertahanan Nasional Malaysia
(Chairman)

Lt Col Prof Madya Ariffin bin Ismail
Faculty of Defence and Management Studies
Universiti Pertahanan Nasional Malaysia
(Internal Examiner)

Prof Madya Dr. Ing. Oskar Hasdinor Hassan
Faculty of Art and Design
Universiti Teknologi MARA
(External Examiner)

APPROVAL

This thesis was submitted to the senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfilment of the requirement for the Master of Science. The members of the Supervisory Committee were as follows.

Major Professor Dr. Muhd Zu Azhan bin Yahya
Faculty of Defence Science and Technology
Universiti Pertahanan Nasional Malaysia
(Main Supervisor)

Lt. Cdr. RMN (R) Mohd Najib bin Abdul Ghani Yolhamid
Faculty of Defence Science and Technology
Universiti Pertahanan Nasional Malaysia
(Co-Supervisor)

UNIVERSITI PERTAHANAN NASIONAL MALAYSIA

DECLARATION OF THESIS

Author's full name : **Farizha bin Ibrahim**

Date of birth : **7th August 1985**

Title : **Development of Nitrocellulose As A Propellant In Rounds 5.56 mm Ball**

Academic session : **2013 to 2019**

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

I further declare that this thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organisation where research was done)*
√	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledge that Universiti Pertahanan Nasional Malaysia reserves the right as follows.

1. The thesis is the property of Universiti Pertahanan Nasional Malaysia.
2. The library of Universiti Pertahanan Nasional Malaysia has the right to make copies for the purpose of research only.
3. The library has the right to make copies of the thesis for academic exchange.

Sinature

N/404105

IC/Passport No

Date: **July 2019**

**Signature of Supervisor/ ~~Dean of CGS~~/ ~~Chief Librarian~~

Major Professor Dr. Muhd Zu Azhan bin Yahya

Date: **July 2019**

Note : * If the thesis is CONFIDENTIAL OR RESTRICTED, please attach the letter from the organisation stating the period and reasons for confidentiality and restriction.

** Witness

TABLE OF CONTENT

3 METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AQ	Anthraquinone
α	Alpha
CH_3COOH	Acetic acid
DS	Degree of Subtitution
DSC	Differential Scanning Calorimetric
EFB	Empty Fruit Bunches
EIA	Energy Information Administration
FRIM	Forest Research Institute of Malaysia
FFB	Fresh Fruit Bunches
HNO_3	Nitric acid
H_2SO_4	Sulphuric acid
K	Potassium
K_e	Kinetic Energy
KI	Potassium Iodine
Mg	Magnesium
MoA	Ministry of Agriculture
MoD	Ministry of Defence
MPOB	Malaysian Palm Oil Board
m/s	Metre/Second
$NaClO_2$	Sodium Chlorite

NaOH	Sodium Hydroxide
NATO	North Atlantic Treaty Organization
NC	NitroCellulose
NG	Nitrogliserin
$(NH_4)_2Fe(SO_4)_2$	Ammonium Ferum (II) Sulfate
PO^{3-}_4	Phosphate
UPNM	Universiti Pertahanan Nasional Malaysia
U.S.P	United States Pharmacopeia
STANAG	Standardization Agreement
S.T.R.I.D.E	Science and Technology Research Institute for Defence
TGA	Thermo Gravimetric Analysis
US	United States
2D	2 Dimension

CHAPTER 1

INTRODUCTION

1.1 Project Background

A main element for modern gunpowder used is sulphur alongside with charcoal as a fuel and saltpetre (potassium nitrate) as its oxidizer. Almost all elementals sulphur are produced as a by-product of removing sulphur-containing contaminants distilled from natural gas and petroleum. In the decline of natural resources such as petroleum, a new invention must be created to ensure the survival of projection power especially in small arms use. Lately, the number of elements that are used to produce black powder are showing sharp decline in production. The most obvious factor is oil usage worldwide, where the usage has increased but the oil supply can only meet 95% of it. (EIA, Annual Energy Review 2005) as depicted in Figure 1.1.

As compared with gunpowder (black powder), modern nitrocellulose explosive can be characterised by great increase in power, giving an enormously greater range, flatter trajectory and better penetration to projectile fired from rifles or artillery (Tadeusz Urbanski, 1965). The idea of having uniqueness not to produce smoke in firing is to cover up exact position of firing (Campbell, 1985).

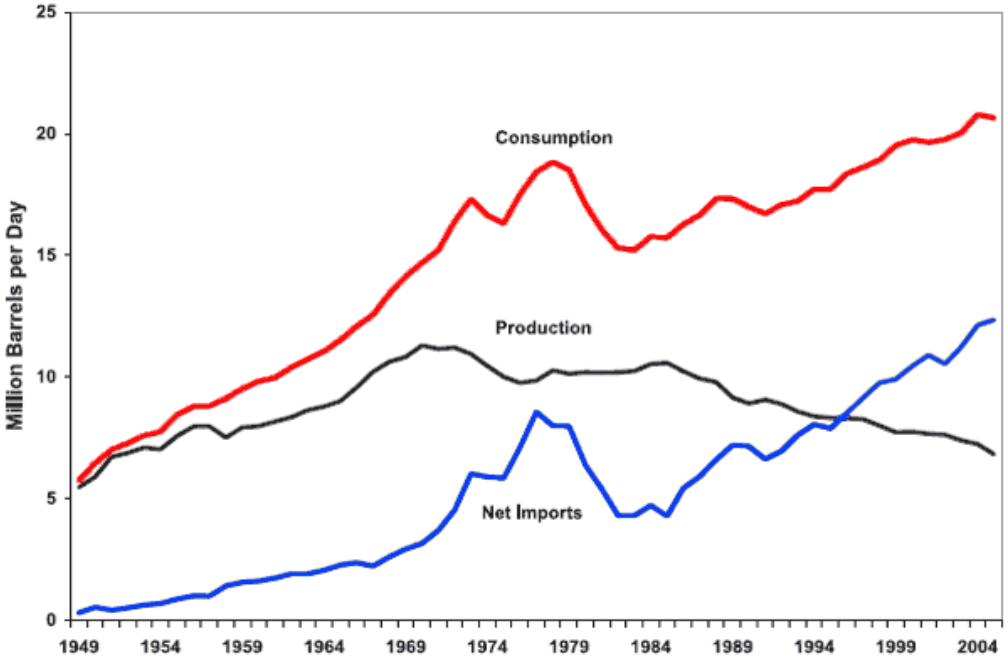

Figure 1.1 US Energy Consumption Production and Imports 1949-2005 (EIA, Annual Energy Review 2005)

This study is mainly done to investigate the powder or propellant charge effect in terms of kinetic energy and calorific value of the small arms bullet using Nitrocellulose sample extracted from *Rhizophora Apiculata*, Kenaf Bast and Palm Oil Empty Fruit Bunches (EFB). It involves the comparison of Nitrocellulose sample and Gunpowder from Rounds 5.56mm Ball (M193) in term of bullets velocity and kinetic energy. Firing test is conducted at STRIDE Batu Arang to analyse the actual propellant performance. Besides, calorimetry test, Thermo Gravimetric Analysis (TGA) and Differential Scanning Calorimetric (DSC) measurement were also carried out at FRIM Kepong to further investigate the properties of nitrocellulose.

1.2 Problems Statement

a. Black powder is the main propellant that has been used in small arms cartridge. However, main element of the black powder viz. sulphur is predicted to be more expensive in relation to the world oil and natural gas shortage crisis in the future. Therefore, a new element for

propellants must be produced as an alternative material to back up the shortage of sulphur in future.

b. There is lack of literature particularly on method of processing pure nitrocellulose from our local raw materials. Therefore, it is anticipated that nitrocellulose-based materials extracted from *Rhizophora Apiculata*, Kenaf Bast and Palm Oil Empty Fruit Bunches (EFB) could have high probability to be used as propellant.

1.3 Objectives

This study is an attempt to produce the best composition chart of nitrocellulose and gunpowder to enhance firing distance and performance.

The specific objectives of this research are:

a. To extract α-cellulose from *Rhizophora Apiculata*, Kenaf Bast and Empty Fruit Bunch (Palm Oil) and process α-cellulose into nitrocellulose.
b. To determine the performance of nitrocellulose-based compared with gun powder as a propellant in Rounds 5.56mm Ball (M193).
c. To appraise the calorific value and thermal properties of the produced nitrocellulose.

1.4 Research Scope

It is too vast for any single research work under a given time to cover all the variables that are related to the internal ballistic. This project therefore will only focus on certain properties of the system.

1. Literature review on propellant of Rounds 5.56mm Ball (M193), nitrocellulose and related information.
2. Raw materials involved in producing nitrocellulose are Rhizophora (Hardwood), Palm Oil Bunches - Empty Fruit Bunches and Kenaf Bast

(Soft Wood).

3. Main values to be compared are velocity and kinetic energy of bullets propelled by produced Nitrocellulose with a gun powder. The type of gun powder used in this research is Rounds 5.56mm Ball (M193).

1.5 Significance of Research

The findings of the study will reveal the capability of produced nitrocellulose as a gun powder. In this research, a comparison of the same mass of nitrocellulose and gunpowder was done to find out which propellant is able to produce longer distance and greater impact. Besides that, the findings will enable the arms industry to use resources that are easier to find compared to resources that are required in producing black powder. It also can improve the sustainability of natural resources for ammo manufacturing as we are able to produce our own propellant using industrial and farming waste. This new application of smokeless gunpowder using nitrocellulose makes troops especially snipers more difficult to be detected by our enemy while at the same time improves our safety and security level.

1.6 Expected Outcome

From this study, the main objective is to find out the performance and capability of produced nitrocellulose from various samples such as Rhizophora (Hardwood), Palm Oil Bunches (Empty Fruit Bunches) and Kenaf Bast (Soft Wood) compared to gunpowder in terms of velocity, calorific value of bullets and kinetic energy produced. This shows a great opportunity for Malaysian defence industry to develop new sources for the most important part of weapon, which is the propellant itself.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Involvement in any modern war is not possible without ammunition. The usage of ammunition is vital in any offensive or defensive actions to be taken by any forces in the world. This issue must be taken into consideration especially when determining force capability as well as the opposition.

This chapter elaborates about the firearms including its cartridges and propellant. In term of producing nitrocellulose aspects, the process started from classification of raw material, preparation and production cellulose until nitrocellulose obtained as well as equipment and the processes involved are also explained in this chapter.

2.2 Firearms

Small firearms is defined as a firearm that is light, mobile and has high rapidity or easy to reload for the purpose to be used by individual user. There are many types of firearm but it consists of two main parts, which are the firing mechanisms and cartridge. Malaysian Armed Forces general issue weapons such as Colt M4A1