DEVELOPMENT, CHARACTERIZATION AND TESTING OF LOCALLY SOURCED EXPLOSIVE

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DECLARATION

I ABDULLAHI SHUAIBU MUYE (2003/14915EH) hereby declare that this research project is my original work and has not been submitted in any form for another degree or diploma in any university or institution to the best of my knowledge. All sources of information and quotations are dully acknowledged.

Student signature

07/11/08

Date

CERTIFICATION

This is to certify that this research project "Development, Characterization and Testing of Locally Sourced Explosive" by Abdullahi Shuaibu Muye (2003/14915EH) was carried out under the supervision of Dr. M O Edoga and submitted to the Department of Chemical Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State in partial fulfillment of the requirement for the award of Bachelor of engineering (B. Eng.) Degree in Chemical Engineering.

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DEDICATION

This research project is dedicated to Almighty ALLAH (SW) for seing me through this project work and my entire program.

AKNOWLEDGEMENT

In the name of Allah, the beneficent, the merciful. All praises and thanks are due to Allah (SW) the creator of all things and the controller of all affairs who sent down the criterion between right and wrong to His messengers and prophets to judge between mankind with justice. May the peace and blessings of Allah (SW) be upon His servant and messenger Mohammad (SAW), his family, his companions and all those who followed the truth up to the last day.

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CHAPTER ONE

1.0 INTRODUCTION

Explosive is a weapon design to release enormous amounts or quantities of energy by expanding suddenly producing heat and large changes in pressure. Explosives could be produced chemically or locally depending on the type of materials to be used during the process.

Explosives are classified into two major classes. These are low (local) explosives such as black powder, flash powder etc. and high (chemical) explosives such as nitroglycerin; trinitrotoluene (TNT) etc. Others include sub high explosives such as primary, secondary and tertiary explosives. In this research, emphasis will be based on the development of black powder explosive.

Black powder is a pyrotechnic composition, an explosive mixture of potassium nitrate, charcoal and sulfur that burns rapidly producing volumes of hot solids and gases which can be used as a propellant in firearms and fireworks. The origin of black powder is obscure and dates back to very remote time. It was not until the invention of firearms that the manufacture and uses of black powder really began to develop, since its invention black powder has been employed in various engineering operations such as mining, road building, dam building, and land improvement among others (Urbanski T, 1967).

The decomposition rate of black powder is so slow and consequently has low brisance hence, classified as low explosive that is, it produces a subsonic deflagration wave rather than a supersonic detonation wave produced by high explosives. The gases produced by burning black powder generate enough pressure to propel a bullet but not enough to destroy the barrel of a firearm. This property of a black powder makes it to be produced using locally sourced materials (Brown, G.I, 1998).

1.1 Aim and Objective

The aim of this research work is to develop an improved and efficient explosive composition using locally sourced materials.

Specifically, the objective is to investigate black powder explosive which involves the mixture of an oxidizer and fuel.

1.2 Approach

The approach to meeting this requirement involves the followings

1. Develop a black powder explosive using local materials.
2. Characterize the black powder explosive developed.
3. Determine the burning rate of the developed black powder explosive.
4. Testing the performance efficiency of the black powder explosives developed.

1.3 Justification

The development of black powder explosive using locally sourced material is in line with its demand for local use as a source of income and to maximize the security system as well as improving the standard of living of this nation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Explosive

An explosive is any chemical or biological mixture that is commonly used or intended for the purpose of producing an explosion and which contain any oxidizing and combustive units or other ingredients in such proportions, quantities or packing that an ignition by fire or by friction of any part of the compound or mixture may cause such a sudden generation of highly heated gases that the resultants gaseous pressure are capable of producing destructive effects of contiguous objects or destroying life or limb. (Kelly J,2004).

2.1.1 Types of explosives

There are a wide explosives classifications or types. They include primary explosives, low explosives, high explosives and blasting agents. Primary explosives include lead azide, lead sulphate and mercury fulminate. They are very sensitive to the heat of fuses hence are good detonators. Low explosives are usually mixture of combustible substances and an oxidant that decomposes rapidly (deflagration). Common ones are black power and flash powder which are prepared locally. High explosives include nitroglycerin, trinitrotoluene (TNT) and acetone peroxide all of which are prepared chemically and undergo detonation at rate of 100m/s to 9000m/s. They are employed in mining, demolition and military war heads. Finally, blasting agents which includes ammonium nitrate + fuel oils (ANFO), dynamite and are all used for excavating and mining (Buchanan, 2006).

For the purpose of this research work, emphasis will be based on low (local) explosives.

2.1.2 Local explosives

Local explosives are usually mixture combustible substances and an oxidant that decomposes rapidly (deflagration) unlike most high explosives which are compounds. Low explosives are normally employed as propellants. Included in this group are black powders and flash powders.

Under normal conditions, low explosives undergo deflagration at rates that vary from few cm/s to approximately 400m/s. However, it is possible for them to deflagrate very quickly producing an effect similar to a detonation but not an actual detonation. This usually occurs when ignited in a confined space (Buchanan, 2006).

For the purpose of this project, the research will be based on the development of black powder explosives using locally sourced materials.

2.2 Black Powder Explosive

Black powder, originally invented in China, is a pyrotechnic composition an explosive mixture that burns rapidly producing volumes of hot gases which can be used as propellant in firearms and fireworks. Black powder is also known as gunpowder. The military mainly used it for the bullet shells and propellants, the propellants and other drivers for the energy, ammunition is an important component. The development of modern black powder is from the black powder in ancient china. During the 12th and 13th century, black powder was first invented in Arab countries and then spread to Greece and Europe and the rest of the world. The earliest record of the application of black powder explosive and firearms in the United States are in the mid 14th century.

Black powder can be divided into: point black powder, propellants, and solid propellants. These propellants are divided into guns used propellant, artillery used propellant. There are also solid propellant for rockets and missiles. According to the external combustion characteristics, black powder can be divided into smokeless and smoke black powder etc.

The modern black powder originated in 1771. a British named P. wolf used synthesis of picric acid, which is a yellow crystal (initially used as yellow dye), and it was late discovered that it has the function of the explosion . In 1779 British chemist E. Howard invented the mercury fulminate as a propellant. Double base powder, detonators, TNT gave a real sense of the military revolution (Urbanski T, 1967).

2.2.1 Standard for black powder explosives

The current standard for black powder explosives developed by pyrotechnicians is 75% potassium nitrate (without chlorites, chlorates, or per chlorates), 15% soft wood charcoal and 10% sulfur (without acidity traces). The burn rate of black powder explosives can be changed by corning. Corning is a process which first compresses the fine black powder meal into blocks with a fixed density (1.7g/cm^3). The equation for the combustion of black powder is

$$2KNO_3 + S + 3C \longrightarrow K_2S + N_2 + 3CO_2$$

A more accurate, but still simplified equation is

$$10KNO_3 + 3S + 8C \longrightarrow 2K_2CO_3 + 3K_2SO_4 + 6CO_2 + 5N_2$$

The product of burning does not follow any simple equation. One study result showed that it produced (in order of descending quantities): 55.91% solid products, potassium carbonate , potassium sulfate , potassium sulfide sulfur potassium nitrate , potassium thiocynate, carbon, ammonium carbonate.42.98% gaseous products. Carbon dioxide, nitrogen, carbon monoxide, hydrogen sulfide, hydrogen, methane, 1.11% water (Urbanski T,1967).

2.2.2 Explosive properties of black powder

From a comprehensive analysis of black powder, the heat of explosion and gas volume naturally depend on the composition of the powder. The heat of explosion is 735kcal/kg at a moisture content of 0.85%. In dry powder, heat of explosion is 740kcal/kg. The gas volume Vo is 280l/kg, the specific pressure *f* is 2800m and the temperature of explosion t is 2380°C. The specific gravity of black powder may vary witjin the limits of 1.50 – 1.80 depending on the intended use. Its apparent density is 0.900 – 0.980.

Black powder explosive is highly sensitive to impact and friction. It explodes when stroked by a 2.0kg weight falling from 70 – 100cm. Its ignition temperature is 300°C. A sack full with black powder takes fire when penetrated by a riffle short. The rate of burning of black of black powder at atmospheric pressure is much greater than that of smokeless powder. But the rate and mode of burning at a pressure higher than atmospheric depends on its compression pressure. Grains of black powder explosive do not burn by parallel layers but all over the mass of charge, if their density is lower than 1.75gcm^{-3}.Above this density, they burn by parallel layers and the burning time then depends on the grain size. Black powder explosive with a density of 1.80 gcm^{-3} shows a rate of burning of about 10cm/sec at a pressure of 1660kg/cm^2 while nitrocellulose or nitroglycerine smokeless powder has a rate of burning of 15.0 – 30.0 cm/sec. A single grain of black powder explosive burns with a rate of 0.4cm/sec. The flame is propagated along the line of grains at the rate of 60cm/sec at atmospheric pressure (Urbanski T, 1967).

2.2.3 Advantages of black powder explosive:

1. Black powder explosives are used in blasting monumental stones like granite and marble.
2. They are used to make fire works by mixing with other substances that produces the desired color.
3. They are well suited for blank rounds, signal flares, burst charges and rescue line launches.

2.2.4 Disadvantages of black powder explosive:

1. Black powder explosives has relatively low density.
2. Combustion converts less than half of black powder to gas while the rest ends up as a thick layer of soot inside the barrel.
3. The residue from burnt black powder is hygroscopic and an anhydrous caustic substances (Buchanan, 2006).

2.3 Composition of the Materials

Black powder explosive is a mixture that supports rapid combustion. Its composition has slightly varied over the century and can be made using different proportions of the ingredients. The different blends affect the speed and how completely the mixture burns. The local materials or ingredients for black powder are potassium nitrate (also known as salt peter), charcoal and sulfur. The charcoal and sulfur provide fuel for the reaction which burn slowly while potassium nitrate serves as an oxide which provides oxygen and greatly speedup the burn rate for fuel resulting in an explosive reaction. The local ratio for the materials is 15: 3:2 of potassium nitrate, charcoal and sulfur respectively by weight and not by volume (Urbanski T, 1967).

2.4 Potassium Nitrate (KNO_3)

Potassium nitrate is a chemical substance with chemical formula KNO_3. A naturally occurring mineral source of nitrogen, KNO_3 Constitutes a critical oxidizing components of black powder. In the past, it was also used for several kinds of burning fuses, including slow matches (BGAI, 2007). Since potassium nitrate readily precipitates, urine was a significant source through various malodorous means form the late middle ages and early modern era through the 19th century.

Potassium nitrate is an oxidizer. The chemical formula KNO3 shows that there is quite a bit of oxygen stored up in each molecule. This is important for black powder because to burn rapidly requires an immediate source of oxygen, Most fires have to draw their oxygen from the air around them so only the outer surface burns well, an can only burn as quickly as fresh oxygen can diffuse through the flame. With an internal oxygen source, combustion goes slowly. By having an oxygen source mixed in with the fuel, combustion is rapid and complete (if the proportions are correct). It can also be notice that if sugar is used in place of charcoal, a purple hue may be observed from the black powder flame. This is because of the potassium ions from the KNO_3 .The electrons in potassium emit a purple light which contrast with the typical orange flame associated with Carbon (BGIA, 2007).

2.4.1 Manufacture of potassium nitrate (KNO_3)

Potassium nitrate is obtainable from natural deposits in hot countries e.g. Egypt, Mexico, India etc. it occurs as result of the microbiological oxidation of organic nitro compound and of the reaction of the product with the alkaline component of the soil. Such salt peter can be used to develop black powder explosive after being refined by crystallization. Potassium nitrate can also be obtained as a result of microbiological process followed by reaction with potassium carbonate (Urbanski T, 1967).

2.4.2 Applications of potassium nitrate

Potassium nitrate is used as an oxidizing component in the development of black powder explosives. It's used as fertilizer, in amateur rocket propellant.

2.5 Charcoal

Charcoal is the blackish residue consisting of impure carbon obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is usually prepared by the destructive distillation of hardwood, animal bones, coconut and sugar respectively. The process in which the material is distilled in the absent of air is called pyrolysis (Stephen A. A, 1998). The charcoal is the primary fuel-that part that actually burns producing the traditional carbondixiode and water of combustion reaction.

2.5.1 Types of Charcoal

There are three major types of charcoal. These are lump charcoal, briquette charcoal and extruded charcoals.

Lump charcoals, are made directly from hard wood material and usually produces far less ash than briquettes.

Briquette charcoals are made by compressing charcoal, typically made from sawdust and other wood by products, with a binder and other additives. The binder is valley starch. Some briquettes may also include brown coal (heat source), mineral carbon (heat source), agent, raw sawdust (ignition aid), lime stone (ash – whitening agent) raw sawdust (ignition aid) and other additives like paraffin or petroleum solvents to aid in ignition.

Extruded charcoal is made by extruding either raw ground wood or carbonized wood to logs without the used of a binder, the heat and pressure of the extruding process hold the charcoal together. If the extrusion is made from raw wood material, the extruded logs are then subsequently carbonized (Chris Pearson, 1944).

2.5.2 Properties and uses of charcoal

1. The charcoal is used in the development of black powder by providing fuel for the reaction in the form of carbon (C).
2. The large porous surface has the property of absorbing gases and the charcoal are used in the gas masks to adsorb poisonous gases in the air.
3. The also absorb coloring material and animal charcoals are used in absorbing the brown coloring matter from brown sugar which is then turned white.
4. Charcoal are very good as fuels.
5. Charcoal are sometimes used to power commercial road vehicles usually buses in countries where oil is scarce or completely unavailable (Stephen A. A, 1998).

2.5.3 Manufacture of charcoal

It is very important to select a suitable type of wood for the manufacture of black powder explosives. This must be soft but not resinous before carbonization; the wood must be debarked and cut into pieces. The material to be carbonized is placed into sheet iron retorts, 1m in diameter and 1.5 – 3m long, one end of which is closed with an air tight lid and the other fitted with an off take for the gaseous products of distillation. These products are usually burnt since it is not worth while recovering them. The combustion of carbon monoxide (CO) is particularly important other wise it may poison the atmosphere. The carbonization last for 3 – 8hr depending on the construction of the furnace and retorts temperature and the type of material to be carbonizes. The charcoal is removed from the retort when it cools (hot charcoal easily ignites) the color, temperature and percentage content of different types of charcoal are shown in the table 2.5.3 below.

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Table 2.1: Types of Charcoal and Their Temperature of Carbonization

Charcoal	Colour	Temperature of carbonization (^OC)	Content of Charcoal (%)
Extruded	Cocoa (red)	140 – 175	52 – 54
Briquettes	Brown	280 - 350	70 - 75
Lump	Black	350 – 450	80 - 85

2.6 Sulfur

Sulfur is the chemical element that has the atomic number 16. It is denoted with the symbol S. it is abundant multivalent non –metal sulfur, in its native form is yellow crystalline solid. In nature, it can be found as the pure element and as sulfide and sulfate minerals. It's an essential element for life and is found in two amino acids, cysteine and methione.

Sulfur works primarily as a stability agent during the development of smell and teary eyes that go along with black powder. The reason for this is because its gives off sulfur dioxide (SO_2) gas which is toxic, mainly because it forms a strong acid (sulfurs acid) when it mix's with water that keep your eyes, throat and lungs moist. Sulfur is not actually necessary in the mixture. Leaving it out still provides a mixture that burns rapidly, but it tends to sputter a bit more (.Zhang, 1986).

2.6.1 Extraction of sulfur

Sulfur can be extracted from crude oil, fresh process and from the surface. For the purpose of manufacturing black powder, the sulfur to be used should be of highest purity refined by distillation. Crude sulfur (which usually contains 2 – 5% of impurities) is distilled from retorts heated to a temperature of 400^0C. The receiver should be maintained at a temperature above 115^0C (120 – 130^0C), i.e. Above the melting point of sulfur (114 – 115^0C). Under these conditions, the distillate condenses to a liquid which is then cast into sticks or blocks. This is the only form of sulfur suitable for the manufacture of black powder explosives (Urbanski T, 1967).

Crude oil gases include mainly hydrogen sulfide (H_2S), Carbon dioxide, (CO_2) and methane (CH_4). The gaseous mixture is passed through an alkaline solution. As hydrogen sulfide and carbon dioxide are acidic gases, they are absorbed by the alkaline solution and can be regenerated by heating the solution. The hydrogen sulfide produced is later oxidized to sulfur by air. The equation for the reaction is as follow

$2H_2S_{(g)} + O_2 \longrightarrow 2S_{(s)} + 2H_2O_{(g)}$ (Stephen A. A, 1998 and Urbanski T, 1967).

2.6.2 Characteristics and uses of sulfur

At room temperature, sulfur is a soft bright yellow solid. Elemental sulfur has only a faint odour, similar to that of matches. Sulfur burns with a blue flame that emits sulfur dioxides, notable for its peculiar suffocating odour. Sulfur is insoluble in water but soluble in carbon disulfide and to a lesser extent in other non-polar organic solvents such as benzene and toluene. Common oxidation states of sulfur include -2,+2,+4 and +6. Sulfur forms stable compounds with all elements except the noble gases. Sulfur in the solid state ordinarily exists as cyclic crown-shaped S_8 molecules (Stephen A. A, 1998).

A noteworthy property of sulfur is that its viscosity in its molten state, unlike most other liquids, increases above temperatures of 200^{O}C due to the formation of polymers. The molten sulfur assumes a dark red colour above this temperature. At higher temperatures, however the viscosity is decreased as depolymerization occurs.

One of the direct uses of sulfur is in the development of black powder explosives where it lowers the temperatures of ignition and helps increase the speed of combustion. It's also used directly in the vulcanization of rubber, where polysulfide crosslink organic polymers. Sulfur reacts directly with methane (CH_4) to give carbon disulfide which is used in manufacturing of cellophone and rayon (Wolfgang, 2006).

2.7 Pyrotechnic Composition

Pyrotechnic composition is a substance or mixture of substance designed to produce an effect by heat, light, sound, gas or smoke or a combinations. Pyrotechnic substances do not rely on oxygen from external sources to sustain the reaction and include black powder flash powder, gas generations smoke compositions colored fireworks compositions and solid propellants.

Some pyrotechnic composition are used in industry and aerospace for generation of large volumes of gas in gas generators (e.g in air bags),in pyrotechnic fasteners, and in other similar applications. They are also used in military pyrotechnics when production of large amount of noise, light or infrared radiation is required e.g. missile decoy flares. Presently a new class of reactive material compositions is now under investigation by military (Kelly J, 2004).

Pyrotechnic compositions are usually homogenized mixtures of small particles of fuel and oxidizers. The particles can be grains or flakes. Generally, the higher the surface area of the particles, the higher the reaction rate and burning speed for some purpose, binders are used to turn the powder into a solid material (Kelly J, 2004).

2.8 Burning Rate of Black Powder Explosive

For a long time attempts have been made to explain why three non-explosive substances, viz; potassium nitrate, charcoal and sulfur, when combined together should form an explosive mixture. It was particulate incompressible that binary mixtures of potassium nitrate with charcoal or with sulfur should be non –explosive or only poorly so the problem was that its more difficult to elucidate since it involves a reaction in the solid phase. It was therefore reported that in the bore of a gun barrel powder decomposes according to the equation.

$$2KNO_3+S+3C \longrightarrow K_2S+N_2+3CO_2$$

If the powder burns in the open potassium sulfide is oxidized to sulfate when black powder burns slowly the products apart from carbon, include components as potassium sulfide, sulfide, carbonate, cyanide, nitrate and nitrite (Urbanski T, 1967).

The burning rate of black powder depends on the size of the particle. Fined grained particles burn faster than grains of larger sizes which burn slowly. It was founded by Gay Lussac that the gases were composed of 52.6% CO_2, 5.0% CO and 42.4% N_2 by volume when the density of the powder was 0.9 being 450 times the volume of the explosive. Piobert therefore disagreed with these result finding a much lower value for the gas volume which he asserted was 250 times the volume of the charge. Hence the burning rate can be determined by dividing the volume of black powder by the time it takes to burn completely.

2.9 Testing of Black Powder Explosive Developed.

In order to test the burn rate of black powder explosive developed, the following are required

1-a stopwatch

2- a can

3- matches

From the magic of the metric system, 1ml = $1cm^3$. Cans are usually marked with the volume in ml [the average can is 340ml]. If cans are not marked, the volume of the black powder can be measured and poured into the can. The entire can may not be necessary as that will be a waste, therefore, half size of the can be used. Or, a full size can be cut using a pair of metal shears and calculate the volume of the can. The volume can be calculated using the formula

$$V = hr^2$$

The height and diameter of the can be measured in centimeters, not inches or miles. This can then be filled to the brim with the powder do not cover the can. Insert a fuse or simple insert a match into the can, with the match head just under the surface of the powder to start burning and time the burn with the stopwatch. The burning rate can be determined by dividing the volume of the black powder (V_{bp}) by time (T) it takes to burn completely (Urbanski T, 1967).

CHAPTER THREE

3.0 METHODOLOGY

This chapter is a step by step accounts of the investigations carried out.

3.1 Materials and Equipments

The major materials and equipments for the development of black powder explosive are as shown in table 3.1 and 3.2 below

Table 3.1: Materials for The Development of Black Powder Explosive

Materials	Sources	Comment
Potassium Nitrate	Kano Road, Kaduna State	Laboratory reagent grade
Charcoal	Minna	Laboratory reagent grade
Sulfur	Kano Road, Kaduna State	Laboratory reagent grade
Distilled Water	Water Quality Laboratory, Minna	Analytical reagent grade

Table 3.2 Equipments for The Development of Black Powder Explosive

Equipment	Sources	Comment
Mortar and Pestle	Chemical Laboratory, FUT Minna	
Weighing Balance	Chemical Laboratory, FUT Minna	CT
Measuring Cylinder	Chemical Laboratory, FUT Minna	Pyrex (25ml)
Stop Watch	Chemical Laboratory, FUT Minna	Second
Tray Drier	Chemical Laboratory, FUT Minna	
Beaker	Chemical Laboratory, FUT Minna	Pyrex (250ml)
Mixer (Manual)	Minna central Market	Emmex
Sieve	Water Quality Laboratory, Minna	2mm Mesh size
Can	Minna Central Market	250ml

3.2 Preparation of Black Powder Explosive

The raw materials (potassium nitrate, charcoal and sulfur) were separately pulverized using mortar and pestle into small particles.

225g, 45g and 30g of potassium nitrate, charcoal and sulfur were measured respectively. The potassium nitrate and sulfur were then mixed together properly in a beaker using the mixer (manual). The measured charcoal was also mixed with the content of the beaker.

The resultant mixture was then sieved using 2.0mm mesh size sieve to obtain the fined particles while the coast particles were re-crushed and re-sieved to obtain the most fine powder particle size. The resultant product was placed on the tray and sundried for 48 hours to ensure complete moisture removal (Urbanski T, 1967).

3.3 Characterization of Black Powder Explosive

The characterization of black powder explosive developed involves the determination of some parameter contained in the black powder explosive which include particle sizing, pore volume, moisture content, density, relative density and burning rate.

3.3.1 Particle sizing:

The smaller the particle size, the bigger the porosity and the higher the porosity, the higher the pore volume. The granules are usually most effective with the size of granular explosive in order to provide enough pressure. Changes in particle sizing distribution can affect the pressure drop.

3.3.2 Determination of moisture content:

This helps determine the moisture content of the black powder explosive developed. The moisture content is often required to define and express its properties in relation to the net weight of the black powder explosive.

To determine the moisture content of black powder explosive, the beaker was well cleaned, dried and weighed empty. It was then filled with black powder sample before sun drying and weighed. The black powder sample was then sun dried for three hours and re-weighed. The moisture content was determined using the expression below

$$MC = \frac{(W_2 - W_1) - (W_3 - W_1)}{(W_2 - W_1)} * 100\%$$

Where

MC = Moisture content (%), W_1 = Weight of empty beaker (g), W_2 = Weight of beaker + sample before sun drying (g), W_3 = Weight of beaker + sample after sun drying (g) (ASTM, 1987).

3.3.3 Determination of density

Density is defined as the mass per unit volume of the material or substance. The S.I unit of density is kgm^{-3} but in laboratory work, the smaller unit of gcm^{-3} may be found necessary. The density of a substance is also defined as the product of the relative density of that substance and the density of water. The density of water is used here because water is the most common liquid and considered to be $1.0gcm^{-3}$ (Anyakoha M.W, 2006).

3.3.4 Determination of relative density

Relative density is the mass (or weight) of a substance per mass or weight of equal volume of water. Mass of volume of water is chosen in this definition because water is the most common liquid. Hence, relative density has no unit. It can also be defined as the ratio of the density of a substance to the density of water.

To determine the relative density of black powder explosive, the relative density bottle was first cleaned, dried and weighed empty. It was then re weighed when $25.0cm^3$ of the black powder sample was poured. The relative density bottle containing the sample was then filled with water and re weighed. Finally, the relative density bottle was emptied and cleaned of any sample particle and filled with water alone. The weight of water was obtained and the relative density was calculated using the expression:

$$R_p = \frac{(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$$

$$R_\rho = \frac{(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$$

Where

Rρ = Relative density, M_1 = Mass of empty bottle (g), M_2 = Mass of bottle + black powder sample (g), M_3 = Mass of bottle + black powder sample + water (g), M_4 = Mass of bottle + water (g) (Anyakoha M.W, 2006).

3.3.5 Determination of burning rate

The burning rate of black powder explosive was determined by measuring 50cm^3 of the sample into a can. A match stick was inserted with the head just under the surface of the powder and lighted to start burning. The time at which the powder burnt completely was noted and used to calculate the burning rate using the expression

$$B_R = \frac{V_{BP}}{T}$$

Where

B_R = Burning rate of black powder sample (cm^{3}s^{-1}), V_{BP} = Volume of black powder sample used (cm^3), T = Time of burning (s) (Ubanski T, 1967).

3.6 Testing of the Performance Efficiency of the Black Powder Explosive

The performance efficiency of the black powder explosive developed was tested using a local gun. This is done by measuring 10.0cm^3 of the sample in to the gun barrel covered with the cap. The trigger of the gun was pulled and released and explosion occurred immediately.

CHAPTER FOUR

4.0 RESULTS AND DISCUSION OF RESULTS

4.1 Results

4.1.1 Characterization of black powder explosive using charcoal obtained from coconut shell

The result for the characterization of black powder explosive using charcoal obtained from coconut shell is shown in the table below

Table 4.1 Characterization of Black Powder Explosive Using Charcoal from Coconut Shell

Parameters	Values
Moisture Content (MC)	0.8547 %
Relative Density ($R\rho$)	1.71
Burning Rate (B_R)	8.3333cm^3/sec
Heat of Reaction (Q_R)	739.0641 ± 15kcal/kg
Density (ρ_{BP})	1.71gcm^{3}m
Pressure (p)	1567.7778N/m^2

4.1.2 Characterization of black powder explosive using charcoal obtained from cassava stem

The result for the characterization of black powder explosive using charcoal obtained from cassava stem is shown in the table below

Table 4.2 Characterization of Black Powder Explosive Using Charcoal from Cassava Stem

Parameters	Values
Moisture Content (MC)	0.8264 %
Relative Density (Rρ)	1.76
Burning Rate (B_R)	6.250cm^3/sec
Heat of Reaction (Q_R)	714.5929 ± 15kcal/kg
Density (ρ_{BP})	1.76gcm^{3}m
Pressure (p)	1623.1111N/m^2

4.2 Discussion of Results

This research is focused on the characterization and testing of black powder explosive developed from locally sourced materials. The characterization was carried out base on the determination of parameters such as moisture content, relative density, density, burning rate, heat of reaction and compared with the standard values.

From the characterization carried out, the moisture contents for black powder developed using charcoal obtained from coconut shell and cassava wood are 0.8547% and 0.8264% respectively as against the standard of 0.85%. The relative densities were 1.7087 and 1.7604 respectively as against the standard of range of 1.50 to 1.80.The densities are reactions are 739.0641 ± 15kcal/kg at a pressure of 1567.7778Pa and 714.5929 ± 15kcal/kg at pressure of 1623.1111Pa against the standard of 735 ± 15kcal/kg.

The differences in the moisture contents, relative densities, and densities compare to the standard values (stated in the literature review) are as a result of excess quantity of the black powder sample measured, present of impurities in the sample and the effect of air on the weighing balance. Though, the differences in the result obtained are negligible compare to the standard values.

The difference in the value of the burning rates is due to excess oxygen during the burning process because despite the oxygen content in the black powder explosive, more oxygen is absorbed from the surrounding air hence affect the burning rates.

The performance efficiency which was tested successfully implies that the black powder explosive developed can be used for military and other purposes as listed in the literature review.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The characterization of black powder explosive developed from locally sourced materials was carried out successfully. The differences found in the respective characterizations compare to the standard values are negligible and the performance efficiency of the developed black powder explosive was satisfactory. Hence the aim of the research project was achieved.

5.2 Recommendations

From the various results of the characterization carried out on the developed black powder explosive, it is therefore recommended that

i. The use of black powder explosive in the various ways as listed in the literature review should be encouraged.

ii. More research work should be carry out on the use of modern raw materials for the preparation of black powder explosive so as to compare it is performance efficiency with that developed from locally sourced materials.

APPENDIX

Constant: Density pf water = $1.0gcm^{-3}$

- Characterization of black powder explosive developed using charcoal obtained from coconut shell.

(1) Determination of moisture content

Weight of empty beaker (W_1) = 90.40g

Weight of beaker + black powder sample before sun drying (W_2) = 160.60g

Weight of beaker + black powder sample after sun drying (W_3) = 160.0g

$$MC = \frac{(160.0 - 90.40) - (160.0 - 90.40)}{(160.0 - 90.40)} * 100\% = \frac{(70.20 - 69.60)}{(70.20)} * 100\% = 0.8547\%$$

(2) Determination of relative density

Mass of empty relative density bottle (M_1) = 6.50g

Mass of bottle + black powder sample (M_2) = 24.10g

Mass of bottle + black powder sample = water (M_3) = 39.60g

Mas of bottle + water (M_4) = 32.30g

$$R_\rho = \frac{(24.10 - 6.50)}{(32.30 - 6.50) - (39.60 - 24.10)} = \frac{17.60}{10.30} = 1.7087$$

(3) Determination of density = $\rho = 1.7087 * 1.0 = 1.7087 gcm^3$

(4) Determination of Burning rate

Volume of black powder (V_{BP}) = $50cm^3$

Time for complete burning of black powder (T_{BP}) = 6.0sec

$$B_R = \frac{50.0}{6.0} = 8.3333 \, {cm^3}/{sec}$$

- Characterization of black powder explosive developed using charcoal obtained from cassava stem

(1) Determination of moisture content

Weight of empty beaker (W_1) = 90.40g

Weight of beaker + black powder sample before sun drying (W_2) = 138.80g

Weight of beaker + black powder sample after sun drying (W_3) = 138.40g

$$MC = \frac{(138.80 - 90.40) - (138.40 - 90.40)}{(138.80 - 90.40)} * 100\% = \frac{(48.40 - 48.0)}{(48.40)} * 100\% = 0.8264\%$$

(2) Determination of relative density

Mass of empty relative density bottle (M_1) = 6.50g

Mass of bottle + black powder sample (M_2) = 23.40g

Mass of bottle + black powder sample = water (M_3) = 39.60g

Mas of bottle + water (M_4) = 32.30g

$$R_\rho = \frac{(23.40 - 6.50)}{(32.30 - 6.50) - (39.60 - 23.10)} = \frac{16.90}{9.60} = 1.7604$$

(3) Determination of density = $\rho = 1.7604 * 1.0 = 1.7604 gcm^3$

(4) Determination of Burning rate

Volume of black powder (V_{BP}) = 50cm^3

Time for complete burning of black powder (T_{BP}) = 8.0sec

$$B_R = \frac{50.0}{8.0} = 6.250\, cm^3/_{sec}$$

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