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Experimental Analysis of Carbon Dioxide Capture Using Calcium Acetate from Animal Bones and Acetic Acid.

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ABSTRACT

The necessity of carbon dioxide also known as carbon iv oxide (CO_2) capture and storage is evident as greenhouse gas emissions continue to contribute to global warming, leading to adverse effects on the climate such as increased atmospheric and ocean temperatures. Carbon Capture, Storage, and Utilization are essential techniques to address this issue. This study focuses on utilizing crushed animal bones to extract calcium ions using acetic acid for capturing carbon dioxide. The experiment involved reacting the solution with carbon dioxide gas in a reactor, resulting in the formation of calcium acetate ($CaCO_3$). The results showed that animal bones effectively absorbed and stored carbon dioxide, demonstrating varying average volumes at different temperatures of absorption as 140.0ft^3 ,199.0ft^3, 231.5ft^3 , and 231.5ft^3 at 65^{0}C, 75^{0}C, 85^{0}C and 95^{0}C respectively. The experiment resulted in the formation of a white precipitate during the reaction process, indicating the successful formation of $CaCO_3$ from the captured CO_2. The various average weights of the $CaCO_3$ deposited due to the Carbon dioxide captured by the grinded cow bones were recorded as 40.4g, 44.7g, 46.5g, and 46.0g at temperatures of 65^{0}C, 75^{0}C, 85^{0}C, and 95^{0}C respectively. The study also indicates that there are small increases in $CaCO_3$ deposits and CO_2 volume when temperatures exceed 85^{0}C. However, the additional CO_2 capture capacity at higher temperatures is minimal compared to 85^{0}C, suggesting that operating the system at temperatures above 85^{0}C may not be feasible due to potential constraints in CO_2 capture capacity of the acetic acid and calcium acetate solution. This research underscores the importance of industries, such as oil and gas and automobile sectors, in capturing and storing carbon dioxide for renewable energy generation and enhanced crude oil recovery using grinded animal bones.

***Keywords**:* Carbon Dioxide, Carbonate, Global Warming, Carbon Capture, Green House Gases

1.0 Introduction

One method for capturing CO_2 is through the use of calcium ions. There are various alternatives to calcium-based sorbent CO_2 separation, such as membrane and cryogenic separation, adsorption, and absorption. However, these methods often require high energy consumption, pressure, and low temperatures, leading to increased costs in energy production. By utilizing a reaction-based system, CO_2 separation can occur at high temperatures and low pressures, reducing the need for costly cooling and compression processes. CO_2 sequestration is the next step in CO_2 management after transportation, involving the capture and compression of CO_2 from major sources for storage in designated areas. Geological sequestration is considered the best method for CO_2 storage, with low environmental risks, large storage potential, long retention times, and mature technology. Mineral sequestration involves permanently binding CO_2 through chemical reactions with metal oxides, while injecting CO_2 into the deep ocean floor is another method of storage.

Capturing CO2 represents a significant portion of the overall cost of Carbon Capture and Storage (CCS), comprising 75% of total expenses. The implementation of CCS could lead to a 50% increase in electricity production costs (Feron & Hendriks, 2005) . In order to encourage widespread adoption of CCS technologies, it is crucial to enhance efficiency and decrease the costs associated with CO_2 capture. This article delves into the advancements in technologies for CO_2 separation and capture, such as absorption, adsorption, membrane, and biotechnology. Amine solutions like MEA are popular for CO_2 absorption due to their high recovery rate of 98% (Yamasaki, 2003). There is room for improvement in enhancing the stability of amines and reducing the energy consumption in the CO_2 stripping process. Adsorption processes that utilize porous solid adsorbents like activated carbon and zeolites are also effective in CO_2 capture, with potential for enhancement through chemical reactions with the adsorbents. The amine absorption process, methyldiethanolamine (MEA) seems to be the most widely studied CO_2 absorption system worldwide. Several areas of MEA absorption were studied recently, such as improve the process design, making partial changes of the absorbents, and/or making great improvement of the process operation (Aboudheir*etal*., 2006; Al-Juaied & Rochelle, 2006; Bello & Idem, 2006; Jassim & Rochelle, 2006).

The use of animal bone idea of CO_2 capture is to properly use a cow animal bone, a bio-composite material, rich in calcium (Sparks, 2005), as a sorbent for the capture of CO_2 deposited in the form of $CaCO_3$, sequestration and separation whereby calcining the $CaCO_3$ forms a pure CO_2 stream and regenerates the CaO sorbent as shown in Equation 1.4. In this process calcium ions were extracted from crushed cow animal bones using an acetic acid as shown in equation 1.1 and 1.2 below. Secondly, CO_2 is passed through the calcium acetate solution where the calcium ions capture the CO_2 and stored in the form of calcium carbonate as shown in Equation 1.1, 1.2 and 1.3 below. The organic acid is then recovered and can be reused again. $CaCO_3 + 2CH_3COOH \rightarrow Ca(CH_3COO)_2 + CO_2 + H_2O$ 1.1

$CaCO3 + 2H+ \rightarrow Ca+2 + H2O + CO2$ 1.2

$H2O + CO2 + Ca(CH3COO)2 \rightarrow CaCO3 + 2CH3COOH$ 1.3

Calcination: $CaCO3 \rightarrow CaO + CO2$

2.0 Materials and Methods

2.1 Apparatus and Reagents:

The apparatus and reagents for this experiment are Reactor, CO_2 filled gas cylinder, receiver empty gas cylinder, hose, bowl, 2.5 liter of acetic acid and grinded cow animal bones.

2.2 Methods

2.2.1 Experimental Procedure

The experiment took place in the petroleum/chemical engineering laboratory at Rivers State University. The setup included a reactor with a volume of approximately 636cm3, two gas bottles (one filled with CO2 gas and the other empty to collect unreacted CO2 gas), a thermometer to monitor the temperature of the incoming calcium acetate solution and CO2 gas, and a stirrer to ensure thorough mixing of the fluids.

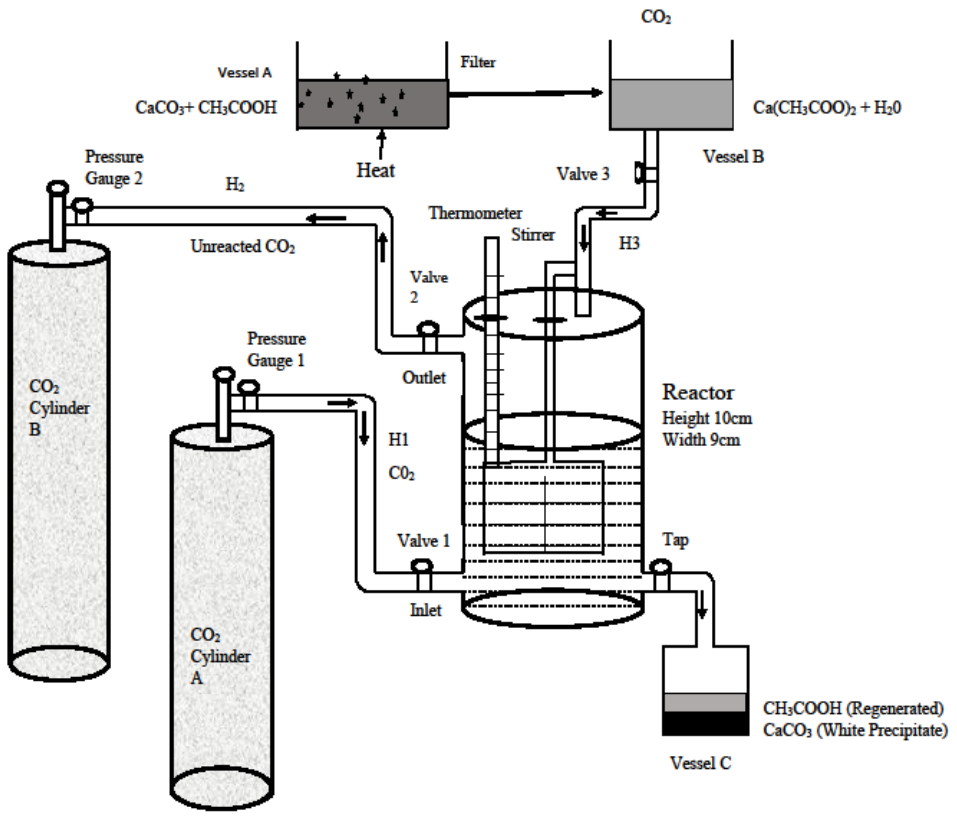


Figure 1: CO_2 capture and sequestration unit

The procedure described in Figure 1 involves obtaining animal bones and grinding them into powder. The next step is to extract calcium ions from the bones by mixing the powder with acetic acid to form calcium acetate, carbon dioxide, and water. The carbon dioxide produced is released into the atmosphere, leaving behind a solution of calcium acetate containing the desired calcium ions.

$$CaCO_3 + 2CH_3COOH \rightarrow Ca(CH_3COO)_2 + CO_2 + H_2O \quad (1)$$

or

$$CaCO_3 + 2H^+ \rightarrow Ca^{2+} + H_2O + CO \quad (2)$$

The solution of calcium acetate is added to the reactor through its cap, followed by the introduction of pressurized carbon dioxide gas from a cylinder via valve 1. This gas enters the reactor from the

bottom, facilitating a thorough reaction with the calcium acetate solution. During this process, the calcium ions trap and store the carbon dioxide, resulting in the production of calcium carbonate and acetic acid as the final products. The chemical equation for this reaction is shown below.

$$CO_2 + Ca(CH_3COO)_2 + H_2O \rightarrow CaCO_3 + 2CH_3COOH \quad (3)$$

The resultant acetic acid and calcium carbonate are collected in a vessel via a bottom tap in the reactor. The calcium carbonate settles in the collection vessel while the acetic acid is recovered for reuse. The carbon dioxide gas produced flows through valve 2 into a gas cylinder for storage, with pressure readings taken.

Pressure variations indicated successful capture and sequestration of CO_2.

Changes in temperature and pressure affected the rate of gas solubility, providing insights into CO_2 capture levels.

A thermometer monitored the reactor temperature during heating to optimize solubility.

A stirrer ensured consistent temperature distribution in the solution.

2.3 Acetic Acid Solution Preparation

The acetic acid solution was prepared using a quantity of acetic acid solution, and then mixed with appropriate amounts of distilled water to obtain the desired concentration.

2.4 Sample Preparation and Characterization:

The process involves selecting, cleaning, crushing, and weighing animal bones in grams. The bones were sourced from sellers and dump sites, crushed, and treated with acetic acid to extract calcium ions. These ions were then mixed with pressurized carbon dioxide in a reactor to measure the CO2 captured. The experiment determined the amount of CO_2 stored for a specific bone quantity, along with the necessary temperature and pressure conditions. The bones were also sieved using a 150-micron sieve. The experiment specifically utilized cow bones. A portion of the acetic acid was recycled for reuse in subsequent reactions with bone. The volume of CO_2 was calculated using the ideal gas equation.

$$PV = nRT \quad (4)$$

Where p = inlet or outlet pressure (psi)

V = volume of CO_2 gas captured (ft^3)

n = number of moles of CO_2 gas captured

R = gas constant and T = reaction temperature^{0}C

The mass of the CO_2 gas was calculated using the equation below.

Mass of calcium acetate +Mass of CO_2 = Mass of Regenerated acid + Mass of $CaCO_3$

While the number of moles was calculated using:

n = M_{CO2}/M, where M_{CO2} is mass of CO_2 captured and M is molecular weight of CO_2.

See appendix iv and v for procedures and calculations for volume of CO_2

Preparation of Reagent

Different concentrations of an acetic acid were used to conduct this experiment.

Molecular formula is CH_3COOH

Where the molecular weight is obtained as follows:

12 +1(3) + 12 +16(2) + 1= 60.05g/mol

Density = 1.05g/cm^3

IM = 60ml dissolved in IL of H_2O

IL of H_2O = 1000ml

.: 1M Concentration of acid = 940ml of H_2O in 60ml of Acid

Reaction Between Bone Powder and Acid

The reaction was conducted in two stages. In the first stage, 100g of bone powder was mixed with a 2.5M concentration of acid in a two-litre reaction vessel. The mixture was heated to 65°C to form calcium acetate solution, which was then filtered to separate it from the bone chaff. In the second stage, calcium acetate solution was mixed with water in a reactor along with CO_2 gas at certain pressures. The reaction times for each concentration of acid were varied, and the mixture was drained into another vessel after a retention time of one hour. An impure white precipitate formed at the base of the vessel, and acetic acid was regenerated in the process.

Reaction temperature of 65^{0}C with 2.5M acetic acid

- P_1 = 12.5 psi
- P_2 = 11.1psi
- Weight of dry bone powder = 100g
- Conc. of acid = 2.5M
- Volume of acid =300ml
- Temperature of ($CaCO_3$) + CH_3COOH = 65^0C
- Reaction time = 2min
- Retention time = 1 hour
- Reaction temperature = 65^0C
- Base temperature 26 ^0C

Reaction temperature of 75^0C with 2.5M acetic acid

1. P_1 = 12.5psi
2. P_2 = 13.1psi
3. Weight of dry bone powder = 100g
4. Conc. of acid = 2.5M
5. Volume of acid =300ml
6. Temperature of ($CaCO_3$) + CH_3C00H = 75^0C
7. Reaction time = 2 min
8. Retention time = 1 hour
9. Reaction temperature = 75^0C
10. Base temperature 26^0C

Reaction temperature of 85^0C with 2.5M acetic acid

1. P_1 = 12.5psi
2. P_2 = 15.0 psi
3. Weight of dry bone powder = 100g
4. Conc. of acid = 2.5M
5. Volume of acid =300ml
6. Temperature of ($CaCO_3$) + CH_3C00H = 85^0C
7. Reaction time = 2min

8 Retention time = 1 hour

9 Reactor temperature = 85^0C

10 Base temperature 26 ^{0}

Reaction temperature of 65^0C with 2.5M acetic acid

1 P_1 = 12.5 psi

2 P_2 = 16.9 psi

3 Weight of dry bone powder = 100g

4 Conc. of acid = 2.5M

5 Volume of acid =300ml

6 Temperature of ($CaCO_3$) + CH_3COOH = 95^0C

7 Reaction time = 2min

8 Retention time = 1 hour

9 Reactor temperature = 95^0C

10 Base temperature 26 ^{0}C

Similarly, the experiment was conducted with class B, C and D bones.

Appendix V

Calculation of mass of CO_2

Using the equation

Mass of calcium acetate + mass of CO_2 = mass of regenerated acid + Mass of $CaCO_3$

$M_{acetate} + M_{C02} = M_{Reg.\ acid} + M_{CaCO3}$

$M_{CO2} = M_{Reg.\ acid} + M_{CaCO3} - M_{acetate}$

Where:

$M_{acetate}$ = mass of calcium acetate = Mac

M_{CO2} = mass of CO_2 captured

$M_{Reg.\ acid}$ = mass of regenerated acid = M_R

M_{CaCO3} = mass of calcium carbonate

Number of mode $n = \frac{M_{CO2}}{M}$

Where M = molar mass of CO_2 =44g/mole

M_{CO2} = mass of CO_2 captured.

<u>At 65^0C</u>

1. M_{CaCO3} = 3.7 2g, Mac = 115g, $M_{Reg.acid}$ = 89

   $115+M_{CO2} = 89 + 37.5$

   M_{CO2} = 10.2g

   $n = \frac{10.2}{44} = 0.23\ mol\ CO_2$

2. For M_{CaCO3} = 38g, $M_{acetate}$ = 115g

   $M_{Reg.acid}$ = 90g

   $115+M_{CO2} = 90+38$

   M_{CO2} =13g

   $n = \frac{13}{44} = 0.3 mol\ CO_2$

   For M_{CaCO3} = 41.6g, Mac = 115g, $M_{Reg.acid}$ = 90g

   $M_{CO2} = 90 + 41.5 – 115$

   M_{CO2} = 16.5g

   $n = \frac{16.5}{44} = 0.37\ mol\ CO_2$

3. For M_{CaCO3} = 42.3g, M_{ac} = 115g, $M_{Reg.acid}$= 91g

   $M_{CO2} = 91 + 42.3-115$

   M_{CO2} = 18.3g

   $n = \frac{18.3}{44} = 0.42\ mol\ CO_2$

4. For M_{CaCO3} = 42g, M_{ac} = 114g

   $M_{Reg.acid}$ = 92g

   M_{CO2} = 92+42.8-115=20.8g

$$n = \frac{20.8}{44} = 0.47 mol\ CO_2$$

At 75^0C

1. $M_{Reg.acid}$ = 87g, M_{CaCO3} = 43.5g, M_{ac}=116g

   M_{CO2} =87+43.5-116=14.5g

$$n = \frac{14.5}{44} = 0.33\ mol\ CO_2$$

2. For M_{CaCO3} = 44g, M_{ac}= 113g, $M_{Reg.acid}$ =88g

   M_{CO2} = 88 + 44- 113

   M_{CO2} = 19g

$$n = \frac{M_{co2}}{M} = \frac{19}{44} = 0.43 mol\ CO_2$$

3. For M_{CaCO3} = 44.6g, M_{ac} = 113g, $M_{Reg.acid}$ = 90g

   M_{CO2} = 90+ 44.6-113=21.6g

$$n = \frac{21.6}{44} = 0.49\ mol\ CO_2$$

4. For M_{CaCO3} = 45.7, M_{ac} = 111g, $M_{Reg.acid}$ =91

   M_{CO2}=91+45.7-111=25.7g

$$n = \frac{25.7}{44} = 0.58 mol\ CO_2$$

5. For M_{CaCO3} = 45.8g, M_{ac} =110g, $M_{Reg.acid}$ = 93g

   M_{CO2} = 93 + 45.8 -110=28.5g

$$n = \frac{28.5}{44} = 0.65 mol\ CO_2$$

At 85^0C

1. $M_{Reg.acid}$ = 86g, M_{CaCO3} 45.7, M_{ac} = 115g

   M_{CO2} = 86 +45.7-115=17.7g

$$n = \frac{17.7}{44} = 0.4 mol\ CO_2$$

2. For M_{CaCO2} = 46.2g, M_{ac} = 112g $M_{Reg.acid}$ = 87g

   M_{CO2} = 87+462-112=21.2g

$$n = \frac{21.2}{44} = 0.48\ mol\ CO_2$$

3. M_{CaCO3} =46.8g, Mac =110g, $M_{Reg.acid}$ = 88g

M_{CO2} = 88 + 46.8-11=24.8g

$$n = \frac{24.8}{44} = 0.56 mol\ CO_2$$

4. M_{CaCO3} =46.9g, M_{ac} =119g, $M_{Reg.acid}$ =91g

M_{CO2} =91+46.9=112 =27.9g

$$n = \frac{27.9}{44} = n = 0.63\ mol\ CO_2$$

5. M_{CaCO3} = 46.9g, M_{ac}= 108g, $M_{Reg.acid}$ = 92g

M_{CO2} = 92 + 46.9 -108 =30.9

$$n = \frac{30.9}{44} = 0.7 mol\ CO_2$$

<u>At 95^0C</u>

1. M_{CaCO3} = 45.7g, $M_{Reg.acid}$=86g, M_{ac}=114g

M_{CO2} =92 +46.9-108=30.9

$$n = \frac{17.8}{44} = 0.4 mol\ CO_2$$

2. For M_{CaCO3} =45.8g, M_{ac} =110g, $M_{Reg.acid}$ =85g

M_{CO2} =85 +45.6-110 = 20.8g

$$n = \frac{20.8}{44} = 0.47\ mol\ CO_2$$

3. For M_{CaCO3} = 46.0g,M_{ac} = 109, $M_{Reg.acid}$ = 87g

M_{CO2} = 87 + 46.0 -109 = 24.og

$$n = \frac{24}{44} == 0.54\ mol\ CO_2$$

4. M_{CaCO3} = 46g, M_{ac} =100g, $M_{Reg.acid}$ =89g

M_{CO2} = 89 + 46.1-108 =27.1g

$$n = \frac{27.1}{44} = 0.61 mol\ CO_2$$

5. M_{CaCO3} = 46.3g, M_{ac} = 107g, $M_{Reg.acid}$ = 92g

M_{CO2} = 91+46.2 -107=30.2g

$$n = \frac{30.2}{44} = 0.68\, mol\ CO_2$$

Calculation of volume of CO_2 captured

The volume of CO_2 captured by the bones by was calculated by using the ideal gas law equations given below

PV = ZnRT

Where:

Z = 1 (for ideal gas),

R = 10.731ft^3 psi R-1 I b – mol^{-1}

P = Pressure read by the gages

T = temperature and V = Volume

P V = n R T, $V = \frac{nRT}{P}$

Where V = Volume of CO_2 captured from cylinder A

P= Pressure reading by gauges at cylinder A

T= Temperature of reactor in each experiment

The volume capture calculation is in accordance with the various temp and pressure of the system.

Pressures assigned for this experiment are: 12.5psi, 14.5 psi, 16.5psi, 18.5psi and 20.5psi.

Temperatures are: 65^0C, 75^0C, 85^0C& 95^0C at conc. 2.5M to produce $CaCO_3$ and CH_3COOH.

At 65^0C

1. P_1 = 12.5psi, n_1=0.23 $mol\ CO_2$

$V_1 = \frac{0.23 \times 10.731 \times 608.67}{12.5}$

V_1 =120.2ft^3

Flow rate,

Q=$\frac{Volume}{time} = \frac{120.2ft^3}{2min} = 60.1ft^3$

2. T_{65} =65$_0$C = 608. 67^{0}R

P_2=14.5psi, n_2=0.3 $mol\ CO_2$

R=10.731

$$V_2 = \frac{nRT_2}{P_2} = \frac{0.3 \times 10.73.731 \times 608.67}{14.5}$$

3. At P_3 = 14.5psi, n_3 =0.37 $mol\ CO_2$

$$V_3 = \frac{0.73\ \times 10.731 \times 608.67}{16.5}$$

V_3 = 146.5ft^3

4. At P_4 = 18.5psi. n_4 = 0.42 $mol\ CO_2$

$$V_4 = \frac{0.42 \times 10.731\ \times 608.67}{18.5}$$

5. At P_5 = 20.5psi, n_5 = 0.41 $mol\ CO_2$

$$V_5 = \frac{0.47 \times 10.731 \times 60867}{20.5}$$

V_5=149.7ft^3

<u>At 75^{0}C</u>

1. P_1 =12.5psi, n_1 = 0.33 $mol\ CO_2$

$$V_1 = \frac{0.33 \times 10.731 \times 626.67}{12.5} = 177.5ft^3$$

Q=$\frac{177.5}{2} = 88.75ft^3/min$

2. At P_2 =14.5psi, n_2 =0.43 $mol\ CO_2$

T_1 =75^{0}C = 626.67^{0}R

$$V_2 = \frac{0.43x10.731 \times 10.731 \times 626.67}{14.5} = 193.7ft^3$$

3. P_3 =16.5psi, n_2=0.49 $mol\ CO_2$

$$V_3 = \frac{0.49 \times 10.731 \times 626.67}{16.5} = 199.7ft^3$$

4. P_4 =18.5psi, n_4=0.49 $mol\ CO_2$

$$V_4 = \frac{0.58 \times 10.731 \times 626.67}{18.5} = 210.8ft^3$$

5. P_5 =20.5psi, n_5=0.5 $mol\ CO_2$

$$V_5 = \frac{0.65 \times 10.731 \times 626.67}{20.5} = 213.22 ft^3$$

At 85^{0}C

1. P_1 =12.5psi, n_1=0.4 $mol\ CO_2$

$$V_1 = \frac{0.4 \times 10.731 \times 662.67}{12.5} = 227.6 ft^3$$

Q= $\frac{221.4}{2} = 110.7 ft^3/min$

2. P_2 = 14.5psi, n_2 = 0.48 $mol\ CO_2$

$$V_2 = \frac{0.48 \times 10.731 \times 644.67}{14.5} = 229 ft^3$$

3. P_3=16.5psi,n_3=0.56 $mol\ CO_2$

$$V_3 = \frac{0.56 \times 10.731 \times 644.67}{16.5} = 234.8 ft^3$$

4. P_4 = 18.5psi, n_4=0.63 $mol\ CO_2$

$$V_5 = \frac{0.63 \times 10.731 \times 644.67}{18.5} = 236 ft^3$$

5. P_5 = 20.5psi, n_5 = 0.7 $mol\ CO_2$

$$V_5 = \frac{0.7 \times 10.731 \times 644.67}{20.5} = 236.2 ft^3$$

At 95^{0}C

1. P_1=12.5psi, n_1=0.4 $mol\ CO_2$

$$V_1 = \frac{0.4 \times 10731 \times 662.67}{12.5} = 227.6 ft^3$$

Q=$\frac{227.6}{2} = 113.8 ft^3/min$

2. P_2 = 14.5psi, n_2=0.47 $mol\ CO_2$

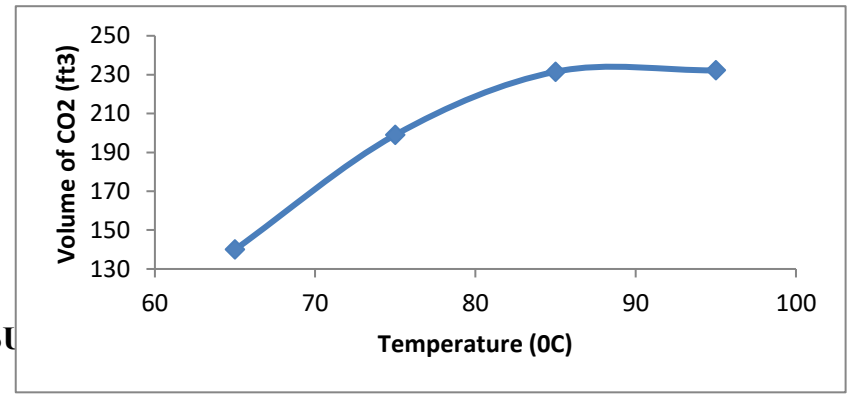
$$V_2 = \frac{0.47 \times 10.731 \times 662.67}{14.5 psi} = 239.5 ft^3$$

3. P_3 = 16.5psi, n_3=0.54 $mol\ CO_2$

$$V_3 = \frac{0.54 \times 10.731 \times 662.67}{16.5} = 232.7 ft^3$$

4. P_4 =18.5psi, n_4=0.61 $mol\ CO_2$

5.



RESU

The average results of the CaCO3 deposit and volume of CO2 are presented below.

Temperature (^{0}C)	$CaCO_3$ deposit(g)	Volume of CO_2 (ft^3)
65	40.4	140.0
75	44.7	199.0
85	46.5	231.5
95	46.0	232.2

Table 1. Average $CaCO_3$ deposit and volume of CO_2 captured

Table 1 above clearly shows the average values of $CaCO_3$ deposit and volumes of CO_2 gas captured according to the specified temperatures ranging from 65^{0}C to 95^{0}C. This table indicates that the average volume of CO_2 gas captured increases greatly from 140.0ft^3 at a temperature of 65^{0}C to 199.0ft^3 at a temperature of 75^{0}C and increased to 231.5ft^3 at 85^{0}C and almost remains constant 95^{0}C resulting in 232.2ft^3 of CO_2 gas captured. This obviously shows that the CO_2 capture process using acetic acid at temperature above 85^{0}C may not produce a favourable result. The consistent buildup of $CaCO_3$ may be due to the weakening of acetic acid strength at very high temperatures or the calcium acetate solution reaching its CO_2 absorption limit. To improve CO_2 capture efficiency with animal bones using acetic acid, it is advisable to keep the temperature below 85°C.

Figure 2 Average Volume of CO_2 at Temperature between 65^{0}C and 95^{0}C

Figure 2 above describes how increase in temperature enhances the CO_2 capture processes of the bones. It shows that at 65^{0}C the amount of CO_2 captured was almost 200ft^3 while at 75^{0}C the amount of CO_2 captured by the bones was about 231ft^3, but the average volumes are almost constant at temperatures between 85^{0}C and 95^{0}C. This is why it will be better to operate this system

not exceeding 85^0C. In other words, the findings suggest that the $CaCO_3$ deposits and CO_2 volume exhibit slight increases at temperatures above 85^0C. The CO_2 capture capacity at higher temperatures is only slightly higher than at 850C, indicating that operating the system at temperatures above 85^0C may not be practical due to potential limitations in CO_2 capture capacity of the acetic acid and calcium acetate solution.

4.4 Atomic Absorption Spectrometry (AAS) Analysis of Bones

Table 2 AAS Results Showing Calcium Concentrations in Bones before Extraction

Bone Label	Element	Concentrations
A	Ca^{2+}	2377.239 ppm
	Na^{+}	909.691ppm
	K^{+}	108.764ppm

In Table 2 above analysis was made on the various classes of bones to obtain the concentrations of the metallic ions that constitute the bones. The ions include Ca^{2+}, Na^{+}, K^{+} and even phosphorus, a non-metal. According to the results obtained Ca^{2+} concentration in the bones is 2377.239ppm and that the concentration of the Ca^{2+} (2377.239ppm) was far higher than that of the NA^{+} which has a concentration of 909.691ppm and K^{+} with a concentration of 108.764ppm in the bones. Refer to appendix I AAS analysis for Ca^{2+}.

4.5 By-products Analysis

Table 3 AAS Results of By-Product Analysis

BoneLabel	Element	Concentrations
A	Ca^{2+}	92.235 ppm

Table 3 above shows that further analysis was made on the by–product of the bones after the calcium ion extraction process to ascertain the effectiveness of the extraction process. Results show that the extraction process was almost 100% perfect as over 96.1 % of the calcium ions in the bones were extracted by the acetic acid at elevated temperatures. It was observed that after the

extraction process there was a drastic reduction of the calcium ions from an initial concentration of 2377.239ppm to a final concentration of 92.24ppm. The result of the by–product analysis is shown above in table 4.4. From the results above the total amount of calcium ions extracted from the bones for the CO_2 capture is given as:

Total Ca^{2+} = 2377.239ppm - 92.235ppm = 2285.004ppm.

4.6 Comparing results with past works

From the Atomic Absorption spectrometry (AAS) Analysis of Bones in Table 2 and 3 the concentrations of the Ca^{2+} before the reaction and after the reaction can be used to determine the effectiveness of this CO_2 capture technique as shown below.

Initial conc. Ca^{2+} before reaction in bones =2377.239ppm.

Final Conc. Ca2+ after reaction in bones = 92.235ppm

Percentage of Ca2+ utilized during reaction =96.1%

This shows that 96.1% of the Ca2+ concentration initially in the bones were used up during the reaction with the CO_2 resulting in the $CaCO_3$ deposit. In other words, if all 96.1% of the Ca^{2+} were allowed to react with the CO_2 yielding $CaCO_3$ deposits.

It therefore means that the capture and sequestration of CO2 using animal 96.1% effective compare to that of the Amine Absorption process (MEA) which is over 95% effective. (Yamasaki, 2003). This shows that the use of animal bones for the capture and sequestrations of CO_2 is very effective while use of animal bones is 96.1% effective Momoethanol Amine (MED) is 95% effective.

5.0 Conclusion

The utilization of cow animal bones as a source of calcium ions for capturing and storing carbon dioxide (CO_2) gas has been demonstrated to be effective. By extracting calcium ions from grinded bones using acetic acid, a calcium acetate solution is obtained. This solution reacts with CO_2 gas to produce calcium carbonate ($CaCO_3$) and acetic acid as by-products. The results indicates that average volumes of 140.0ft^3 ,199.0ft^3, 231.5ft^3, and 231.5ft^3 of CO_2 at different temperatures of

65^0C, 75^0C, 85^0C, and 95^0C were captured by the grinded bones respectively. The experiment resulted in the formation of a white precipitate during the reaction process, indicating the successful formation of $CaCO_3$ from the captured CO_2. The various average weights of the CaCO3 deposited were recorded as 40.4g, 44.7g, 46.5g, and 46.0g at temperatures of 65^0C, 75^0C, 85^0C, and 95^0C respectively. This captured CO_2 in the form of $CaCO_3$ can be recovered and converted for various purposes, including energy production and enhanced oil recovery. The study indicates that there are small increases in $CaCO_3$ deposits and CO_2 volume when temperatures exceed 85^0C. However, the additional CO_2 capture capacity at higher temperatures is minimal compared to 85^0C, suggesting that operating the system at temperatures above 85^0C may not be feasible due to potential constraints in CO_2 capture capacity of the acetic acid and calcium acetate solution.

Implementation of this method could benefit both upstream and downstream companies by facilitating the separation and storage of CO_2 from reservoir fluids like natural gas, thereby mitigating the impact of global warming. The stored CO_2 in the form of $CaCO_3$ can also be utilized for various applications over an extended period of time. This study has been conducted using the current equipment, knowledge, and methods available. It is recommended that further research be conducted using more advanced tools and techniques to confirm the carbon dioxide capture capacity of animal bones and determine the optimal temperature for carbon dioxide capture. It is also suggested that government and CO_2 production companies allocate funds to support the development of an effective CO_2 absorption system using animal bones to minimize CO_2 emissions into the atmosphere. This study has shown that animal bones can be effectively utilized for capturing and sequestering carbon dioxide, presenting a cost-effective and easily accessible method compared to other approaches. Additionally, the research suggests that animal bones can serve as a purification system for natural gas pipelines and vehicles, where captured carbon dioxide can be separated and sequestered before or after fuel combustion.

References

Aboudheir A, Tontiwachwuthikul P, and Idem R, (2006). *Rigorous model for predicting the behavior of CO_2 absorption into AMP in packed-bed absorption columns*. Industrial and Engineering Chemistry Research, 45(8): 2553-2557.

Al-Juaied M, and Rochelle G T, (2006). *Absorption of CO_2 in aqueous diglycolamine*. Industrial and Engineering Chemistry Research, 45(8): 2473–2482.

Anson M, Marchese J, Garis E, Ochoa N, and Pagliero C, (2004). *ABS copolymer-activated carbon mixed matrix membranes for CO_2/CH_4 separation*. Journal of Membrane Science, 243: 19–28.

Aoki K, Kusakabe K, and Morooka S, (2000). *Separation of gases with an A-type zeolite membrane*. Industrial and Engineering Chemistry Research, 39: 2245–2251.

Bello A, and Idem R O, (2006). *Comprehensive study of the kinetics of the oxidative degradation of CO_2 loaded and concentrated aqueous monoethanolamine (MEA) with and without sodium metavanadate during CO_2 absorption from flue gases*. Industrial and Engineering Chemistry Research, 45(8): 2569-2579.

Haywood H M, Eyre J M, and Scholes H, (2001). *Carbon dioxide dequestrtion as table varbonate minerals–Environmental barriers*. Environmental Geology, 41: 11–16.

Herzog H J, and Drake E M, (1996*). Carbon dioxide recovery and disposal from large energy systems*. Annual Review of Energy and the Environment, 21: 145–166.

Huang H P, Shi Y, LiW, and Chang S G, (2001*). Dual alkali approaches for the capture and separation of CO_2*. Energy and Fuels, 15(2): 263–268.

Jassim M S, and Rochelle G T, (2006). *Innovative absorber/stripper configurations for CO_2 capture by aqueousmonoethanolamine*. Industrial and Engineering Chemistry Research, 45(8): 2465–2472.

Resnik K P, Yeh J T, and Pennline H W, (2004). *Aqua ammonia process for simultaneous removal of CO_2, SO_2 and NO_2*. International Journal of Environmental Technology and Management, 4(1-2): 89–104

Riahi K, Rubin E S, and Schrattenholzer L, (2004*). Prospects for carbon capture and sequestration technologies assuming their technological learning*. Energy, 29: 1309–1318.

Sparks, Angela (2005). *High Reactivity Calcium-Based Biomineral Sorbents for CO2 Capture*. A Bachelor of Science Thesis. Department of Chemical and Biomolecular Engineering at The Ohio State University.

Yamasaki A, (2003). *An overview of CO_2 mitigation options for global warming – Emphasizing CO_2 sequestration options*. Journal of Chemical Engineering of Japan, 36(4): 361–375.