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Year 9 Student Research Project 2015

SCIENTIFIC REPORT

Topic: How does temperature affect bovine waste decomposition and the subsequent production of methane gas?

Background Information:

Methane gas is a greenhouse gas similar to carbon dioxide that has been scientifically proven to contribute significantly to global warming. Although methane occurs in a lower concentration in the atmosphere than carbon dioxide it is much more harmful, producing 21 times more warming than carbon dioxide and accounting for approximately 20% of the 'enhanced greenhouse effect' (BBC Climate Change Centre). On average one cow produces 100kg of methane gas each year and cattle are responsible for 20% of all methane output on Earth. According to some studies this means that the methane contributions of cattle exceed those of all fossil fuel combustion processes combined.

Methane is not actually produced directly by the cattle, but by microorganisms and bacteria that live in the stomachs of the cows. The symbiotic relationship between the microorganisms and the cows is very efficient – the cow provides the microorganisms with a safe place to live and the organisms eat the cellulose in the grass eaten by the cow. However, these microorganisms are not as efficient in eating as they are in the symbiotic relationship they share with the cow and they waste 6-10% of what they eat. This waste is methane and along with other undigested material and gases it is excreted from the cow and is contained in the cow waste until the waste decomposes. When the waste is decomposed enough the methane ascends into the atmosphere and contributes to global warming.

The gas produced by cow excrement is not purely methane but also hydrogen and oxygen in very small amounts, nitrogen and carbon dioxide. Methane makes up 26.8% of the gas produced during bovine waste decomposition (Sniffen, C.J. and H. H. Herdt. The Veterinary Clinics of North America).

Decomposition of organic matter is very dependent on a small number of key variables like temperature, light and soil type (if it is decomposing on the ground). My investigation focusses on how temperature affects the decomposition of cow waste and how this influences the amount of methane gas produced by the cow waste. Heat is a key catalyst in organic decomposition and my investigation aims not only to document how the temperature of the cow waste affects the decomposition but also how much methane is produced at each different temperature.

The results of my investigation could be used to predict or identify where more methane gas is produced around the world and which countries would have the highest methane production rates specific to the number of cows they had and the climate of the country. For example, if the highest temperature (35°C) sample produced the most methane gas this data could be used to identify places on Earth where methane production rates by cattle would be higher due to the temperature that optimises cow waste decomposition and thus leads to increased methane gas production.

Aim: To investigate how temperature affects bovine waste decomposition and the subsequent production of methane gas.

Hypothesis: The highest temperature setting used will cause the most efficient decomposition process and produce the most methane gas.

Method:

1. The following items were collected:
    - 8 samples of fresh cow manure – 100 g each
    - 8 identical conical flasks

- 8 identical 'zip-lock' plastic bags (zip-lock section cut off)
- 8 short pieces of string (for sealing the plastic bags at conclusion of experiment)
- Scientific scales (0.01g precision)
- Tape
- 2 thermometers
- Camera

2. The plastic bags were weighed and their *weights with no gas inside* were recorded for reference at the conclusion of the experiment. The pieces of string were also weighed for reference (see logbook for these weights). These materials were weighed to ensure they remained controlled variables in the investigation.
3. Each 100 g sample of cow manure was placed in a separate conical flask and the plastic bags were secured over the top of the conical flasks using tape to stick the plastic firmly to the flasks – see diagram:

Photo of flask set up

4. The samples were then placed in 4 temperature controlled environments. Samples 1 and 2 were placed in an incubator at 35°C, Samples 3 and 4 were placed in a water bath at 25°C, Samples 5 and 6 were placed in a water bath at 15°C and Samples 7 and 8 were placed in a refrigerator set at 5°C. There were 2 samples at each temperature setting to increase result reliability and accuracy.
5. The samples were then left to decompose for 4 days without any interference. During this time the samples were exposed to as little light as possible. The camera was used to take pictures of the samples during this period.
6. When the 4 day period had concluded the samples were removed from the temperature controlled environments and the pieces of string were tied above the head of the flask where the plastic bag was taped. They were tied very tight to ensure no gas could escape.
7. The sealed plastic bags were then removed from each flask and were separately weighed on the scales. The weights were recorded to use in the calculations below. All tape used to attach the plastic bags to the flasks was removed to not interfere with the weights of the bags.
8. The weight of the gas inside each plastic bag was calculated using this equation:

   Weight of gas = Weight of plastic bag at conclusion of investigation – (weight of plastic bag at start of investigation + weight of piece of string used)

9. The amount of methane in each plastic bag was calculated using this equation:

   Amount of methane (g) = weight of gas x 0.268

   NB: As stated in the background information, methane gas constitutes 26.8% of the gas produced by cow waste.
10. The amount of methane produced by each sample was recorded and the practical investigation was concluded. Disinfectant was used to clean all equipment that had come in direct contact with the manure.

Safety Audit:

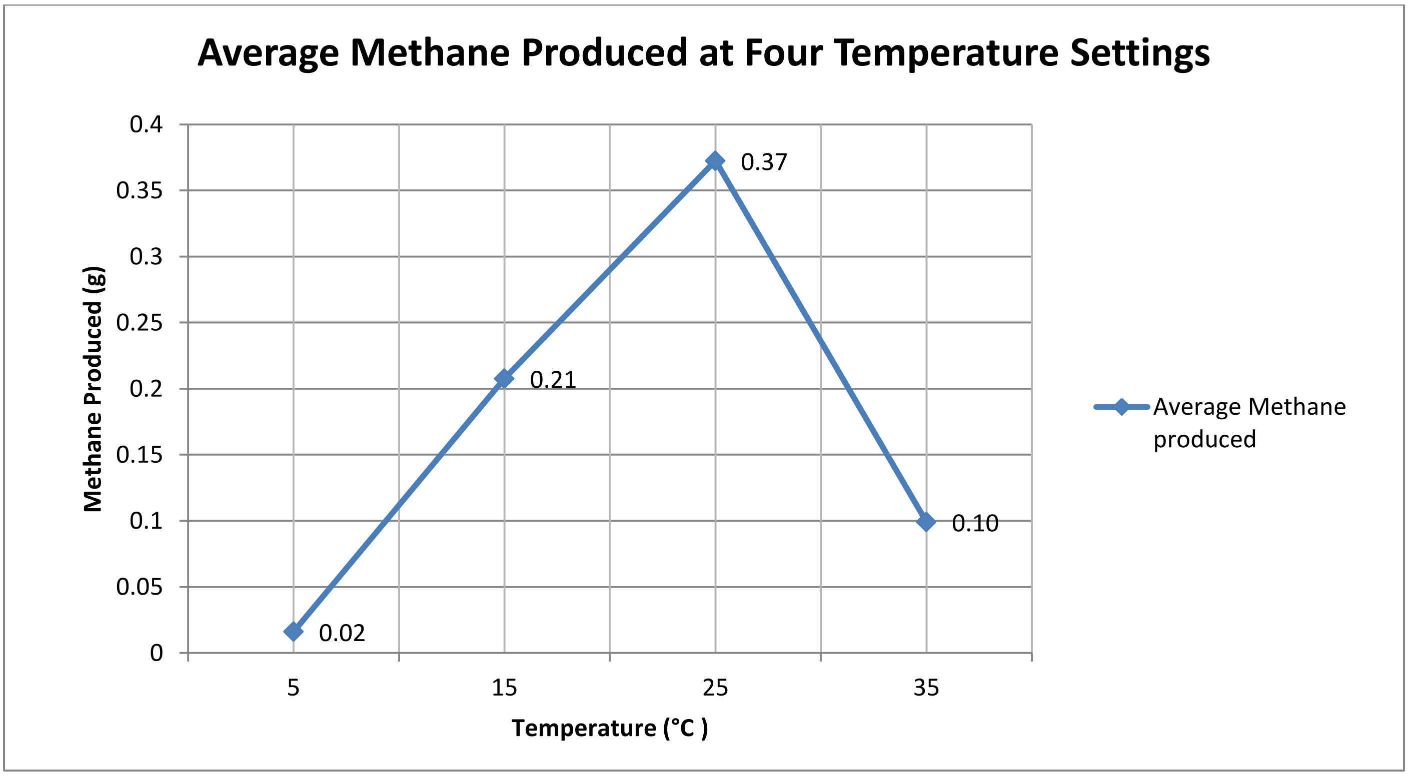
Methane gas is a poisonous gas that can severely harm the body's internal systems if inhaled in a large quantity. The weighing and disposing of the manure and gas was performed in a well-ventilated environment and gas bags were kept away from open flames.

Plastic gloves were used when handling the manure to avoid hygiene issues and the manure was disposed of in a tightly closed bag in the bin. Disinfectant and antibacterial wipes were used to disinfect all equipment at the conclusion of the investigation.
This investigation involved the use of a scientific incubator and water baths. These are sensitive pieces of scientific equipment and were handled with care. The incubator presents a burning risk if the hot metal is touched.
Glass was used in this investigation and was handled with care. If a breakage did occur the glass would be picked up using a dustpan and brush and wrapped in paper or bubble-wrap before being disposed.

Results:

Sample No.	Temperature (°C)	Methane produced (g) (rounded to 2 dp.)	Average methane produced (g) (rounded to 2 dp.)	Decomposition Efficiency Ranking 1-4 (based on average)
1	35	0.11	0.10	3
2	35	0.09		
3	25	0.34	0.37	1
4	25	0.41		
5	15	0.20	0.21	2
6	15	0.21		
7	5	0.02	0.02	4
8	5	0.01		

Graph of Results:



Observations:

There were a couple of interesting developments over the 4 day test period. The most surprising of these was the growth of white, furry mould on the 35°C samples (numbers 7 & 8) during the third and fourth days of the test period. The effects of this mould will be addressed in the discussion section of the report. Another development was that of water condensation on the plastic bags from the water baths, however this water evaporated before the bags were weighed, meaning the water didn't affect the weights of the bags.

Photographs of the samples:

Samples 7 & 8 - 5°C

15°C and 25°C samples post investigation

Samples 5 & 6 - 15°C in water bath

Weighing the plastic bags and recording results.

Photograph of the mould on samples 1 & 2 - 35°C.

Discussion:

The investigation yielded interesting and informative results. The samples that produced the most methane gas were the 25°C samples, disproving the hypothesis. This shows that of the 4 temperature settings of the 8 samples used 25°C was the optimum temperature for methane production from bovine waste during decomposition. There are a few key factors that indicate why these samples produced the most methane.

Heat is a key catalyst in the decomposition of organic waste and 25°C provided a warm environment in which the manure could decompose healthily. This was not the case with the 35°C samples, which were so warm that mould grew on the manure as it decomposed in the conical flasks. This mould could have inhibited the 35°C samples from releasing as much methane gas as the 25°C samples by forming a layer of insulation around the manure meaning the methane could not escape. A future experiment could be conducted to investigate how mould affects the amount of methane produced by bovine waste to ascertain how the mould growth on the 35°C samples affected the results of this investigation.

The 5°C samples produced the least methane gas and this is because they were the coldest samples. The cold temperature meant there was less heat to penetrate and burst the pockets of methane gas in the manure, thus decreasing the amount of methane produced. It also meant the manure decomposed more slowly, thus decreasing the methane produced. These results also indicate a surprising trend in methane production at different temperatures. More methane was produced at more average temperatures 15°C and 25°C – while the methane production from the two more extreme temperature settings - 5°C and 35°C – was considerably lower. This reflects reality in many ways as most of the world's cattle live at average temperatures between 15°C and 25°C, meaning these conditions would be the temperatures at which the microorganisms in the cattle's stomachs have adapted to most efficiently co-exist with their cow hosts. This also means that it is highly likely that the majority of methane production from cattle originates in regions of the world where these temperatures are the norm, such as in Australia or Southern Asia. These temperatures are also seen in coastal regions of the US, India, and in Southern Europe, however the terrain in many areas of these areas inhibits cattle grazing due to mountain ranges and valleys and lack of fertile soil. It is likely that a large majority of the methane produced by cows originates from around the equator, as this is where these ambient temperatures are most common. These points also add to the significant validity of the investigation. This investigation, in conjunction with other scientific studies, could be used to ascertain where methane production would be higher depending on the temperatures in different regions of the world.

There were a number of steps included in the investigation to ensure result reliability and accuracy. There were two samples at each of the four temperature settings, meaning the average amount of methane produced at these temperatures was more reliably calculated as it had more than one set of data to support it. Furthermore, the weights of the plastic bags and strings used were all weighed individually and each sample bag and sample string was used for the corresponding sample of manure (i.e. bag 1, string 1 were used for sample 1). The plastic bags and strings did vary in weight and the matching of each set of materials to the corresponding manure sample made the final weighing of the gas more precise and accurate. Despite this the experiment could have been run in multiple trial sets to gather more data and thus increase reliability, as is the case with most scientific investigations; however two samples at each temperature allowed an accurate average to be obtained.

While many measures were taken to ensure result reliability, there were a number of factors that could have been sources of error. The weighing of the plastic bags before and after (in addition to the weight of string) to ascertain the weight of the gas was effective however it would have been more exact had there not been the need to weight each bag and piece of string individually to find the weight of the gas. The weight of the gas produced by each sample could also have been affected by the porosity of the plastic bags or a fault in the sealing of the bags during the investigation and afterwards as gas could have been accidentally released before weighing. The porosity of the plastic bags could have in turn been affected by the heat in the four different temperature environments (i.e. the plastic bags in the warmer temperatures had increased porosity as in heat substances expand while the bags in the cooler temperatures had less porosity as they contracted in the cold). This would mean that the warm samples released gas accidentally through the pores of the plastic bags. While this may have occurred in the 35°C samples as reflected in the low production rate recorded from these samples, it was unlikely this was the case in the 25°C samples as they produced the most methane gas.

There are a number of queries that could be investigated that would contribute significantly to this topic. One question that arises from this investigation is that of the condition of the manure. Does the age of the manure affect how much methane gas is produced? An investigation conducted on manure samples of varying ages from very fresh to weeks old would provide a solution that would add to the investigation of the topic. Another query that could be investigated is that of how the breed and age of the cow affects the methane produced. Although the manure used in this investigation came from the same breed of cow, the ages of the cows probably differed and the age of the cows could impact on the efficiency of the microorganisms in their stomachs when digesting grass and thus producing methane. This is a variable that could be investigated in further detail to ascertain how age and breed would affect the results of this investigation.

This investigation was stimulating and informative and enhanced my knowledge of methane gas, the nature of its production and the nature of bovine waste decomposition at varying temperature.

Conclusion:

In conclusion, it is clear that temperature does affect bovine waste decomposition and the production of methane gas. The results of this investigation, while disproving the hypothesis, establish that there is an optimum temperature at which the methane gas production from bovine waste decomposition is maximised. 25°C was shown to be the temperature at which the samples tested produced the most methane gas, with the other samples of 5°C, 15°C and 35°C producing considerably lower levels of methane gas. This investigation has been one that has produced very interesting results that are relevant to current issues pertaining to methane gas in the world and has allowed me to expand my knowledge on an interesting and unique topic that plays an important role in the agricultural and environmental spheres of the scientific world.