

Greenhouse Gas Emission Benefits of Sodium Bisulfate used in Poultry Litter Treatment

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Abstract

This study evaluated the life cycle greenhouse gas emissions (in units of carbon dioxide-equivalent, CO₂-equivalent) from the production and distribution of sodium bisulfate, used in poultry litter treatment to control ammonia levels. The study also evaluated the comparative life cycle greenhouse gas emissions and benefits from sodium bisulfate application in poultry houses in reducing ventilation energy requirements, both heating fuel and cooling electricity, from reduced ammonia levels. The method involved modeling the production and transportation of raw materials needed per ton (907 kg) of sodium bisulfate, modeling the final product sodium bisulfate, allocating emission results for co-product in the production process, and modeling the usage reduction in propane (for heating) and electricity (for ventilation) in poultry houses from the application of sodium bisulfate during an entire operating year (spring/summer and winter). This was applied to a poultry house that was 1,858 square meters and housed 25,000 birds for the 907 kg of sodium bisulfate required per year. The life cycle greenhouse gas emission was found to be about 318 kg of CO₂-equivalent for the production and distribution of sodium bisulfate per 907 kg. The avoided life cycle greenhouse gas emission from the energy usage reductions in field studies conducted during winter in eastern and south-eastern U.S. kg regions was estimated to be approximately 735 kg of CO₂-equivalent from the use of 907 of sodium bisulfate and approximately 1,410 kg during summer and spring. This equates to a CO₂-equivalent savings of 0.0294 kg per bird in winter and 0.0564 kg per bird in summer and spring. The results show a significant environmental benefit in reducing greenhouse gas emissions and energy conservation from poultry farming with the use of sodium bisulfate.

Keywords: Poultry litter treatment; Sodium bisulfate; Life cycle analysis; Greenhouse gas emissions

Introduction

This study evaluated the life cycle greenhouse gas emissions (in units of carbon dioxide-equivalent, CO₂-equivalent) from the production and distribution of sodium bisulfate, used in poultry litter treatment, including all aspects of raw material extraction, manufacturing, energy use and transportation. CO₂-equivalent refers to the weighted summation of all gaseous emissions responsible for global warming; these include carbon dioxide, methane, nitrous oxide and several fluorinated gases. Sodium bisulfate is widely used in the commercial poultry industry as a top dressing to poultry litter to control ammonia in poultry houses [1]. The application of sodium bisulfate in poultry house operation controlled ammonia levels up to 30 days relative to untreated control [2], multiple applications in two-week intervals reduced ammonia concentration by 22 to 56 percent [3], and cumulative ammonia emission was reduced by 51.7 percent with bi-weekly sodium bisulfate application under field production conditions [4]. Ammonia gas is released from the microbial breakdown of the poultry litter and high ammonia levels cause health problems and performance issues to poultry, including irritation and damages to the eyes and respiratory system [5]. Young chicks in particular cannot maintain body temperature and it is usual practice to heat the air in poultry houses to 95°F (35°C). As ammonia levels rise, the air needs to be periodically ventilated, thereby increasing ventilation energy requirements. Sodium bisulfate controls ammonia

release by converting the ammonia gas to ammonium sulfate, a non-volatile salt. As a direct benefit in poultry house operation, the application of sodium bisulfate could reduce heating fuel and ventilation electricity usage through reduced ammonia levels. Meat production in large and intensive farming systems is one of the major contributors to global environmental impacts [6,7], with as high as 31 percent of the emissions related to manure management [8,9]. Emissions related to manure storage and processing represent a major category of emissions for poultry operations, followed by post-farm emissions and on-farm energy use, predominantly arising from broiler production; various life cycle assessments conducted on poultry farming and meat production in the U.S., Europe, Australia and Brazil indicate greenhouse gas emissions in the range of 2.5 to 5.0 kilograms CO₂-equivalent per kilogram of chicken [10].

The study also evaluated the comparative life cycle greenhouse gas emissions (in CO₂-equivalent) and benefits from sodium bisulfate application in poultry house operation. The scope included a cradle-to-use system boundary, which was broader than just point-of-use considerations, and involved the life cycle approach of considering upstream emissions resulting from the extraction and provisions of raw materials, manufacturing, transportation, energy and fuel use, and operation.

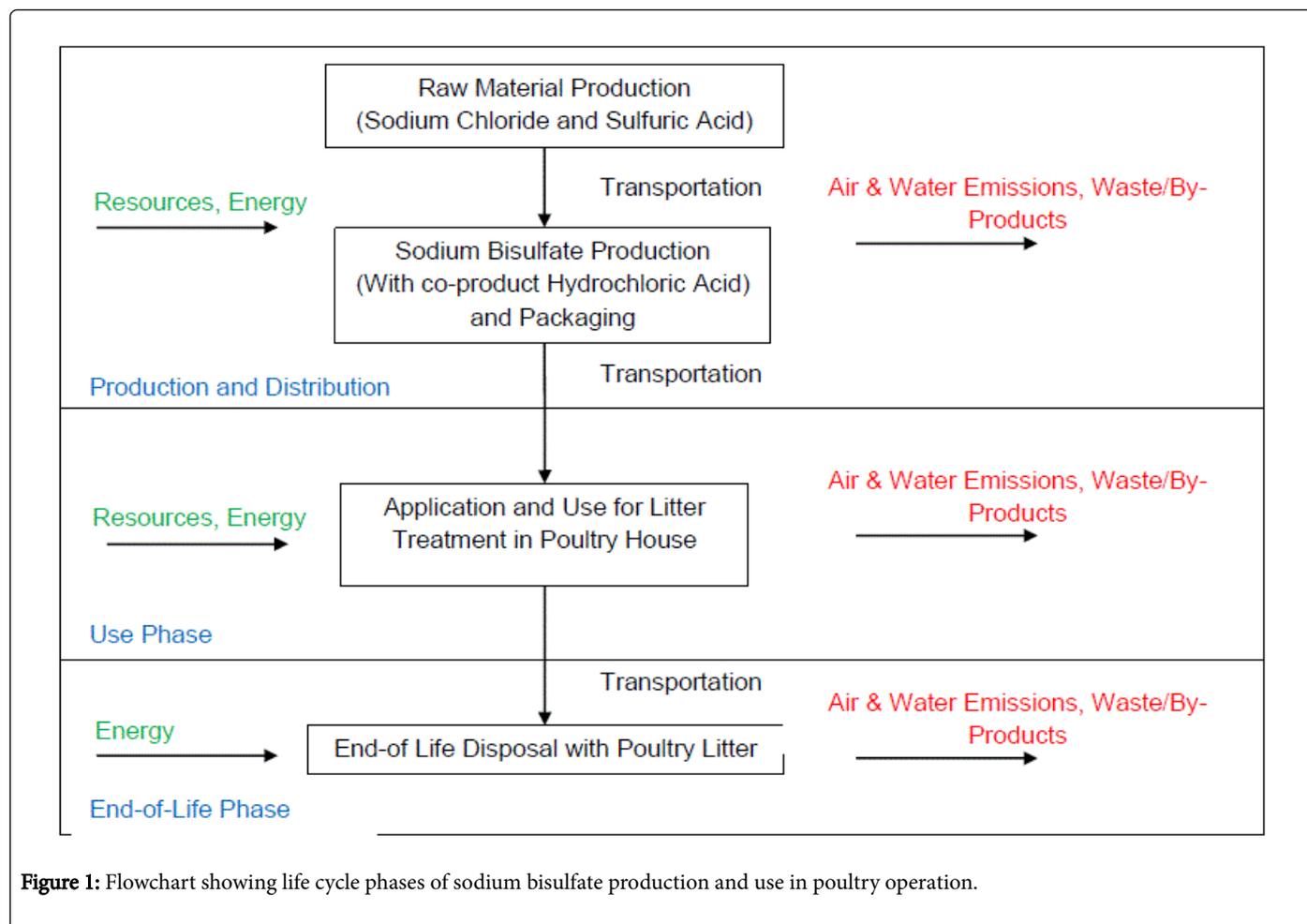
Materials and Methods

The study was conducted following guidelines provided in the ISO 14040 series on life cycle assessment (LCA), and covered the four phases of goal and scope definition; inventory analysis involving the

compilation and quantification of inputs and outputs for products and processes; impact assessment aimed at evaluating the magnitude and significance of potential environmental impacts of products and processes; and interpretation of results. The study utilized the widely used GaBi LCA modeling software (Thinkstep, 2015) [11]; inventory data from the U.S. Life Cycle Inventory (U.S. LCI) Database created by the National Renewable Energy Laboratory (NREL) [12]; the U.S. Environmental Protection Agency (U.S. EPA) TRACI method of impact assessment [13]; LCA data and resources from the U.S. EPA [14]; and emission data and factors from the U.S. Department of Energy - Energy Information Administration (U.S. DOE EIA) [15].

Data was collected via field studies at a commercial poultry house in Northwest Ohio that housed approximately 25,000 chickens in 20,000

square feet (1,858 square meters) over an entire operating year. The data was collected over a one week period for each of the four seasons (spring, summer, fall, and winter). The field studies were conducted by a manufacturer of sodium bisulfate during winter and during summer and spring in eastern and south-eastern U.S. regions, were utilized to analyze the effects of sodium bisulfate on poultry farm's heating and ventilation requirement. Figure 1 shows the life cycle phases of sodium bisulfate production and use in poultry operation; in this study, the life cycle greenhouse gas emissions from the production and distribution phase has been modeled and compared to emission reductions from decreased energy consumption in the use phase of the product.



The functional unit, which provides a basis for equivalence and comparison between alternative systems, was chosen as the operation of a standard-design poultry house, 500 feet (152.4 meters) by 40 feet (12.2 meters), for a 6 week grow-out period in typical eastern and south-eastern U.S. climate regions. Two operational scenarios with and without the application of sodium bisulfate were considered for separate comparative analyses during winter condition and during summer/spring condition. At a standard application rate of 100 pounds (45.4 kilograms) per 1,000 square feet (93 square meters) of floor space, a poultry house requires 1 ton (2,000 pounds or 907 kilograms) of sodium bisulfate for 1,858 square meters and 25,000 birds and the LCA data analysis and results for scenario with sodium

bisulfate application are representative on a per ton basis of the product. This equates to 36.3 grams of sodium bisulfate per bird per year. Results from field studies conducted by a manufacturer of sodium bisulfate on effects of the product on poultry farm's heating and ventilation requirement were utilized for analyzing scenario without the product's application. The entire poultry house operation over the 6-week period that would include animal feed, water, bedding, total heating fuel and electricity use was not modeled in this comparative study; only the additional propane and ventilation electricity in operation without sodium bisulfate was modeled.

The method involved modeling the production and transportation of raw materials sodium chloride and sulfuric acid needed for the

production of 1 ton of sodium bisulfate; modeling the production, packaging and transportation of sodium bisulfate; allocating emission results for co-product hydrochloric acid in the sodium bisulfate production process; and modeling the usage reduction in propane (for heating) and electricity (for ventilation) in poultry house operation from the application of sodium bisulfate. For the production of 1 ton of sodium bisulfate, 0.51 ton (1,020 pounds or 463 kilograms) of sodium chloride and 0.82 ton (1640 pounds or 744 kilograms) of sulfuric acid is needed.

Production of sodium chloride was modeled in GaBi using unit process inventory data from U.S. LCI with input flows of electricity, natural gas, diesel and coal, which in turn were accounted for all their up-stream use of natural resources and energy. Production of sulfuric acid was modeled using aggregate inventory data that included all up-stream resource and energy usage and did not require additional input flows; in the absence of U.S. LCI data, aggregate data from the European Union was used and was co-related to sulfur (raw material for sulfuric acid) production data for the U.S. and several European countries for consistency. Inventory data for both sulfuric acid and sulfur production indicated substantial energy recovery in the production processes; however, results showed positive net greenhouse gas emission from both the sulfur and sulfuric acid production processes. Raw material transportation involved life cycle modeling (using U.S. LCI data) of all of the sodium chloride shipment by rail for 250 miles (402 kilometers), 75 percent of the sulfuric acid shipment by rail for 350 miles (563 kilometers) and 25 percent of the acid shipment by truck for 10 miles (16 kilometers).

Production of 1 ton of sodium bisulfate requires inputs of electricity, natural gas and water; each was modeled separately in GaBi with aggregate inventory data and added together. Packaging was modeled with aggregate data for plastic (high-density polyethylene) resin and poly-bag manufacturing unit process with energy input flows; 1 ton of sodium bisulfate was assumed to be packaged in 40 bags, each with 50 pounds (22.7 kilograms) of the product, and requiring 0.2 pound (0.09 kilogram) of plastic per bag. Finished product transportation was modeled for shipment by truck for 350 miles (563 kilometers). Production of sodium bisulfate generates hydrochloric acid as a co-product; total production records showed that sodium bisulfate and hydrochloric acid were produced in the ratio of 53 percent to 47 percent by weight.

The greenhouse gas emissions from raw material production, raw material transport and sodium bisulfate production are attributable to both sodium bisulfate and hydrochloric acid, and co-product allocation on a weight basis was done accordingly. Field studies conducted by the sodium bisulfate manufacturer indicated that application of 1 ton of sodium bisulfate in a poultry house during a 6 week grow-out period in winter months resulted in an average reduction of 625 U.S. gallons (2366 liters) of propane as heating fuel and 4,355 kilowatt-hour of electricity in ventilation requirement, and 200 U.S. gallons (757 liters) of propane during summer/spring months (electricity was not monitored in summer/spring study and would have shown a corresponding reduction); this reduction is related to sodium bisulfate ability to reduce ammonia levels significantly in comparison to poultry house operation without the product application. Avoided life cycle greenhouse gas emission for the propane production and electricity generation were modeled in GaBi using U.S. LCI aggregate inventory data, and that for propane combustion in on-farm heating equipment was modeled using emission factors from U.S. DOE EIA.

Results and Discussion

Results

The life cycle greenhouse gas emission was found to be about 700 pounds (318 kilograms) of CO₂-equivalent per ton (2,000 pounds or 907 kilograms) for the production and distribution of sodium bisulfate.

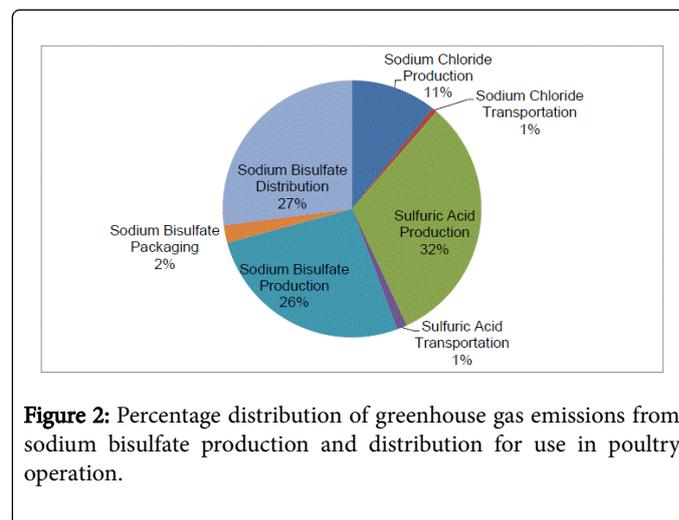


Figure 2: Percentage distribution of greenhouse gas emissions from sodium bisulfate production and distribution for use in poultry operation.

The avoided life cycle greenhouse gas emission from the energy usage reductions in field studies conducted during winter in eastern and south-eastern U.S. regions was estimated to be about 16,200 pounds (7358 kilograms) of CO₂-equivalent from the use of 1 ton of sodium bisulfate. The avoided life cycle greenhouse gas emission from the propane usage reduction in field study conducted during summer and spring was estimated to be about 3,100 pounds (1,414 kilograms) of CO₂-equivalent from the use of 1 ton of sodium bisulfate.

Tables 1 and 2 list the greenhouse gas emission in kilograms of CO₂-equivalent for poultry house operation in winter condition and summer/spring condition respectively, with and without the application of sodium bisulfate on a per ton basis of the product. Figure 2 shows the percentage distribution of greenhouse gas emissions from sodium bisulfate production and distribution for use in poultry operation.

Description	Poultry Operation with Sodium Bisulfate Application	House with Sodium Bisulfate Application	Poultry Operation without Sodium Bisulfate Application	House without Sodium Bisulfate Application	Unit
Sodium Chloride Production	34				kilogram CO ₂ -equivalent
Sodium Chloride Transportation	2				kilogram CO ₂ -equivalent
Sulfuric Acid Production	101				kilogram CO ₂ -equivalent
Sulfuric Acid Transportation	4				kilogram CO ₂ -equivalent
Sodium Bisulfate Production	84				kilogram CO ₂ -equivalent

Sodium Bisulfate Packaging	7		kilogram CO ₂ -equivalent
Sodium Bisulfate Distribution	86		kilogram CO ₂ -equivalent
Additional Propane Usage ¹		4,418	kilogram CO ₂ -equivalent
Additional Electricity Usage ¹		2,940	kilogram CO ₂ -equivalent
Total	318	7,358	kilogram CO ₂ -equivalent

¹This represents only the additional propane and electricity usage in poultry house during winter without the application of sodium bisulfate and reflects the life cycle greenhouse gas emission advantage of the product; total propane and electricity usage over the entire 6 week grow-out period was not modeled in this comparative analysis.

Table 1: Comparison of greenhouse gas emissions for 1 ton (2,000 pounds or 907 kilograms) sodium bisulfate - winter operation.

Description	Poultry House Operation with Sodium Bisulfate Application	Poultry House Operation without Sodium Bisulfate Application	Unit
Sodium Chloride Production	34		kilogram CO ₂ -equivalent
Sodium Chloride Transportation	2		kilogram CO ₂ -equivalent
Sulfuric Acid Production	101		kilogram CO ₂ -equivalent
Sulfuric Acid Transportation	4		kilogram CO ₂ -equivalent
Sodium Bisulfate Production	84		kilogram CO ₂ -equivalent
Sodium Bisulfate Packaging	7		kilogram CO ₂ -equivalent
Sodium Bisulfate Distribution	86		kilogram CO ₂ -equivalent
Additional Propane Usage ¹		1,414	kilogram CO ₂ -equivalent
Total	318	1,414	kilogram CO ₂ -equivalent

¹This represents only the additional propane usage in poultry house during summer/spring without the application of sodium bisulfate (summer/spring study did not monitor ventilation electricity usage and would have shown a corresponding reduction with sodium bisulfate use) and reflects the life cycle greenhouse gas emission advantage of the product; total propane usage over the entire 6 week grow-out period was not modeled in this comparative analysis.

Table 2: Comparison of greenhouse gas emission for 1 ton (2,000 pounds or 907 kilograms) sodium bisulfate - summer/spring operation.

Discussion

The results show an enormous environmental benefit in reducing greenhouse gas emissions and energy conservation from poultry farming with the use of sodium bisulfate. Further, the field studies

conducted by the manufacturer of sodium bisulfate have recorded significant bird weight improvement in poultry house operation with the use of sodium bisulfate; the winter study showed an average weight increase of 3,600 pounds (1,633 kilograms) per house. While weight increase would have associated increase in feed requirement, a portion of weight improvement could be attributed to improved bird performance and feed conversion through the use of sodium bisulfate. Additionally, the field studies have also recorded the reuse of poultry litter through the beneficial effect of sodium bisulfate in lowering litter pH. Avoided greenhouse gas emission from litter reuse has not been quantified in this study.

Production of raw materials for manufacturing sodium bisulfate (sodium chloride and sulfuric acid) contribute to 43 percent of the greenhouse gas emissions, while the sodium bisulfate production process itself contributes to 26 percent. Transportation of the two raw materials to the production facility, majorly by rail over 250 to 350 miles (402 to 563 kilometers), contributes to only 2 percent of the greenhouse gas emissions in comparison to 27 percent from the distribution of sodium bisulfate by truck over 350 miles (563 kilometers). Modeling results for the two modes of transportation show greenhouse gas emissions of 0.033 kilogram CO₂-equivalent per ton-mile (1 ton-mile=1.46 tonne-kilometer) for rail, while that for truck transportation is almost seven and a half times at 0.245 kilogram CO₂-equivalent per ton-mile.

Conclusions and Applications

LCA results indicate that 1 ton (907 kg) of sodium bisulfate application in a single poultry house operation for a 6 week grow-out period has the benefit of reducing life cycle greenhouse gas emissions by about 16,200 pounds (7,350 kg) of CO₂-equivalent during winter operation and by about 3,100 pounds (1,410 kg) during summer/spring operation through reduced heating fuel and ventilation electricity usage, while the production and distribution sodium bisulfate per ton only generates about 700 pounds (320 kg) of CO₂-equivalent life cycle greenhouse gas emissions. This equates to a CO₂-equivalent savings of 0.0294 kg per bird in winter and 0.0564 kg per bird in summer and spring as the study examined a poultry house that housed 25,000 birds. The Apart from ammonia control, the use of sodium bisulfate shows a significant advantage in reducing life cycle greenhouse gas emissions from poultry farming and contributes in reducing the total carbon footprint of poultry production.

Acknowledgement

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