A Study on Estimation of Methane Gas Emission by Enteric Fermentation from Goat in Bangladesh

A production report submitted in partial satisfaction of the requirement for the Degree of Doctor of Veterinary Medicine (DVM)

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Session: 2016-17

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Abstract

In Bangladesh, the goat is popular livestock among rural people with low income and also among some commercial farmers due to its high prolificacy and high profitability. Nowadays many farmers making commercial goat farms due to the increased demand and higher profitability. As a result, the goat population of the country is also increasing gradually every year. Due to this increasing population of goats and other livestock the emission of greenhouse gases is also on a rise. In our study, we have discussed about the methane emission from the total goat population of Bangladesh. We followed Intergovernmental Panel on Climate Change (IPCC) guidelines in our study. We used the Tier-2 method for the calculation of total methane emission from goats. We developed emission factors for Black Bengal and Jamunapari goat separately using their average body weight and gross energy (GE) intake following the IPCC (2019) guidelines. After calculation using the different emission factors for Black Bengal and Jamunapari goats, in 2016-17, 2017-18, 2018-19, 2019-20, and 2020-21 the total emission of methane from the goat population of Bangladesh is 60.112, 60.509, 60.891, 61.281and 61.673 Gigagrams/year respectively using Tier-2 method and 129.650, 130.500, 131.350, 132.150 and 133.000 Gigagrams/year respectively using Tier-1 method; the emission from Black Bengal goat was 52.297, 52.638, 52.975, 53.314 and 53.654 Gigagrams/year respectively using Tier-2 method and 116.700, 117.450, 118.200, 118.950 and 119.700 Gigagrams/year using Tier-1 method respectively; the emission from Jamunapari goat was 7.815, 7.866, 7.916, 7.967, and 8.018 Gigagrams/year using Tier-2 method and 12.950, 13.050, 13.150, 13.200 and 13.300 Gigagrams/year using Tier-1 method respectively.

Key words : Goat, Livestock, Methane emission, Black Bengal, Jamunapari, Gigagrams, Tier-1, Tier-2.

Introduction

Livestock is an integral part of agriculture and is likely to be one of the most important instruments for the economic growth and development of Bangladesh (Hoque et al.,2017). The agriculture sector is the second largest contributor of anthropogenic greenhouse gas emissions after the energy sector (Patra,2012). Livestock contributes about 18% to the global anthropogenic greenhouse gas emissions accounting for 39% of anthropogenic methane (FAO,2020).

Goats are a major means of employment and income for women, children, and aged people in the tropical and subtropical regions (Bezabih and Berhane,2014). Morphologically versatile goat species with unique browsing potential adapt to a changing climate more readily and they continue to be an important source of income and nutrition to many poor and marginal farmers (Feleke et al.,2016). The goat population of Bangladesh is increasing every year. The goat population of Bangladesh in the last five years are 25.93 millions (2016-17), 26.10 millions (2017-18), 26.27 millions (2018-19), 26.44 millions (2019-20), 26.60 millions (2020-21) (DLS,2021).

With the increasing population of livestock, methane emission is also increasing gradually. In this study, we will show the methane emission from the total goat population in Bangladesh perspective.

Objectives: Here we will calculate the total methane emission from goats by enteric fermentation using the Tier-2 formula provided by the IPCC 2019 guidelines for national greenhouse gas inventories and we will show the rising levels of methane emission by enteric fermentation with the increasing population of goats. The study was performed for the following objectives:

1. To estimate the total methane emission from the goat population of Bangladesh per year.
2. To assess the increase in greenhouse gas emission every year due to increasing livestock population.
3. To compare between the Tier-1 and Tier-2 method of estimation of methane emission.

Review of Literature

IPCC (2019) provided three different methods of estimation of greenhouse gas (methane) emission from livestock by enteric fermentation of feed. Among the three methods, Tier-1 is the most simple method for estimation of methane emission from livestock but the other methods are also used according to the purpose of estimation and for country-specific estimation of methane emission. In the Tier-1 method, the emission factors for different categories and subcategories of livestock are provided by IPCC (2019) guidelines based on the area, production system, common feeding system, average body weight of each category of livestock, etc. To calculate the total emission from livestock the emission factor for a specific category or subcategory is multiplied by the total population of that livestock category or subcategory.

In the Tier-2 method, the emission factor for each livestock category and subcategory should be developed based on the average body weight, gross energy (GE) intake, or based on dry matter intake. Then the calculated factor of emission is multiplied by the population to obtain the total emission.

In the Tier-3 method, country-specific estimation systems are used. This method is more accurate as it provides estimates of methane emissions for a specific country.

According to Das et al.(2020), the greenhouse gas emission from livestock in Bangladesh was estimated. In this study, the Tier-1 method was used for the estimation of methane from livestock by enteric fermentation. The methane emission was converted to CO2 equivalent after calculation.

According to Hoque et al.(2017), total methane emissions from enteric fermentation of ruminant livestock were estimated. In this study, the Tier-2 method was used. The emission factor for the livestock categories was calculated based on dry matter intake.

In our study the average body weight of Black Bengal and Jamunapari goats in Bangladesh at birth, weaning, and sexual maturity was obtained from the study by Khan and Naznin (2013). The percentage of Black Bengal and Jamunapari goats in the total goat population was also obtained from this study.The data on the total goat population of Bangladesh was obtained from the "Annual report on Livestock 2021" by the Department of Livestock Services (DLS), Bangladesh (DLS,2021).

Materials and Methods

Based on IPCC (2019) guidelines, there are three methods (Tier-1, Tier-2, and Tier-3) for the estimation of methane produced by enteric fermentation (IPCC,2019). Here we will describe the Tier 1 and Tier 2 method of estimation of methane emission by enteric fermentation from goats and will show our calculation based on this method.

Tier-1 method :

This is more simplified method compared to Tier 2 method. Here total goat population will be subdivided into two categories (Black Bengal and Jamunapari) , then the population of each category will be multiplied by the IPCC (2019) provided emission factor and divided by 10^6. The sum total of methane emission from each category is the total methane emission from goat.

The formula for emissions from a livestock category according to Tier 1 method as provided by IPCC (2019) guidelines is :

$$E_T = \sum_{(p)} EF_{(T,P)} \times \left(\frac{N_{(T,P)}}{10^6}\right)$$

Where:

E_T = methane emissions from Enteric Fermentation in animal category T, Gg CH_4 yr^{-1}.

$EF_{(T,P)}$ = emission factor for the defined livestock population T and the productivity system P, in kg CH_4 $head^{-1}$ yr^{-1}.

N(T,P) = the number of head of livestock species / category T in the country classified as productivity system P.

T = species/category of livestock.

P = productivity system, either high or low productivity.

Formula for total emission from livestock enteric fermentation is :

$$Total\ CH_4\ enteric = \sum E\ ip$$

Here:

E i,p = is the emission from i^{th} livestock category and subcategories based on production system (P).

Tier-2 method :

In the case of the Tier-2 system, we need to calculate specific emission factors for each category of goat. There are three steps of the Tier-2 method (IPCC,2019).

- **Step-1:** Specific goat populations with subcategories should be collected e.g., Black Bengal goat, Jamunapari goat.
- **Step-2:** Calculation of emission factor. The emission factor should be calculated based on 'Gross Energy' (GE) (IPCC,2019). Animal performance and diet data are used to estimate feed intake which is the amount of energy (MJ/day) animal needs for maintenance and for such as growth, lactation, and pregnancy. The equations used to calculate GE are as follows:

➢ **Net energy for maintenance** (NEm) is the net energy required for maintenance, which is the amount of energy needed to keep the animal in equilibrium where body energy is neither gained nor lost.

$$NE_m = Cfi \bullet (Weight)^{0.75}$$

Where:

NE_m = net energy required by the animal for maintenance, MJ day^{-1}.

Cfi = a coefficient that varies for each animal category (Coefficients for calculating NE_m), MJ $day^{-1}kg^{-1}$

Weight = live-weight of animal, kg .Coefficient for calculating net energy for maintenance

(NE_m) for goat is ; Cfi = 0.315 $MJd^{-1}kg^{-1}$ (IPCC,2019).

- **Net energy for activity** (NE_a) is the net energy for activity, or the energy needed for animals to obtain their food, water, and shelter.

$$NE_a = C_a \bullet (\text{Weight})$$

Where:

NE_a = net energy for animal activity, MJ day^{-1}.

C_a = coefficient corresponding to animal's feeding situation, MJ day^{-1} kg^{-1}.

Weight= live-weight of animal, kg.The coefficient corresponding to animal's feeding situation (C_a) for lowland goats where animals walk and graze lowland pasture is;C_a= 0.019MJ$day^{-1}kg^{-1}$ (IPCC,2019).

- **Net energy for growth** (NE_g) is the net energy needed for growth (i.e., weight gain) for goats is:

$$NE_g = \frac{WG_{kid} .(a+0.5b(BW_i + BW_f))}{365}$$

Where:

NE_g = net energy needed for growth, MJ day^{-1}.

WG_{kid}= the weight gain (BWf – BWi), kg yr^{-1} .

BW_i = the live bodyweight at weaning, kg .

BW_f = the live bodyweight at 1-year old or at slaughter (live-weight) if slaughtered prior to 1 year of age, kg .

a, b = constants.

The live body weight at weaning of Black Bengal goat is 5.35 kg and of Jamunapari goat is 6.69 kg. And the live body weight of a mature Black Bengal goat is 9.53 kg and of a mature Jamunapari goat is 13.65 kg (Khan and Naznin,2013).

The constants for use in calculating NE_g for goats are; a = 5.0 $MJKg^{-1}$ and b = 0.33 $MJKg^{-1}$ (IPCC,2019).

- **Net energy for lactation** (NE_l) is the net energy for lactation. The net energy for lactation if the milk production is unknown is calculated as;

$$NE_l = \left[\frac{(5 \cdot WG_{wean})}{365}\right] * EV_{milk}$$

Where:

NE_l = net energy for lactation, MJ day^{-1}.

WG_{wean} = the weight gain of the kid between birth and weaning, kg.

EV_{milk} = the energy required to produce 1 kg of milk, MJ kg^{-1}. A default EV_{milk} value of 3 MJ/kg can be used which corresponds to a milk fat content of 3.8 percent by weight for goats (IPCC,2019).

The average weight gain of kids of Black Bengal and Jamunapari breeds between birth and weaning is 4.157 kg and 5.225 kg respectively (Khan and Naznin,2013).

- **Net energy for pregnancy** (NE_p) is the energy required for pregnancy. . For goats, the NE_p requirement is estimated for the 147-day gestation period, although the percentage varies with the number of kids born.

$$NE_p = C_{pregnancy} \cdot NE_m$$

Where:

NE_p = net energy required for pregnancy, MJ day^{-1}.

$C_{pregnancy}$ = pregnancy coefficient.

NE_m = net energy required by the animal for maintenance, MJ day^{-1}.

The pregnancy coefficient for double birth (twins) in goats is; $C_{pregnancy}$ = 0.126 (IPCC,2019).

- **The ratio of net energy available in the diet for maintenance to digestible energy consumed (REM):** For sheep and goats, the ratio of net energy available in a diet for maintenance to digestible energy (REM) is estimated using the following equation:

$$REM = [\ 1.123 - (4.092*10^{-3}*DE) + (1.126*10^{-5}*(DE)^2) - (25.4/DE)\ ]$$

Where:

REM = ratio of net energy available in the diet for maintenance to digestible energy.

DE = digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy).

- **The ratio of net energy available for growth in a diet to digestible energy consumed (REG):** For sheep and goats the ratio of net energy available for growth (including wool growth) in a diet to digestible energy consumed (REG) is estimated using the following equation:

$$REG = [\ 1.164 - (5.16*10^{-3}*DE) + (1.308*10^{-5}*(DE)^2) - (37.4/DE)\ ]$$

Where:

REG = ratio of net energy available for growth in a diet to digestible energy consumed.

DE = digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy).

The digestibility of feed in growing dairy goats is 0.7246 (DE/GE) or 72.46% (Souza et al.,2020).

➢ **Gross energy (GE):** GE requirement is derived based on the summed net energy

$$GE = \left[\frac{\left(\frac{NEm + NEa + NEl + Nep}{REM} \right) + \left(\frac{NEg + NEwool}{REG} \right)}{DE} \right]$$

requirements and the energy availability characteristics of the feed(s).

Where:

GE = gross energy, MJ day^{-1}.

NE_m = net energy required by the animal for maintenance, MJ day^{-1}.

NE_a = net energy for animal activity, MJ day^{-1}.

NE_l = net energy for lactation, MJ day^{-1}.

NE_{work} = net energy for work, MJ day^{-1}.

NE_p = net energy required for pregnancy, MJ day^{-1}.

REM = ratio of net energy available in a diet for maintenance to digestible energy.

NE_g = net energy needed for growth, MJ day^{-1}.

REG = ratio of net energy available for growth in a diet to digestible energy consumed.

NE_{wool} = net energy required to produce a year of wool, MJ day^{-1}.

DE = digestibility of feed expressed as a fraction of gross energy (digestible energy/gross energy).

➢ **Emission Factor Development:**

Based on the gross energy intake equation of emission factor will be:

$$EF = \left[\frac{GE * (Y_m/100) * 365}{55.65} \right]$$

Where,

EF= emission factor, kg CH_4 $head^{-1}$ $year^{-1}$.

GE= gross energy intake, MJ $head^{-1}day^{-1}$.

Y_m= methane conversion factor; percent of gross energy in feed converted to methane.

The factor 55.65 (MJ/kg CH4) is the energy content of methane.

The methane conversion factor (Y_m) for goats is 5.5% (IPCC,2019).

- **Step-3:** Total emissions calculation

The methane emissions from each livestock category are calculated using the following formula;

$$Emissions = EF_T * (N_T/10^6)$$

Where,

EF_T = emission factor for each livestock category.

N_T = number of population in each livestock category.

Emission of Methane

Based on Tier-1 method

Step-1 : (Categorization of Total Goat Population)

The categories of goat population are shown in table-1. The Black Bengal goat is 90% and the Jamunapari goat is 10% of the total goat population (Khan and Naznin,2013).

Table-1: Total goat and Black Bengal and Jamunapari goat population of BD (DLS,2021).

Year	Total Goat (millions)	Black Bengal (millions)	Jamunapari (millions)
2016-2017	25.93	23.34	2.59
2017-2018	26.10	23.49	2.61
2018-2019	26.27	23.64	2.63
2019-2020	26.44	23.79	2.64
2020-2021	26.60	23.94	2.66

We will calculate the methane emissions from Black Bengal and Jamunapari goats separately from their total population and add the emissions to get the total picture.

Step-2 : (Emission Factor collection from IPCC guidelines)

Emission factors are provided by IPCC (2019) guidelines for Tier-1. We will calculate using the emission factor for low productive goat aacording to body weight (Khan and Naznin, 2013).

Table-2: Enteric fermentation emission factors for Tier-1 method (Kg CH_4 $Head^{-1}$ Yr^{-1}) (IPCC,2019)

Livestock	High productivity systems	Low productivity systems	Liveweight
Goats	9	5	50 kg – high productive system 28 kg – low productive system

Step-3 : (Total Emission Calculation)

Total emission will be calculated by multiplying the number of goats with the emission factor.

Based on the Tier-2 system

Step-1 : (Categorization of Total Goat Population)

The total goat population is categorized based on the data obtained from DLS (2021) and Khan and Naznin (2013) as shown in table-1.

We will calculate the methane emissions from Black Bengal and Jamunapari goats separately from their total population and add the emissions to get the total picture.

Step-2 : (Emission Factor Development)

Emission factor is developed separately for Black Bengal and Jamunapari goats based on the gross energy (GE) intake and their average mature body weight (Khan and Naznin,2013).

Table-3: Emission Factor (kg CH_4 $Head^{-1}$ $Year^{-1}$) for Black Bengal and Jamunapari goat.

Breed	**Avg. Mature BW (Kg)**	**Emission Factor (Kg CH_4 $Head^{-1}$ $Year^{-1}$)**
Black Bengal	9.53	2.24
Jamunapari	13.65	3.014

Step-3 : (Total Emission Calculation)

Total emission will be calculated by multiplying the number of goats with the emission factor.

Results

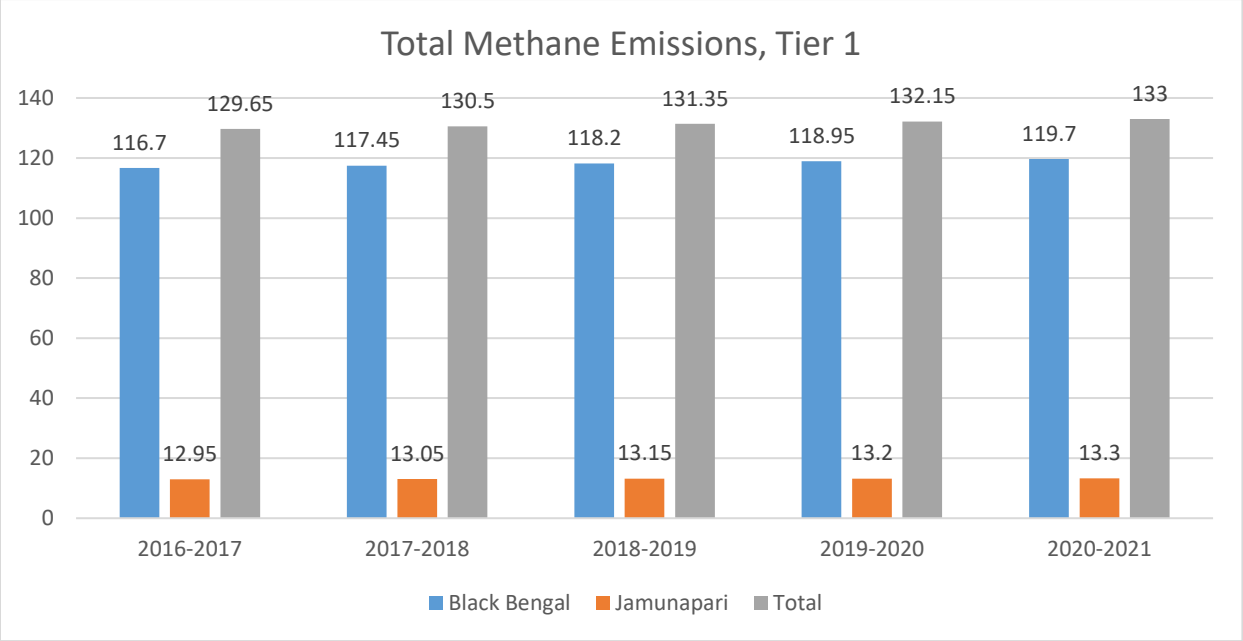
Emissions based on Tier-1 method

The total emissions from enteric fermentation based on the Tier-1 method is shown here. Table-4 and figure-1 show the annual methane emissions from the Black Bengal and Jamunapari goat populations and the total goat population of Bangladesh according to year.

Table-4: Methane emission (Gigagrams per year) based on emission factor provided for Tier-1 method of IPCC (2019) guidelines for low productive goats.

Year	Emissions fromBlack Bengal	Emissions from Jamunapari	Total
2016-2017	116.70	12.95	129.65
2017-2018	117.45	13.05	130.50
2018-2019	118.20	13.15	131.35
2019-2020	118.95	13.20	132.15
2020-2021	119.70	13.30	133.00

Figure-1: Methane emission (Gigagrams per year) from the total goat population of Bangladesh baswd on Tier-1 method.



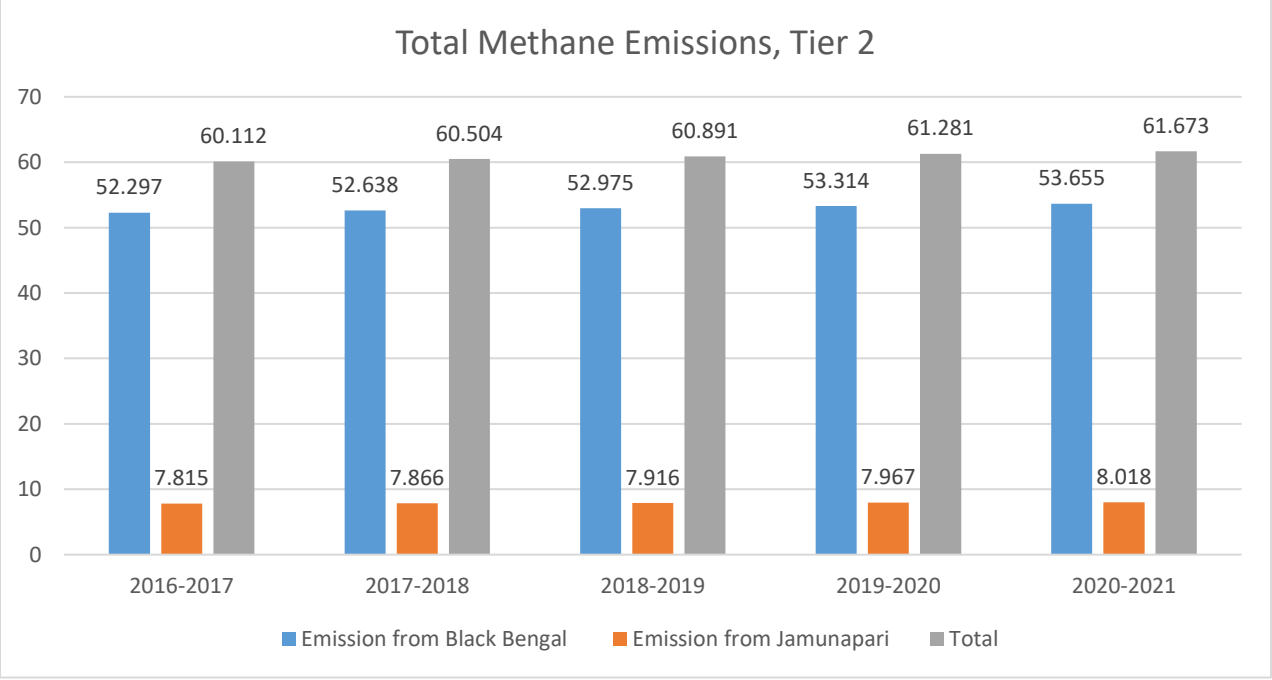
Emissions based on Tier-2 method

The total emissions from enteric fermentation based on the Tier-2 method is shown here. Table-5 and figure-2 show the annual methane emissions from the Black Bengal and Jamunapari goat populations and the total goat population of Bangladesh according to year.

Table-5: Methane emission (Gigagrams per year) based on emission factor developed from Tier-2 method of IPCC (2019) guidelines.

Year	Emission from Black Bengal	Emission from Jamunapari	Total
2016-2017	52.297	7.815	60.112
2017-2018	52.638	7.866	60.504
2018-2019	52.975	7.916	60.891
2019-2020	53.314	7.967	61.281
2020-2021	53.655	8.018	61.673

Figure-2: Methane emission (Gigagrams per year) from the total goat population of Bangladesh based on Tier-2 method.



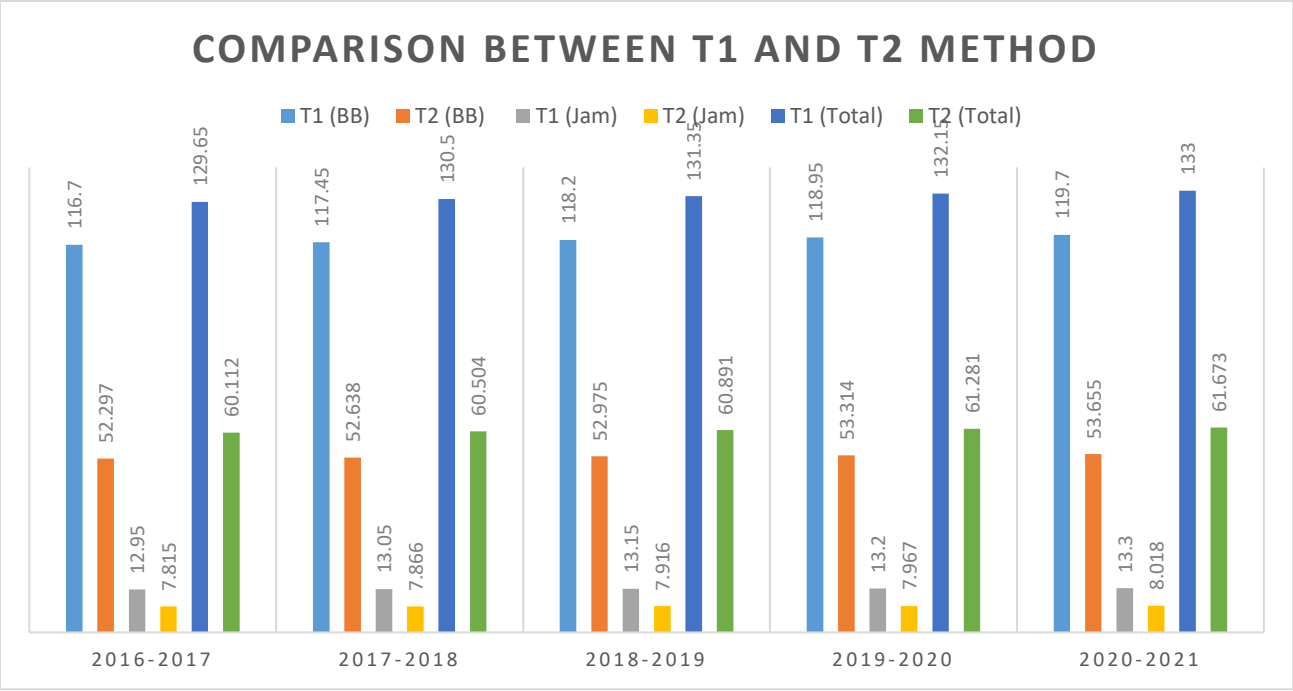
Comparison between Tier 1 and Tier 2 method

Here we will show the comparison between the total methane emissions based on the estimation of methane emission using Tier-1 and Tier-2 method. In Tier-1 method the IPCC(2019) provided emission factor was used. In Tier-2 method emission factor was calculated for each species of goat based on their mature body weight and gross energy (GE) intake.

Table-6: Comparison between Methane emission (Gigagrams per year) based on methane emission calculated using Tier-1 and Tier-2 method of IPCC (2019) guidelines.

Year	T1 (BB)	T2 (BB)	T1 (Jam)	T2 (Jam)	T1 (Total)	T2 (Total)
2016-2017	116.700	52.297	12.950	7.815	129.650	60.112
2017-2018	117.450	52.638	13.050	7.866	130.500	60.504
2018-2019	118.200	52.975	13.150	7.916	131.350	60.891
2019-2020	118.950	53.314	13.200	7.967	132.150	61.281
2020-2021	119.700	53.655	13.300	8.018	133.000	61.673

Figure-3: Methane emission (Gigagrams per year) from the total goat population of Bangladesh based on Tier-1 and Tier-2 method.



Discussion

In the study it was found that, the calculated emission factor for the Black Bengal and Jamunapari goat breeds are 2.24 and 3.014 kg $head^{-1}$ $year^{-1}$ based on the Tier-2 method of IPCC (2019). The emission factors are lower than the emission factor provided by the IPCC (2019) guidelines of Tier-1 method of methane emission estimation where the emission factor for goats in low productivity system i.e. live weight is less than 28kg, is 5 kg $head^{-1}$ $year^{-1}$ (IPCC,2019).

The difference in the emission factor for Black Bengal and Jamunapari breeds is probably due to their difference in birth weight, weaning weight, and the mature body weight which is higher in Jamunapari goats than in Black Bengal goats.

In the years 2016-17, 2017-18, 2018-19, 2019-20, and 2020-21 the total methane emissions from goats were 60.112, 60.504, 60.891, 61.281, and 61.673 Gigagrams/year respectively calculated by Tier-2 method; but when calculated using the emission factor provided by the IPCC (2019) guidelines for Tier-1 method, the total emissions were more than double of the total emission found using Tier-2 method which are 129.650, 130.500, 131.350, 132.150 and 133.000 Gigagrams/year respectively. The total methane emissions from goats are rising gradually with the gradual increase in the goat population.

In the years 2016-17, 2017-18, 2018-19, 2019-20 and 2020-2021; the methane emission from Black Bengal goats were 52.297, 52.638, 52.975, 53.314, and 53.654 Gigagrams/year using Tier-2 method and 116.700, 117.450, 118.200, 118.950 and 119.700 Gigagrams/year using Tier-1 method; and from Jamunapari goats were 7.815, 7.866, 7.916, 7.967, and 8.018 Gigagrams/year using Tier-2 method and 12.950, 13.050, 13.150, 13.200 and 13.300 Gigagrams/year using Tier-1 method respectively.

Conclusion

In Bangladesh, the livestock population is gradually increasing every year and the goat population has also increased in the past years. With the gradual increase in livestock population, greenhouse gas emissions are also rising. As a result, the effects of greenhouse gas and climate change are seen on a major scale. Necessary actions should be taken to reduce the emissions from the livestock sector and new methodologies should be applied to collect the greenhouse gases which are emitted from the livestock and agriculture sector and used constructively.

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Acknowledgments

I'm most grateful to Almighty Allah. I am very grateful to my honorable supervisor Professor **Dr. Md. Ashraf Ali Biswas** sir, Department of Animal Science and Nutrition, Chattogram Veterinary and Animal Sciences University (CVASU), Chattogram for his guidance and encouragement to complete the report.

I am also grateful to Professor **Dr. Goutam Buddha Das** (Vice-Chancellor, CVASU) and Professor **Dr. Mohammad Alamgir Hossain** (Dean, Faculty of Veterinary Medicine), Professor **Dr. AKM Saifuddin** (Director, External Affairs) of CVASU.

Biography

I am Md. Rabbi Rahul an intern student of the Faculty of Veterinary Medicine at Chattogram Veterinary and Animal Sciences University from Borguna (Upazilla: Patharghata). I completed my Secondary School Certificate (SSC) and Higher Secondary Certificate (HSC) in 2014 and 2016 respectively from Chattogram. As a future veterinarian after completing my DVM degree, I would like to be a researcher and pursue higher studies in the field of public health and one health and contribute to the world with my knowledge and skills.