# A Review: Utilization of Seaweed in Reducing Methane for Ruminants

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## ABSTRACT

*Ruminants contribute to the production of methane gas as a result of the feed fermentation by methanogenic bacteria in the rumen. Methane (CH4) is one of the reason that cause greenhouse gas effect and has a 25x greater effect than CO2 in catching heat that causes global warming. Methane gas production in ruminants can be reduced through animal feed supplementation, includes the addition of ionophores, legumes, essential oils, chemical compounds, fats, probiotics, and secondary metabolites in plants (halogenated, pholrotannin, tannin, saponin, iodine). Seaweed is one commodity that has the potential as a feed additive in reducing ruminant methane. Seaweed is a fishery commodity that has great potential to be developed in Indonesia because Indonesia is an archipelagic country. In 2018 the production of wet seaweed in Indonesia reached 10.32 million tons. Seaweed can be used as a feed additive which has the ability to reduce the production of methane gas in ruminants. Seaweed contains protein, carbohydrates, fats, vitamins, minerals, oils, and amino acids also several secondary compounds (phlorotannin, iodine, and halogenated compounds). Some of these compounds has been proved to be able to reduce the production of methane gas in ruminants because of its anti-methanogenic properties. Bromoform content in seaweed has also been shown to be effective in inhibiting the emission of methane gas from the digestive tract due to its ability to interfere with the methanogenesis process. Utilization of seaweed in reducing methane can be used as additional feed for ruminants.*

***Keywords:*** *Methane gas, ruminants, seaweed.*

## INTRODUCTION

Greenhouse gases (GHG) are one of the global climate change causes as a result of rising temperatures on the earth's surface. Greenhouse gases (GHG) are defined as a collection of gases resulting from global warming that are released into the atmosphere and form the greenhouse effect. These gases such as $CO_2$, $N_2O$, CFC, $HFC_s$, SF6, and $CH_4$ are radioactive gases and cause global warming also the main factors causing climate change (1). Global warming is caused by various activities such as industry, residue from burning fossil fuels, to agricultural activities. Livestock is one of the agricultural sub-sectors that contribute to greenhouse gas emissions, especially $CH_4$ and $N_2O$. The global livestock sub-sector accounts for 28% of the total methane emissions of other agricultural sectors (2). $CH_4$ or methane gas is one of the greenhouse gases that has 28 times stronger effect than carbon dioxide ($CO_2$) for 100 years and 80 times stronger for 10-20 years since it was released into the atmosphere (3). Methane gas emissions from livestock activities mainly come from ruminants such as cattle, goats, sheep and buffalo.

Ruminant livestock is the largest emitter of methane gas compared to non-ruminant livestock. The methane gas emission comes from enteric fermentation and manure. Rojas et al. (2017) reported that 39.1% of emissions came from enteric fermentation and 4.3% came from manure management (4). Beef cattle produce methane gas emissions of 47 kg/head/year while dairy cattle are 61 kg/head/year (5). BPS shows that the population of beef cattle in Indonesia reaches 18.05 million heads while dairy cattle are 578 thousand heads, there will be at least 848 million kg/year of methane emissions produced from beef cattle and 35 million kg/year of emissions is produced from dairy cattle (6). Methane gas emissions produced by livestock not only harm the environment but also harm livestock because some of the feed energy consumed is lost as methane. Hidayah (2016) reported that there are two important reasons why ruminant methane reduction is important. First, it will reduce the amount of methane gas in the atmosphere thereby reducing the effect of greenhouse gases (7). Second, increasing livestock productivity due to the achievement of feed efficiency because the energy produced is not wasted into methane gas.

Efforts to reduce methane gas production in ruminants can be done by utilizing feed additives through feed supplementation. Several compounds that have been shown to be able to reduce or inhibit methane gas emissions include ionophores, legumes, essential oils, chemical compounds, fats, probiotics, and plants secondary metabolites (halogenated, phlorotannin, tannin, saponin, iodine) (8,9). One commodity that has the potential to be used as a feed additive is seaweed. Seaweed is Indonesia's leading export commodity. KKP reported that the production of wet seaweed in Indonesia in 2018 reached 10.32 million tons. Meanwhile, the export value of seaweed in 2020 reached 177 thousand tons (6,10). Types of seaweed that are widely cultivated in Indonesia are *Euchaeuma cottonii*, *Gracilaria* sp, *Euchaeuma spinosum*, and *Caulerpa* sp. Climatic conditions, geography (water pressure, water flow, water quality, salt content, sunlight) and Indonesian waters are in accordance with the biological needs and growth of seaweed, making Indonesian seaweeds of good quality.

Seaweed can be used as a feed additive which has the ability to reduce the production of methane gas in ruminants. Seaweed contains protein, carbohydrates, fats, vitamins, minerals, oils, and amino acids as well as other secondary compounds (phlorotannin, iodine, and halogenated compounds) (11,12). These compounds is proven to be able to reduce the production of methane gas in ruminants because of its anti-methanogenic properties. Hikmawan et al. (2019) research reported that the substitution of seaweed *Euchaeuma cottonii* at the level of 4% was able to produce the smallest methane gas production of 18.49mM (13). *Eucheuma cottonii* contains a lot of unsaturated fatty acids, fat that enters the rumen will undergo a biohydrogenation process. The formation of methane gas requires the presence of hydrogen and carbon dioxide. The biohydrogenation process is the process of saturation of fat (hydrogenation) by diverting hydrogen, so that the formation of methane gas is inhibited. The bromoform content in seaweed has also been shown to be effective in inhibiting the emission of methane gas from the digestive tract due to its ability to interfere the methanogenesis process. Kinley et al. (2020) reported the use of seaweed *Aspargopsis toxiformis* is very effective in reducing methane gas production in the rumen by in-vitro because it contains secondary compounds of bromoform which are able to manipulate the microbial digesting enzymes that play a role in the production of methane gas (14).

## METHANE PRODUCTION IN RUMINANT

Ruminants produce methane gas emissions from two sources, there are enteric fermentation and manure. The highest production of enteric methane gas is in the rumen (87-90%) and in the large intestine (10-13%) (15). also reported that 1 head of beef cattle produces 47 kg of methane gas emissions per year while 1 dairy cattle produces 61 kg of methane gas emissions per year. The formation of methane gas occurs in the rumen. Methane is formed naturally as a methanogenesis. During this process, rumen microorganisms use it as an energy source. Methanogenesis is carried out by methanogenic bacteria by reducing $CO_2$ with $H_2$ and forming methane, then excreted 83% through eructation, 16% through respiration, and 1% through the anus (16). The process of reducing $CO_2$ by $H_2$ is then catalyzed by enzymes from methanogenic bacteria to form methane gas. The higher the availability of hydrogen, it will be directly proportional to the availability of the methane gas-forming substrate. Ruminants enteric methane gas is the result of the anaerobic fermentation process of feed organic matter by microbes and produces substrates include $CO_2$ and $H_2$, then utilized by methanogens in the reduction pathway. Methane gas from enteric fermentation is a by-product of ruminant digestion process and is produced by methanogenic microorganisms, namely *Archaea* during the methanogenesis process (17). Methanogenesis is a mechanism by the rumen as the end result of the chemical macromolecules feed fermentation in order to avoid the hydrogen accumulation.

Ruminants release methane gas into the atmosphere by expelling it through the mouth and nostrils. There is a difference in the concentration of gas produced during the animal's breathing. Large ruminants such as cattle produce 7 to 9 times more methane gas than sheep or goats (18). In addition to harming the environment due to the greenhouse gases effects, methane gas also causes disadvantage to livestock, that is not optimal productivity. Digestion of feed components by rumen microbes (bacteria, protozoa, and fungi) produces volatile fatty acids (VFA) such as acetate, propionate, and butyrate which are used by livestock as an energy source (17). During the fermentation process gas ($CO_2$ and $CH_4$) is also formed where the gas is then excreted through the eructation process. Cassandro et al. (2018) stated that the microbial metabolism process produces $H_2$ then together with $CO_2$ and $H_2$ will be converted into methane gas ($CH_4$) (18). The productivity of ruminants is not optimal because some of the energy of the feed is lost to methane. Loss of feed energy in the ration indicates that the use of feed is inefficient. Furthermore, Mayberry et al. (2019) reported that the methanogenesis process resulted in about 3 to 12% of the digested energy of the feed being lost (19). However, the methanogenesis process is very important to support the optimal performance of the rumen because it prevents the hydrogen accumulation which will cause inhibition of dehydrogenase activity involved in the oxidation of reduced cofactors.

## SEAWEED

Seaweed is a macroalgae and belongs to the *Tallophyta* division which has a body skeleton structure in the form of a stem (*thallus*) and does not have leaves and roots. Van Bosse expedition in the Siboga Sea in 1899-1900 reported that Indonesia have a source of seaweed germplasm of about 555 species from about 8000 species of seaweed in the world and can grow well in the Indonesian territory (20). There are three different groups of seaweed, red algae (*rhodophyta*), green algae (*chlorophyta*), and brown algae (*phaeophyta*) (21). In Indonesia, there are four types of seaweed that widely cultivated, *Euchaeuma cottonii*, *Gracilaria* sp, *Euchaeuma spinosum*, and *Caulerpa* sp. Indonesia has become one of the world's major producers of wet seaweed. Wet seaweed production in Indonesia in 2018 reached 10.32 million tons (22). Meanwhile, the export value of seaweed in 2020 reached 177 thousand tons (5). World production of fresh seaweed through aquaculture reached more than 30 million tonnes in 2016 (23). Seaweed has the potential to be used as feed for ruminants, especially the utilization of seaweed bioactive compounds in reducing methane gas emissions for ruminants. Seaweed contains secondary bioactive compounds that are beneficial in the welfare and health of livestock (24).

## SEAWEED BIOACTIVE COMPOUNDS IN REDUCING RUMINANT METHAN

Several studies have reported that the secondary bioactive compounds of seaweed have been shown to have anti methanogenic abilities (25). Seaweed contains proteins, carbohydrates, fats, vitamins, minerals, oils, and amino acids as well as other secondary compounds (phlorotannin, iodine, and halogenated compounds). In addition, seaweed also has benefits for livestock health due to the presence of nutrients such as protein, unsaturated fatty acids, and minerals (26). Phytochemically, seaweed generally contains phlorotanin and halogenated compounds. Brown algae has the highest content of polyphenolic compounds, such as phlorotanin, around 20-140 g/kg DM (21). Seaweed also contains bromoform which is an antimethanogenic compound. Types of seaweed *Asparagopsis* spp. is red algae species, whichcontains bromoform about 1.32-1.72 mg/g DM. Prayitno et al. (2019) reported that *Gracilaria* sp. is a type of seaweed included in tje red algae species that contains halogen compounds, especially bromoform, tannins, and saponins (27).

Berghuis et al. (2019) reported that methanogenic *Archaea* bacteria use one of the three methanogenic pathways, namely hydrogen-requiring and $CO_2$-reducing or called hydrogenotropic, methylotropic, and acetoclastic (28). These pathways require a group of genes to produce $CH_4$, namely methyl-coenzyme reductase (MCR). (29,30). One of the halogenated compounds either bromoform or chloroform has been shown to block the function of the corrinoid enzyme and inhibit MCR (31). Halogen compounds such as bromoform are anti-methanogenic compounds that will react with vitamin B12 which will inhibit the enzymes of methanogens to form methane gas (32). Denman et al. (2007) stated that bromoform can specifically inhibits the work of methanogenic bacteria (33). Bromochloromethane will reduce the activity of coenzyme cobalamin or vitamin B12 and coenzyme methyl M-reductase or mcrA contained in methanogenic DNA. Halogenated compounds will block the function of specific enzymes and inhibit the work of MCR along with methyl group transfer during the methanogenesis process (33,34,35).

## SEAWEED UTILIZATION APPLICATION ON RUMINANT FEED

The application of seaweed utilization in ruminant feed has been conducted by several researchers who have been shown to be able to reduce methane production. Research by in vivo was done by several following researcher. Roque et al. (2019) research reported that *Asparagopsis armata* is used at levels of 0.5-1% DM in holstein cows feed ration. *Asparagopsis armata* at the *sporophyte* stage was mixed with 400 ml of molasses and water to increase palatability, then mixed by hand into the total mixed ration (25). With this treatment, methane production decreased by 50%. Kinley et al. (2020) reported that use of *Asparagopsis taxiformis* was able to reduce methane production up to 98% (14). *Asparagopsis taxiformis* at the gametophyte stage was freeze-dried, then ground milled, mixed, and homogenized into TMR (Total Mixed Ration) of Brangus steers, the level of addition of *Asparagopsis taxiformis* was 0.05-0.2% DM. Research by Li et al. (2018) also use *Asparagopsis taxiformis* and was able to reduce methane gas up to 80.7% (22). The harvested *Asparagopsis taxiformis* were ground and sieved of 3 mm. Lupine seeds that have been crushed were given to merino-cross sheep as carriers mixed or not with *Asparagopsis* (0-3% DM). The composition of the treatment feed was (basal diet + lupine seeds with/without *Asparagopsis*). Different from previous research use BCM to reduce methane gas in goat (34). BCM (Bromochloromethane) was given 2 times a day to the feed of Murciano-Granadina lactating goats. The BCM formulation is wrapped in cellulose paper, mixed with 10g ground oats and coated with molasses. The feed ingredients used are (Alfalfa + concentrate + BCM (0-0.3g/100kg BW)). This treatment was able to reduce the production of methane gas by 33%. Stefenoni et al. (2021) harvested *Asparagopsis taxiformis* was freeze-dried and then ground and seive in 1 mm screen. Feed was given to Holstein cows in TMR (basal diet + *Asparagopsis taxiformis* (0.25-0.50%)) once a day (37). This treatment can reduce methane gas production by 29%. Research reported that Jersey cows is treatment using brown seaweed *Ascophyllum nodosum* (kelp meal) mixed with concentrate blend as much as half of the total daily treatment (113g/day) (38). Jersey cows were fed 2 times a day, morning and afternoon. The result was methane gas production is decrease about 9%. Using 2% of *Gracilaria sp.* flour can decrease 49% methane production. Meanwhile, using *Euchaeuma cottonii* flour at the level of 4% can decrease estimated methane gas production up to 14% by in vitro.

**Table 1. Utilization of Seaweed Reduces Methane Production**

| Trial | Treatment | $CH_4$ Production | Reff |
|---|---|---|---|
| Dairy cattle | 0,5-1 % *Asparagopsis armata* (OM) | Decrease 50% (15,0 > 7,5 g/kg DM) | (39) |
| Beef cattle | 0,05-0,2 % *Asparagopsis taxiformis* (OM) | Decrease 98% (10,4 > 0,2 g/kg DM) | (23) |
| Sheep | 0,5-3 % *Asparagopsis taxiformis* (OM) | Decrease 80,7% (15,0 > 2,9 g/kg DM) | (26) |
| Dairy goat | 0-0,3g/100kg BW Bromochloro methane | Decrease 33% (29,9 > 19,9 g/kg DM) | (1) |
| Dairy cattle | 0,5 % *Asparagopsis taxiformis* | Decrease 29% (13,9 > 9,8 g/kg DM) | (41) |
| Dairy cattle | 113 g/day *Ascophyllum nodosum* | Decrease 9% (22,6 > 20,6 g/kg DM) | (3) |
| In Vitro | 2% *Gracilaria sp.* | Decrease 49% | (36) |
| In Vitro | 4% *Euchaeuma cottonii* | Decrease 14% (21,61 > 18,49 mM) | (19) |

## CONCLUSION

Seaweed is proven to contain various bioactive compounds that have the ability to reduce the production of methane gas in ruminants. The application of seaweed utilization in reducing methane can be used as additional feed for ruminants.

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