Technical Solutions towards Environmental Sustainability of Cattle Production

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The interpretation of the concept of "Sustainable Cattle Production" varies among stake-holders; consumers may associate sustainability with animal health and welfare, whereas farmers may associate sustainability primarily with livelihood and economical aspects. However, also the environmental aspects of sustainability, such as nitrate leaching, ammonia emission, P eutrophication, and especially emission related to climate impact and carbon-footprint of products are important.

Major focus is on the cattle sector, where production is accompanied by production of significant amounts of greenhouse gases. This is mainly due to the production of enteric methane arising from microbial fermentation, primarily in the rumen. Enteric methane contributes to the high climate footprint of beef and milk, accounting for about 1/3 of the greenhouse gas emissions from Danish agriculture. A high yielding dairy cow produces around 700 L of methane on a daily basis, and the methanogenic process is closely linked to the amount and pattern of fermented carbohydrates. The key player in methanogenesis is hydrogen generated during microbial fermentation, and methanogenic archaea (methanogens) subsequently reduce carbon dioxide with hydrogen to form methane and water.

The technical solutions towards reducing in enteric methane productions therefore include three options: 1) Reduction of the production of hydrogen from rumen carbohydrate fermentation. 2) Promotion of alternative and energetically favorable pathways for use of hydrogen. 3) Inhibition of methanogenic archaea without compromising rumen fermentation. Reduction of the production of hydrogen from carbohydrate fermentation is related to production of acetate and butyrate versus propionate, as formation of the first two results in production of 4 and 2 moles of hydrogen, respectively, whereas formation of the latter consumes 2 moles of hydrogen per mole of glucose. Rumen hydrogen and methane production is thereby in broad terms promoted by fermentation of fiber (produces acetate) and sugar (produces butyrate) and restricted by fermentation of starch (produces propio-nate), although fermentation patterns depend highly on other factors too, such as pH, motility and feed retention time in the rumen. The apparent solution is therefore to feed diets high in concentrate and high maize silage:grass silage ratio. However, such diets are associated with a higher risk for metabolic diseases and a high carbon footprint from the production of feed, whereby the net result per kg of milk produced is limited or even negative. Formation of methane is a major hydrogen sink due to thermodynamic superiority, hydrogen partial pressure and substrate availability, and the promotion of alternative and energetically favorable pathways for use of hydrogen is therefore challenging. However, addition of H sinks, such as nitrate and sulfate, have reduced methane production by up to 25%, but addition of large amounts of nitrate (N) is associated with the risk of pollution swapping and maybe animal toxicity, and addition of sulfate is associated with palatability issues and unacceptable reductions in feed intake.

Thus, the most promising mitigation strategy is to directly inhibit methanogenic archaea without compromising rumen fermentation. Replacement of fermentable matter with fat in the diet has toxic effects on methanogens, but unfortunately also on fibrolytic bacteria. Multiple feed additives have been tested in vitro and in vivo for potential mitigation effects, but often with disappointing results. An upcoming new additive, 3-NOP, has shown promising results. Currently, also breeding for low emitting animals as well as technical solutions for collection methane at barn level are being investigated.