LIFE DAIRYCLIM

Best feeding strategies to decrease GHG emissions and CF of dairy cows

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Background

The increase in greenhouse gases (GHG) concentration in the atmosphere is one of the factors responsible of the global warming.

The impact of the agricultural sector on the total anthropic greenhouse gases emissions is estimated at **14%** (Tubiello et al., 2015).

Different GHG are emitted by the sector; the main gases are

- **Methane** (CH_4) emitted during ruminal fermentation but also during manure deposit
- **Nitrous oxide** (N_2O) emitted at spread of fertilisers (organic + mineral)
- **Carbon dioxide** (CO_2) emitted in all the operations requiring fuel: tractor use, feed production, …and land use change (deforestation, …)

Usually total GHG emissions are expressed in eq CO_2.

CH_4 and N_2O emissions are converted in eq CO_2 taking into account their global warming potential (GWP) in comparison of CO_2

The GWP of CH_4 is 24 – the GWP of N_2O is 298.

Methane emissions (Ton eq CO_2) = methane emissions (Ton) X GWP

Inventory of the different GHG emitted by the agricultural sector

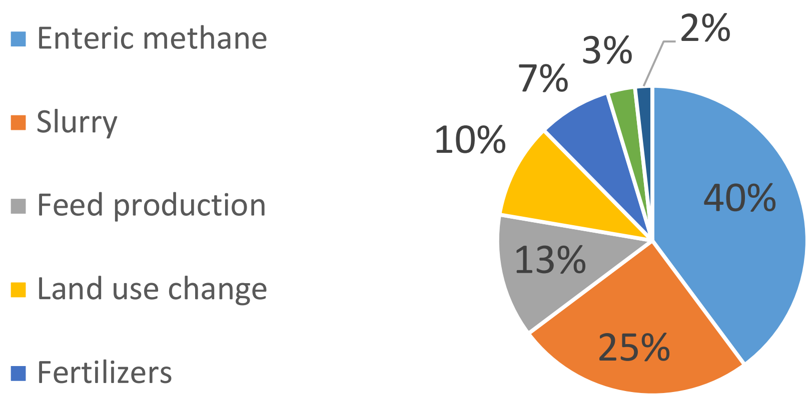


Figure 1 - Proportion of the different GHG emitted by the agricultural sector.

Different GHG are emitted by the sector: methane (CH_4) which is emitted mainly during ruminal fermentation but also by animal manure, nitrous oxide (N_2O) which is released at handling of organic and mineral fertilisers, and finally carbon dioxide (CO_2) linked to energy use for feed production, farm works and after production process. Some CO_2 emissions are linked to land use change.

Project Life DairyClim

The project Life Dairyclim, financed by the European Commission, began on 1st October 2015 and ended on 30 September 2019. One of its objectives was to decrease the environmental impact of the dairy sector in the three participating countries: Belgium, Denmark and Luxembourg.

Several partners collaborated on this project: the University of Liège, which is the coordinator, the C.T.A., Centre of Agronomic Technologies, Dumoulin, the industrial partner producing livestock feedstuffs, the University of Aarhus (Denmark) and Convis, the Luxembourg breeders association.

This project focused on two axes. Firstly, it aims to mitigate enteric methane emissions by promoting optimised feeding strategies at barn and at grazing. The improvement of grazing management was the second axe of the project.

How to decrease GHG emissions of agriculture?

The GHG emissions of cattle can be mitigated by several means. Two of them were investigated during the Life Dairyclim project:

One of the most developed is the feeding approach (Martin et al. 2010).

One other proposed method (IPCC, 2019) is to enhance carbon sequestration in the soil.

This approach was mainly conducted by improving grazing efficiency.

A proportion of GHG emissions can be mitigated by the carbon sinking potential of permanent grasslands

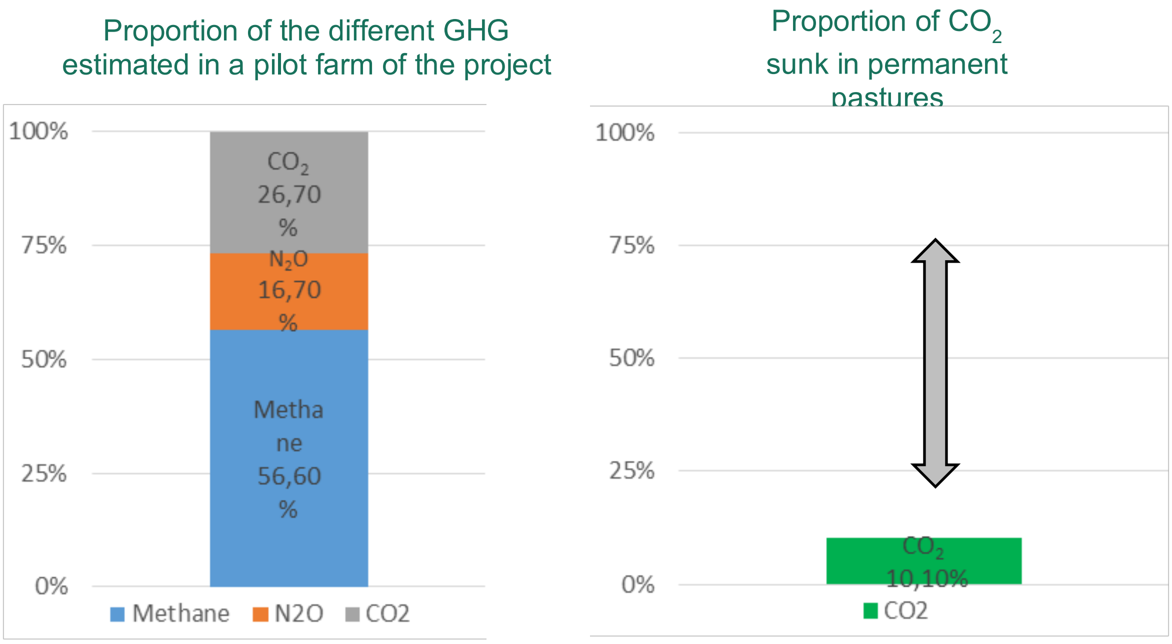


Figure 2 - Proportion of CO_2eq sunk by permanent grasslands and hedges and its contribution to the mitigation of the total GHG emissions of a pilot farm of the project Life Dairyclim.

The inventory was completed with the software CAP'2ER

Digestion of carbohydrates in ruminants

One of the particularities of the ruminant is its capacity to transform the cellulose contained in forages into high value food (milk and meat). It is made possible thanks to the rumen, one of the stomachs of the ruminant.

Forages are rich in carbohydrates. These ones can be classified into 2 categories according to their fermentation rate (Figure 3). The digestion process is summarised in Figure 4.

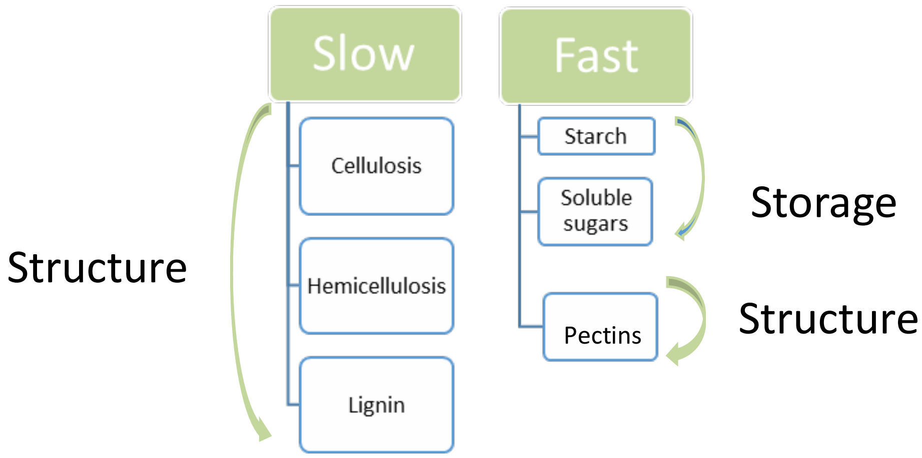


Figure 3 - Classification of carbohydrates following the speed of ruminal fermentation.

Methane production

Methane is produced during the fermentation of carbohydrates (i.e. cellulose, hemicellulose, starch, pectin) occurring in the rumen (one of the 4 stomachs of the cow).

This process leads to the production of 3 volatile fatty acids:

acetate - butyrate which liberate hydrogen (H_2)

and **propionate** which sinks it.

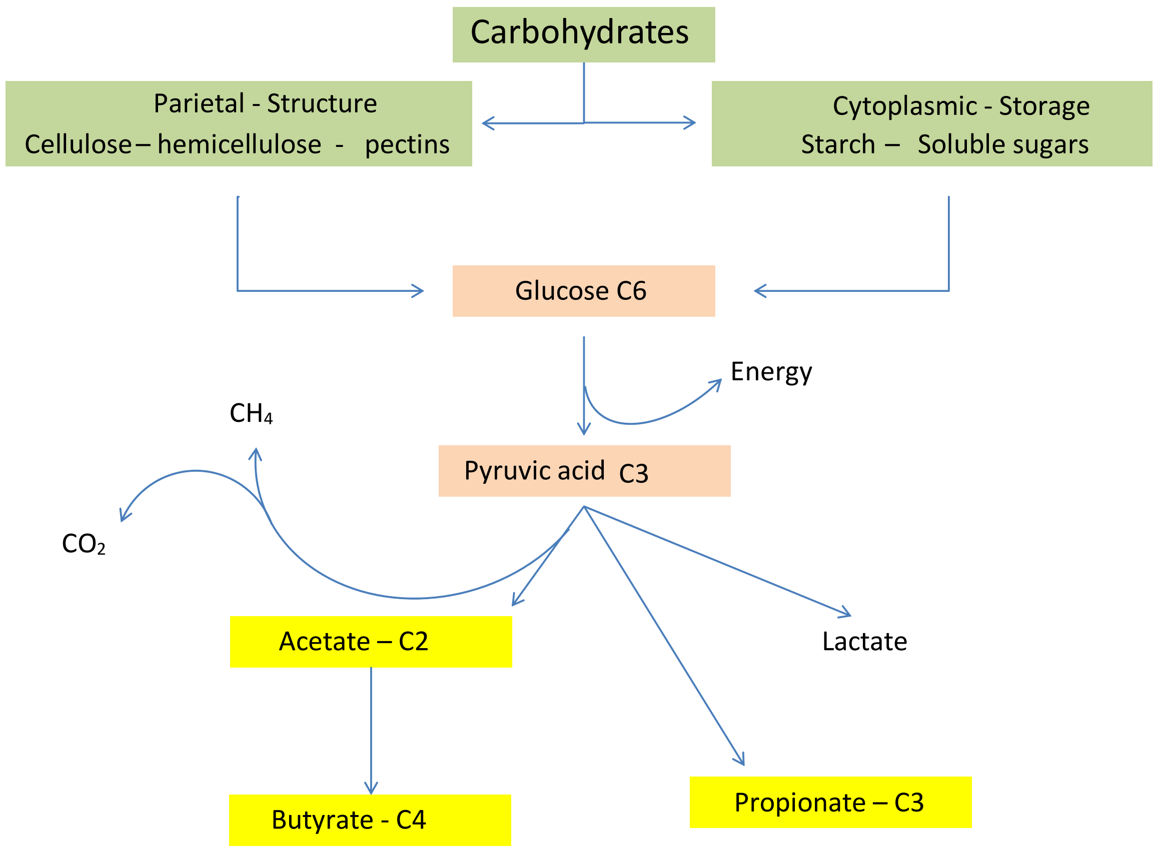


Figure 4 – Production of acetate, butyrate, propionate from fermentation of carbohydrates in the

The produced hydrogen is converted in methane (CH_4) by the ruminal flora.

The ruminal flora is composed of protozoa, bacteria, yeasts and fungi.
All these species play a complementary role in feed digestion.

Figure 4 - Ruminal flora

The production of methane limits the diet efficiency as it generates a loss of energy by 2-12% (Martin et al., 2010).

Decreasing methane production allows to increase feed efficiency

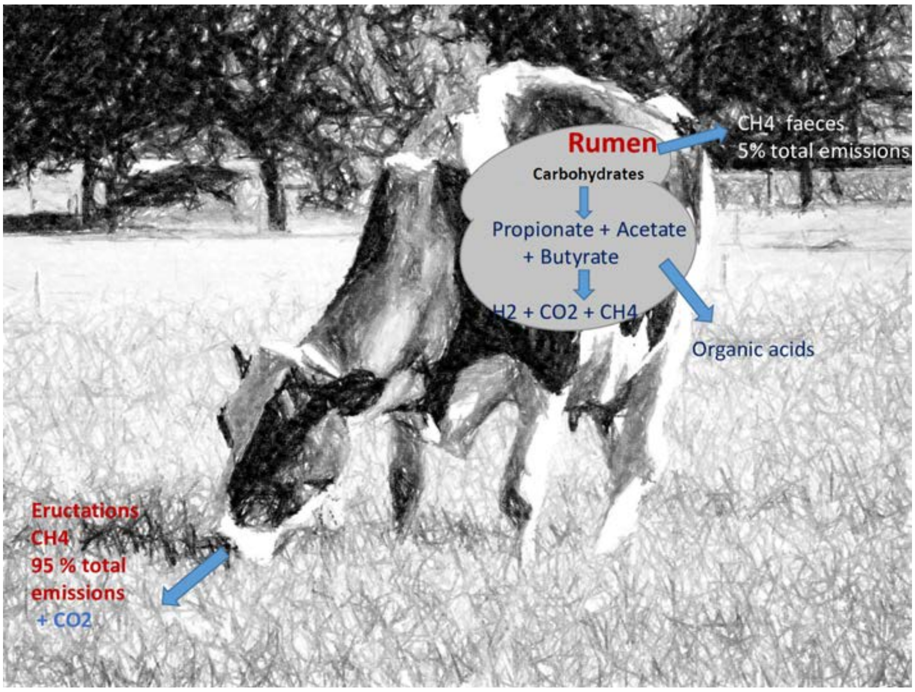


Figure 5 - Digestion process in the rumen.

Impact of feeding practices on methane production

Relative proportions of **acetate, butyrate and propionate** are linked with the diet **composition**.

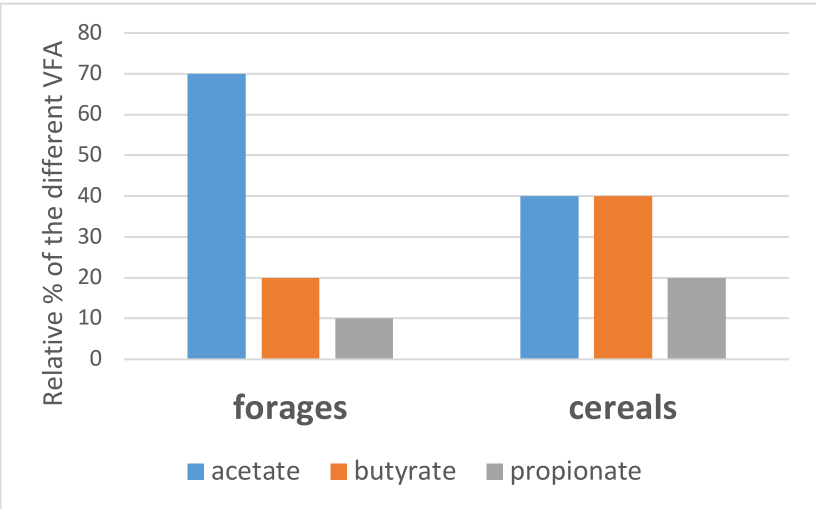


Figure 6 - Proportion of the different volatile fatty acids in relation with the fed diet.

A diet rich in cereals produces

- less acetate and butyrate
- more propionate
- less methane
- more acetate and butyrate
- less propionate

- A diet rich in forages produces
    - more methane

How to decrease methane emissions by adapting feeding strategies?

- Increasing the ratio concentrate/fibers
- Enhancing the digestibility of the ration and then reducing the retention time in the rumen
- Using additives and plant compounds to modify the ruminal microbial flora
- Using alternative energy sources to carbohydrates as lipids

We need to find a balance between **productivity, animal welfare** and **feeding costs.**

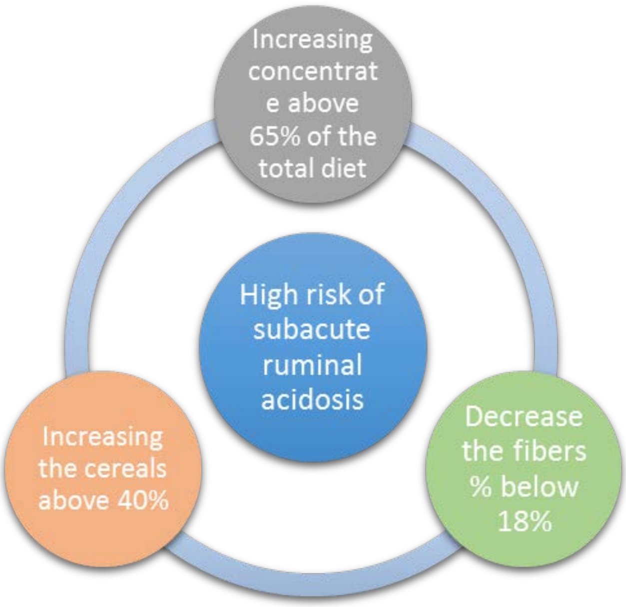


Figure 7 - Factors favoring occurrence of subacute ruminal acidosis.

Impact on animal welfare

Some practices can impair cows' health: high energy density of diet (e.g. high concentrate to fiber ratio) may cause rapid release of VFA and lactate in the rumen. The consequence is a drop of ruminal pH and thus if prolonged, the onset of subacute ruminal acidosis as shown in Figure 8 (Plaizier et al., 2008).

Drop in ruminal pH may cause a shift in ruminal flora with disappearance of protozoa and of some bacteria species.

Impact on productivity

Diets including high starch content can lower milk fat % with an impact of the milk sale price.

Subacute ruminal acidosis is linked to a decrease in milk yield (Kleen et al., 2003).

Impact on feeding costs

Some feed formulations as extrusion processing require more energy leading to an increased sale price. Feeding recommendations have to consider the potential rise in feeding costs.

Best feeding strategies tested during the LIFE Dairyclim project

In order to decrease methane emissions, tested feeds were given in the automatic concentrate supplier (ACS) or added to diet in the wagon trailer.

These concentrates supplemented a total mixed ration which was similar to these commonly offered to the cows in Wallonia and Luxembourg.

Ration fed to the cows.

The offered total mixed ration was mainly composed of maize silage, grass silage and completed by some by-products following the trials.

During the project Life Dairyclim, we tested

- concentrates rich in starch
- concentrates rich in lipids
- high ratio of concentrate to forages
- inclusion of oil in the ration
- introduction of a rising percentage of grazed grass

How were the trials organised?

To estimate the effect of supplementation with the different tested concentrates, 2 groups were formed:

Group 1: Control concentrate

Group 2: Test concentrate

The 2 groups were comparable in terms of **stage of lactation** and **milk yield** recorded before the start of measurements.

The tested concentrates were always supplied as a supplement to the total mixed ration.

Which measurements were carried to assess the different impacts of best feeding strategies?

- **Environmental** : methane emissions and carbon footprint
- **Zootechnical** : milk yield and composition
- **Economic** : estimation of feeding costs

Statistical analysis was performed to **highlight** the differences between the groups.

Methane emissions were measured by 2 methods

One method measured directly the methane emitted from the breath of the animals. When the cow comes to eat at the automatic concentrate supplier, she is recognised by her ear tag. While she eats, methane emissions are measured in her breath every 3 seconds.

The second method is based on milk composition. An equation allows to predict methane in milk samples (Vanlierde et al., 2016).

The mitigation potential of starch depends on several factors

- The **digestibility** of starch can be enhanced by different processes like grinding, rolling, flaking: these processes increase the availability of starch and thus the rate of fermentation.
- A substantial part of **starch is digested in the small intestine**, thus diminishing the formation of methane in the rumen. On the other hand, non-digested starch might be found in faeces, contributing to GHG emissions from manure.
- The **fermentation rate (%/h)** depends on the cereal species: wheat is degraded 3,7 times as fast as corn and 2,7 times as fast as barley (Hererra et al., 1990).

The cereal composition of the concentrate supplied was a mix of several species:

wheat, maize, barley and triticale

Wheat Barley Corn

Figure 8 - Different cereals usually offered to the cows.

Concentrates rich in starch

Concentrates rich in starch were supplied as a supplement to the ration fed to the cows. The quantities were adjusted to the needs of each cow.

The amount (%) of starch in the diet was on average **13,8 % in the test group and 10,8% in the control group.**

The mean amount of concentrate delivered to the cows was set at **4,5 kg/day**.

Increasing the starch content was expected to

- rise the proportion of propionate in the rumen (Knapp et al., 2014)
- enhance the ruminal fermentation and thus limit the retention time in the rumen (Hatew et al., 2015)

Results of the trial

Concentrate rich in starch

No significant difference was observed regarding methane emissions per cow per day.

This lack of effect could be due to a low percentage of starch in cows' diet or to a lower concentrate consumption than expected.

Due to the lowered milk yield, methane emissions per kg milk[1] were higher in the group receiving the concentrate rich in starch.

[1] To harmonize results, we made the decision to express methane emissions/cow/d and per /kg milk

From this trial, it was noted:

This trial did not shown the expected effect on the emissions of methane.

Concentrates rich in fat

Concentrates rich in fat were supplied as a supplement of the total mixed ration.

The amount (%) of fat in the test group diet was on average **4,4%.**

The control diet contained from **3%** to **3,6%** depending of the amount of concentrate delivered to the cows. This amount was on average: **5 kg/cow/d**.

Increasing the fat content was expected to:

- change the **ruminal flora** to modify the fermentation pattern, as lipids are mainly digested in the intestine
- increase the energy input
- some sources of fat provide **polyunsaturated** acids that can sink H2 (Beauchemin et al., 2008).

Different compositions were tested with inclusion of rapeseed and extruded linseed.

Extrusion is a thermo-physical treatment of linseed leading to the release of oil components without any damage to their nutritional properties. It aims also to inactivate anti-nutritional components.

Results of the trial

Concentrate rich in fat
First source of fat: rapeseed

Fat: **4,7%** in the tested ration

% fat in the diet was **3,4 %** for the control diet. The fat content of the tested ration increased thus by **38%**. No difference in concentrate consumption was noted between rapeseed and control.

Milk yield tended to increase by 1,5 kg (+4,3%) with rapeseed.

Methane emissions/cow/d decreased (ns).

Methane/kg milk decreased by 7,1% (± 2,8) (sig[2]).

From this trial, it was noted:

Rapeseed induced a significant decrease in methane emissions per kg milk but not by cow/day.

Results of the trial

Concentrate rich in fat
Second source of fat: Extruded linseed (ELS)

-11% in the concentrate
Fat: **4%** in the test ration

% fat in the diet was **3,1** % for the control diet. The fat content of the tested ration increased thus by **29%**.

Concentrate consumption was slightly decreased (4%) with ELS.

Milk yield increased by 1,1 kg (+3,6%) with ELS (ns).

Methane/kg milk decreased slightly (ns).

[2] Sig = statistically significant

From this trial, it was noted:

- The ration including ELS 11% caused a slight decrease in methane emissions but this effect was not significant.
- Inclusion of a higher % of fat was thus tested

Concentrate rich in fat
Second source of fat: Extruded linseed (ELS)

-15% ELS in the concentrate

Fat: **4,8 %** in the tested ration

% fat in the diet was **3,6%** for the control diet.

The fat content of the tested ration increased thus by **33%**. Concentrate consumption was decreased (8%) with ELS.

Milk yield increased by 2,2 kg with ELS (+6,4%) (sig).

Methane emissions/cow/d decreased by 4,7% (sig***).

Methane/kg milk decreased by 11,6% (sig***).

From this trial, it was noted:

- With ELS 15%, methane emissions per cow per day and per kg milk decreased very significantly.

Concentrate rich in fat: some conclusions

Introduction of high amount of fat in cows' diet can be effective to reduce methane emissions per cow per day and per kg milk. The maximum observed decrease reached 13% with the concentrate rich in extruded linseed (15% in the concentrate).

The effectiveness of this strategy depends on several factors:

- The percentage of fat included in the diet:

In the trials held during the project, it seems that below 4% fat, no decrease of methane emissions was observed.

- The source of fat supplement:

To reduce methane emissions, extruded linseed was more efficient than rapeseed. Indeed, the more the fatty acid unsaturated, the more it has the potential to bind H_2 (Dijkstra et al., 2011). Linseed contains mainly polyunsaturated fatty acids (PUFA) while rapeseed is rich in monounsaturated fatty acids (MUFA)[3].

- The composition of the total mixed ration:

The effect of fat inclusion depends on the complemented forages: different effects are observed with maize silage compared with by-products and grass silage.

The tested concentrates show difference in fatty acids composition

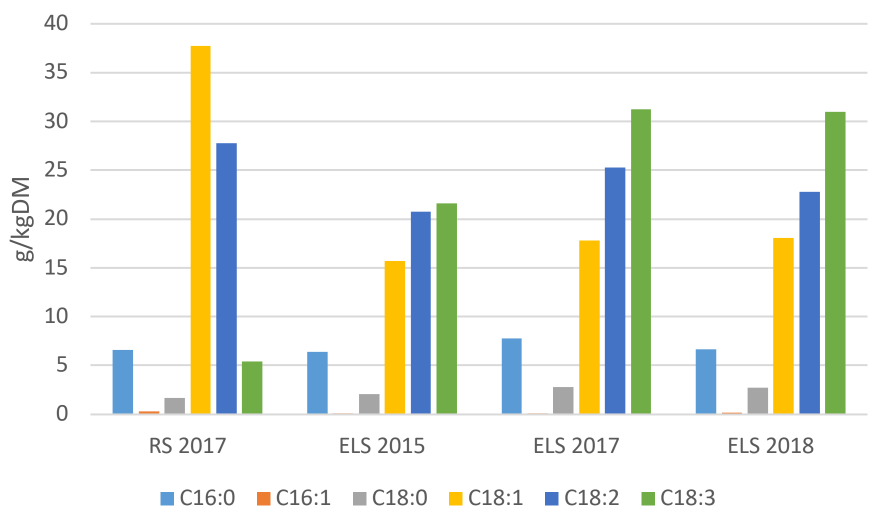


Figure 9 - Composition in fatty acids of the tested concentrates.

The concentration of C18:1 (oleic acid) was quite doubled in rapeseed compared with extruded linseed.

Depending on the composition of the concentrate rich in extruded linseed, the input of linolenic acid (C18:3) varied with a maximum of 25,3 g/kgDM.

Abbreviations: DM: dry matter; RS: rapeseed; ELS: extruded linseed; C16:0: palmitic acid; C18:0: stearic acid; C18:1: oleic acid; C18:2: linoleic acid; C18:3: linolenic acid

[3] We tested a concentrate ELS (13,4%) containing sunflower with less impact on methane emissions. The hypothesis to explain it is the different profile in polyunsaturated fatty acids.

Inclusion of linseed oil in cows'ration

- To investigate the effects of pure oil inclusion, we added progressively linseed oil in cows'diet.
- The inclusion of fat rose from 2,8% in the control diet to 3,8% and 4,2% in diet + linseed oil.

Results of the trial with linseed oil inclusion

Comparison of two different percentages

The initial percentage of fat in the control diet was **2,8%**. The level of fat increased by **35%** and **50%** for the diets including 1% and 1,5% oil respectively.

The inclusion of oil in the diet of the cow did not affect milk yield.

Methane emissions/cow/d decreased by **11** and **21%** respectively for 1% and 1,5% oil.

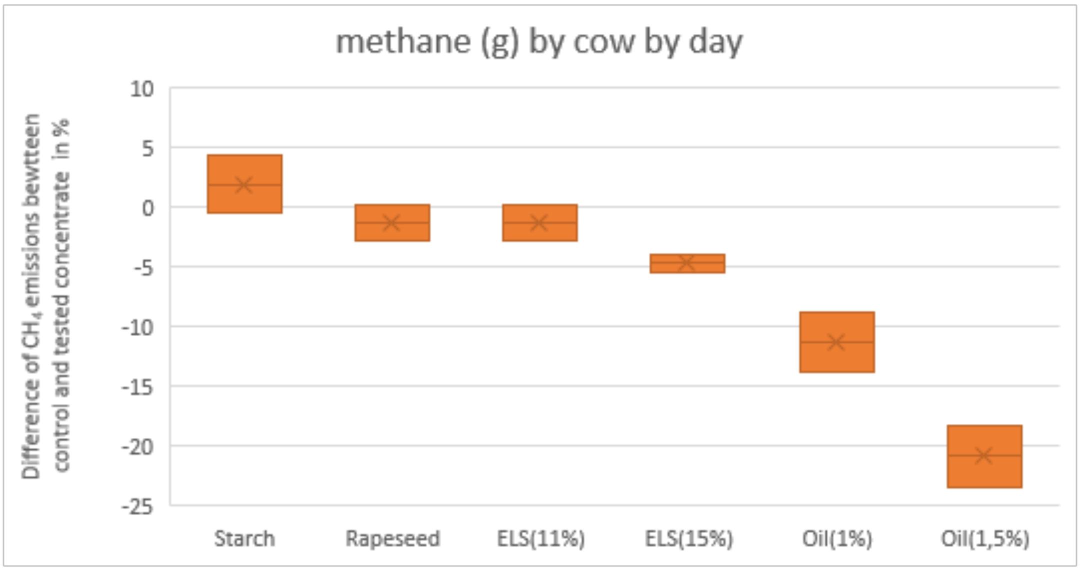
Methane/kg milk decreased by 21% for 1,5% oil.

From this trial, it was noted:

- Oil inclusion in the cow's ration has the best effect on the decrease in methane emissions by cow, especially with 1,5% oil.

Summary of trials

Percentage of difference of methane emissions between control and tested ration.



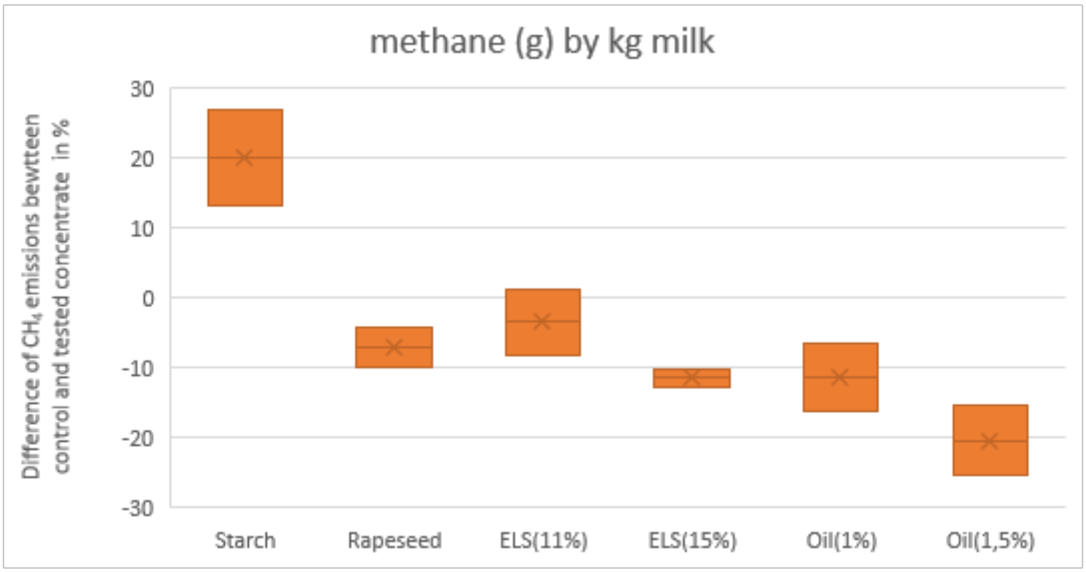


Figure 10 - Percentage of difference of methane emissions/cow.d and /kg milk between control and tested rations.

Increasing the ratio concentrate/forages

Intensive farms sometimes take the decision to keep the cows indoors and to give them a constant diet based on concentrate even when it is possible to graze.

To evaluate the effect of this strategy, we divided the herd into 2 comparable groups: one receiving a dry ration composed of 70% concentrate and one receiving 83% forages as grazed grass.

Results of the trial

Increasing the ratio concentrate/forages

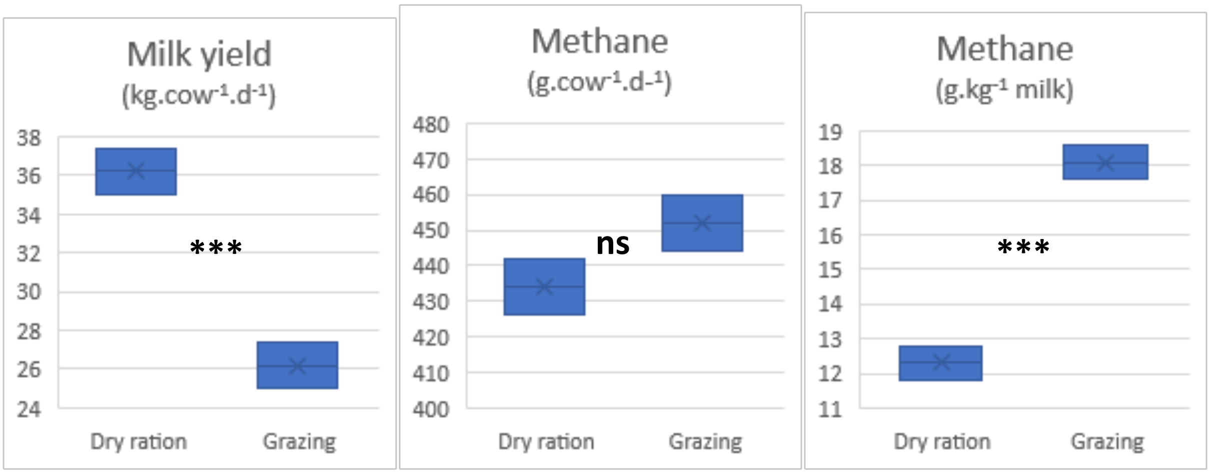


Figure 11 - Results of the trials comparing rations composed of concentrates vs grazed grass (% of the differences observed between the grazing group and the group with dry ration). % SE: percentage standard error - ns: results no statistically different - *: results significantly different

Fat % of the produced milk with dry ration compared with grazing was significantly lower (3,03% vs 3,52% at grazing) affecting milk quality.

From these trials, it was noted:

The cows receiving more concentrate had a higher milk yield (+40%). However, their milk fat content was very low.

No difference in methane per cow per day but huge decrease (-32%) per kg milk in favour of dry ration.

Comparing 3 diets with an increased percentage of grazed grass

Diets with 3 levels of grazed grass, 0%, 50% and 100% were tested. In 0% and 50% groups, the diet was completed with a mixture of forages (silages of maize, grass, alfalfa, beet pulp), barley and concentrate.

Results of the trial

Comparison of three different percentages of grazed grass

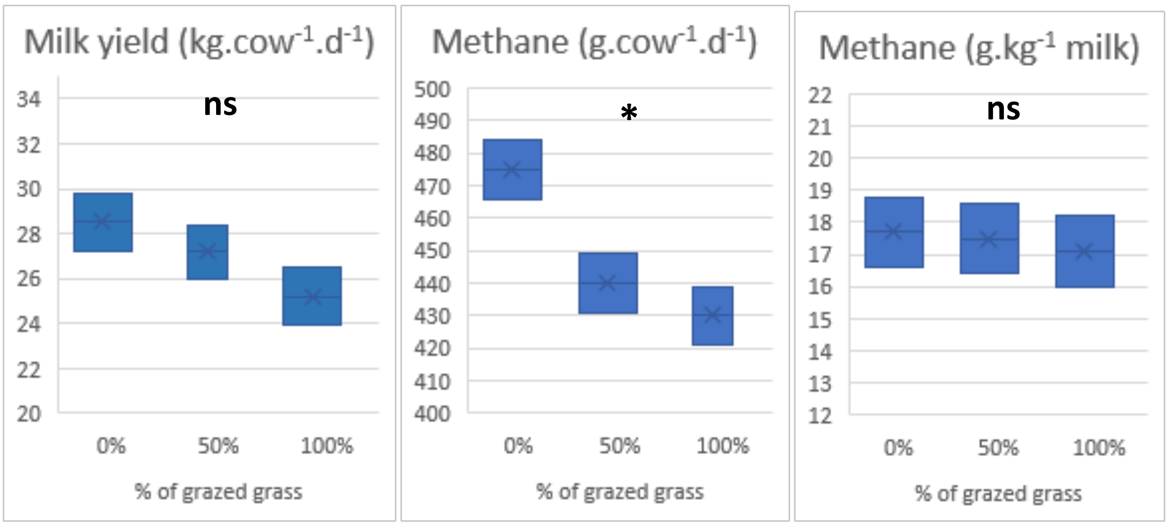


Figure 12 - Results of the trial comparing rations with an increasing % grass.
- ns: results no statistically different - *: results significant

From these trials, it was noted:

- The milk yield was numerically lower in the group 100% grass, but it was not statistically significant.
- Decrease in methane emissions/cow/d by 9% was observed in the group 100% grass compared with the group 0%.
- Methane/kg milk was not statistically different.

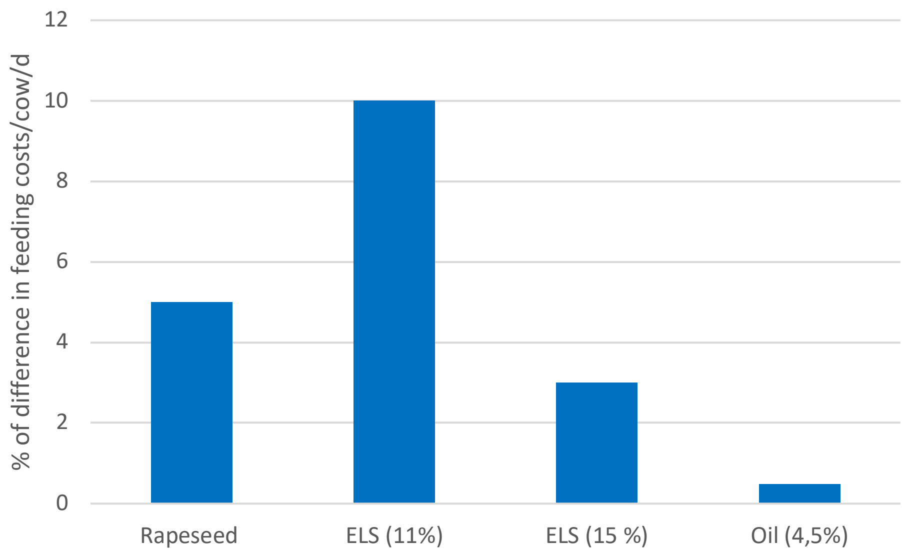
Economic impact: calculation of feeding costs

- Feeding costs represent a large part of production costs in a dairy farm accountancy.
- Thus, they were calculated to evaluate the impact of the tested feeding strategies.
- We used the accountancy data for purchased feedstuffs and for the forages, the estimation provided by Fourrages Mieux as official basis for wildlife damage compensation.
- The feeding costs were calculated per cow per day but also per kg produced milk.

Feeding costs for the tests

- Feeding costs per cow and per.day were increased at use of concentrate rich in fat, rapeseed or extruded linseed.
- When taking into account the milk yield, the difference was lowered with a maximum of 0,4 €/100 kg milk at use of extruded linseed.

The Figure 14 shows the difference (%) in feeding costs regarding the tested feed versus the control. These values were calculated per cow and per day and per 100 kg milk.



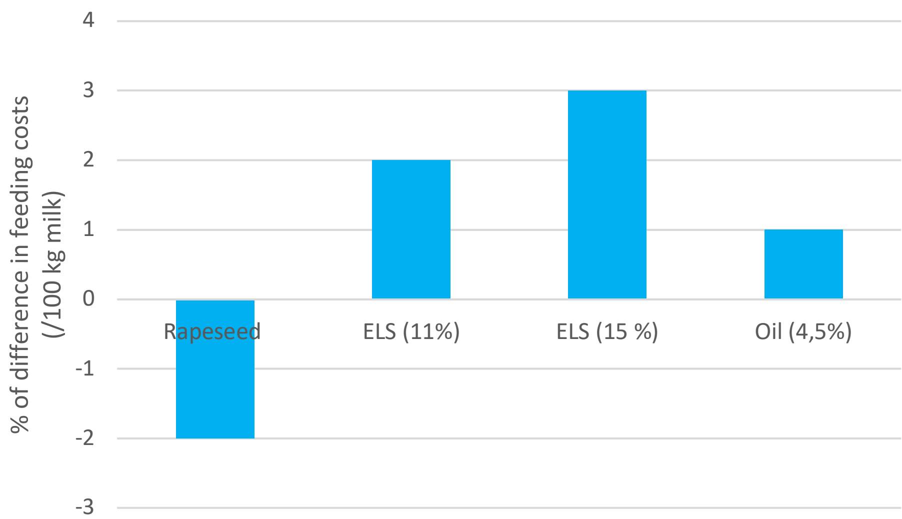


Figure 13 - Differences in feeding costs between Tested and Control per cow per day (Figure below) and per 100 kg milk.

- Feeding costs for tests including grazed grass

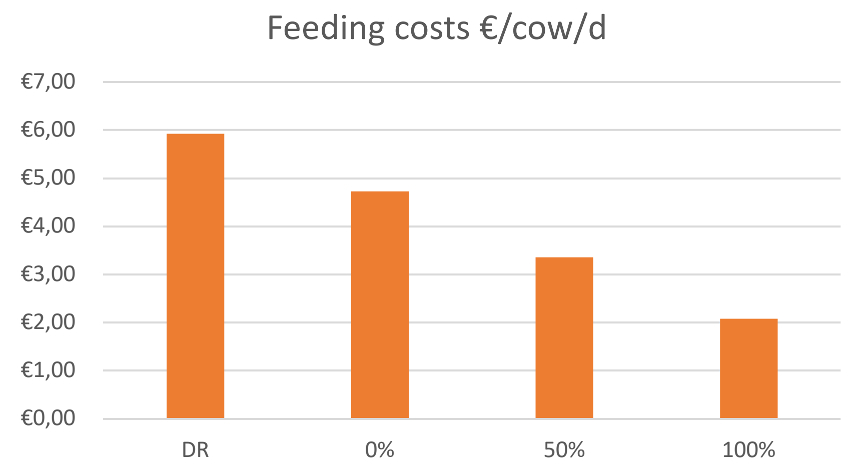


Figure 14 - Comparison of feeding costs per cow per day at grazing.

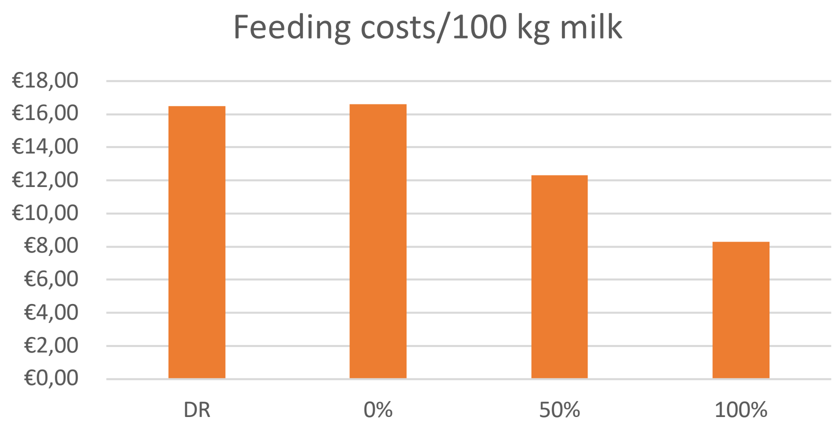


Figure 15 - Comparison of feeding costs per 100 kg milk at grazing.

Feeding costs at grazing decreased per cow and per day as per 100 kg milk produced.

Even with the higher milk yield observed with the dry ration, feeding costs are still higher than with 100% grass diet.

Environmental impact

- Beside the methane emissions determined during the trials, the carbon footprint of these feeding practices was estimated.
- Yet, we want to be sure that the positive effect on methane emissions would not cause negative effect on other GHG emissions.
- Thus, we estimated the global environmental impact using the methodology of lifecycle assessment (LCA).

The LCA approach is based on the inventory of all the inputs and outputs of the farm (Flysjö et al., 2011).

Inputs are emissions linked to the feed production/energy necessary on farm and out the farm (feed produced by feed industry)

Outputs are emissions linked to farm production: calves, milk and meat.

The environmental impact can be expressed per ha or kg milk or per animal.

By using LCA methodology, emissions related to feed production, methane emissions (enteric + manure), manure handling were summed for each of the trials.

When compared with control, the diet including the tested concentrate showed most of the time a slight increase in total impact.

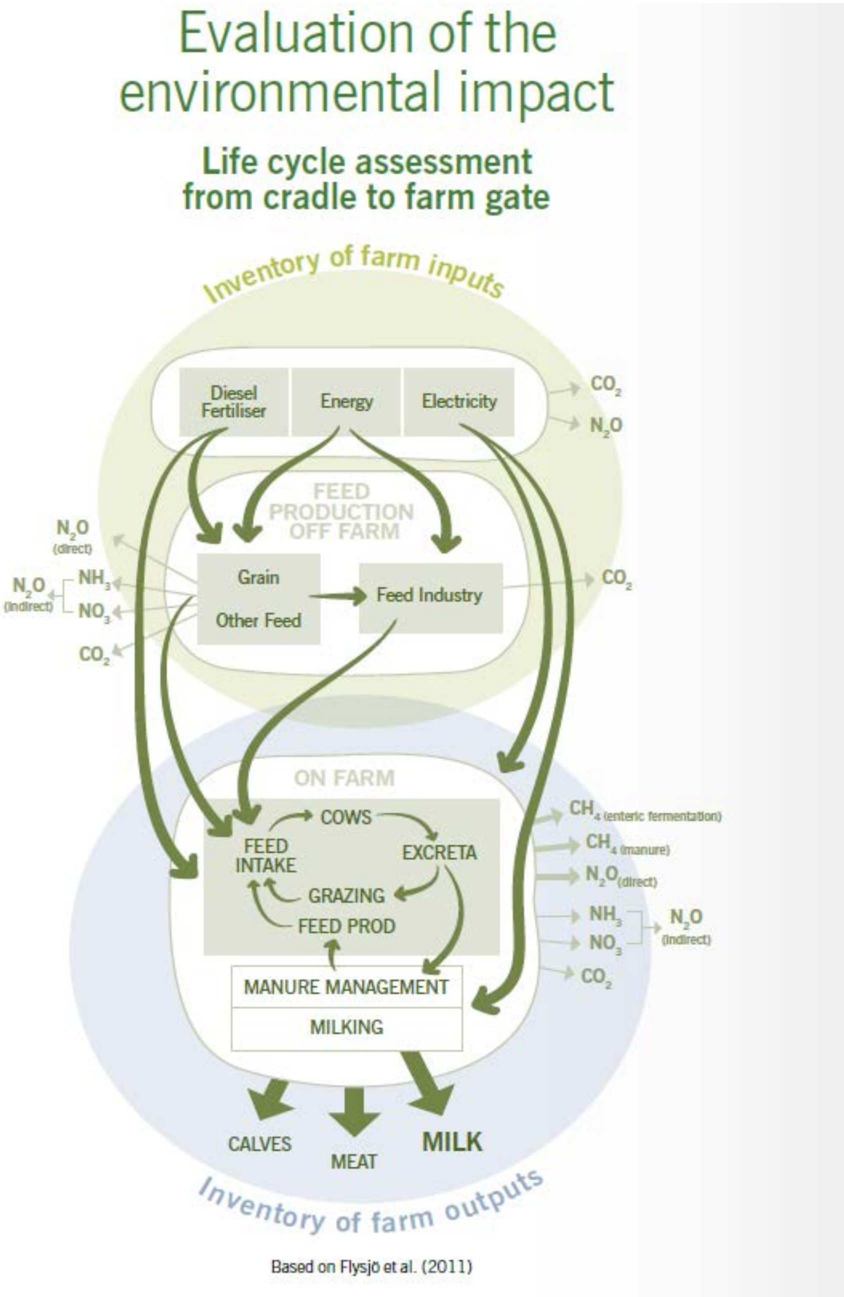


Figure 16 - Inventory of inputs and outputs taken into consideration for the lifecycle assessment at farm level based on Flysjö et al. 2011.

An emission factor was attributed to each feed component of the tested diet. This value was weighted on basis of the delivered quantities. Finally, all the values were summed to calculate the climate impact of the tested diet4.

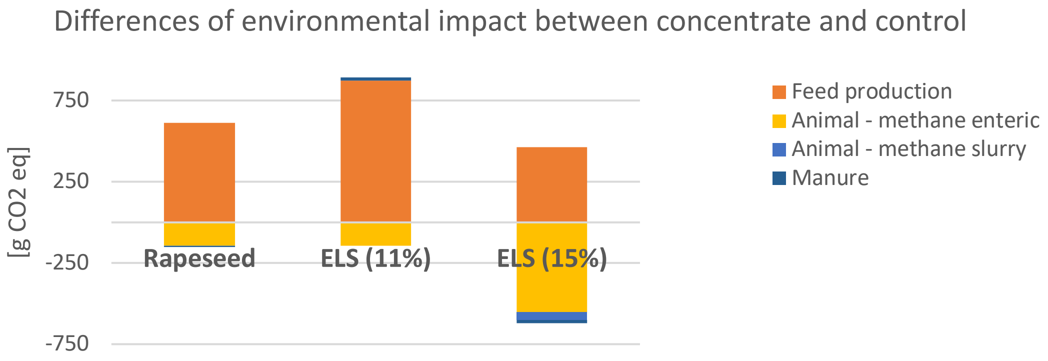


Figure 17 - Differences of environmental impact of each concentrate compared to control.

Differences in milk yield appeared following the treatments; it seems thus fair to report the climate impact per kg produced milk.

Therefore, the total environmental impact was divided by the milk production. This one was calculated as energy corrected milk5.

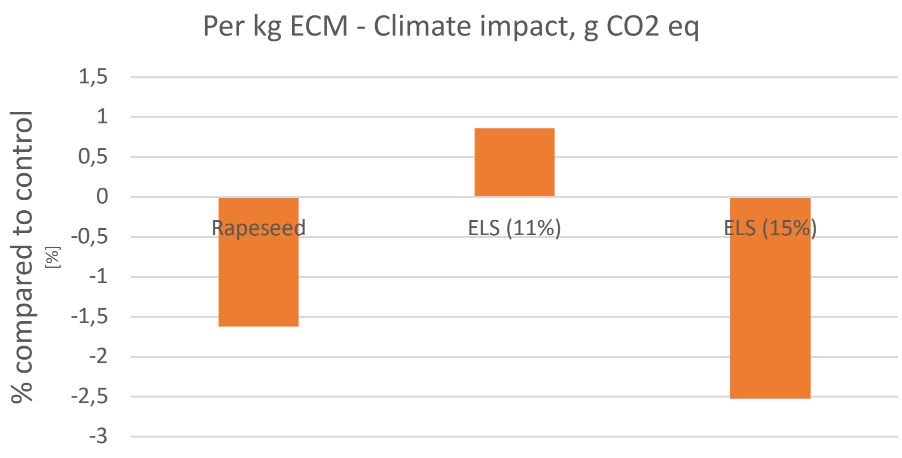


Figure 18 - Comparison of the climate impact of the different rations offered at barn reported per kg energy corrected milk produced (ECM). CO2eq: emissions reported per CO2 equivalent. ECM (kg.cow-1.d-1)

By using this methodology, the climate impact of control and tested diets are becoming very close.

[4] These figures do not take into consideration carbon soil changes.
[5] Energy corrected milk = milk yield of a standard milk with 4% fat and 3,2% protein.

Inclusion of grazed grass

ECM (kg.cow-1.d-1)

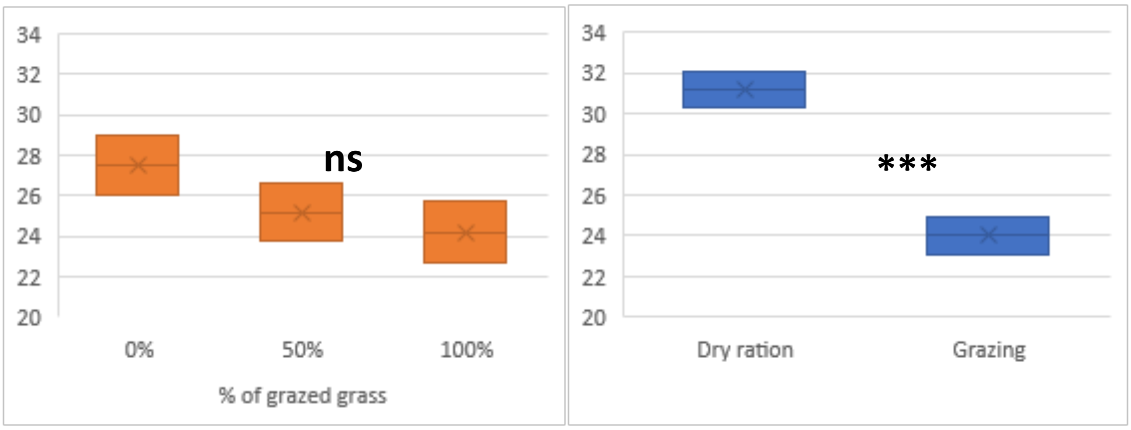


Figure 19 - Comparison of the climate impact of the different rations offered at barn reported per kg energy corrected milk produced (ECM).

The LCA analysis shows the complexity of the assessment of environmental impact as a tested diet can have a positive impact on methane enteric emissions but a negative impact on methane slurry. Using the LCA analysis allows a complete overview.

The climate impact of the dry ration was compared with the 100% grazed grass using the same method.

The total climate impact was much lower for 100% but when reported per kg ECM produced, the lowest milk yield recorded in the grazing group changed the trend with a higher climate impact (eqCO2) for the diet based on grass.

When reported per ha, the diet based on grass was again more eco-friendly.

These results underline the importance of the measurement unit used for results presentation.

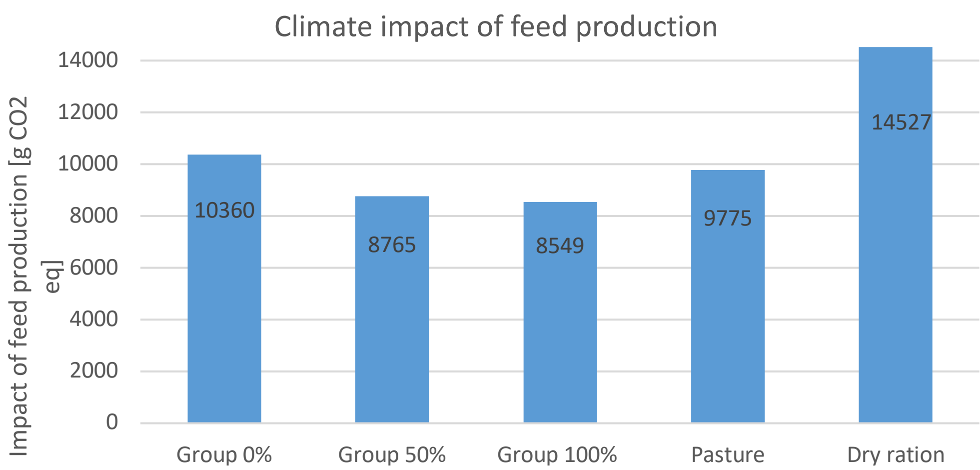


Figure 20 - Comparison of the climate impact of feed production of the different rations offered at grazing in total, reported per kg energy corrected milk produced (ECM) and per ha. Abbreviations: CO2eq: emissions reported per CO2 equivalent.

The feeding strategies to be still investigated

Some strategies suggested by the literature (Beauchemin et al., 2008; Hristov et al., 2013; Martin et al., 2010) were not investigated during the project's duration.

- Use of high quality and well conserved forages (Gerber et al., 2013).
- Increase the ratio maize silage/grass silage
- Introduce cereal crop silage
- Use of saponins - tannins
- Use of yeast extracts

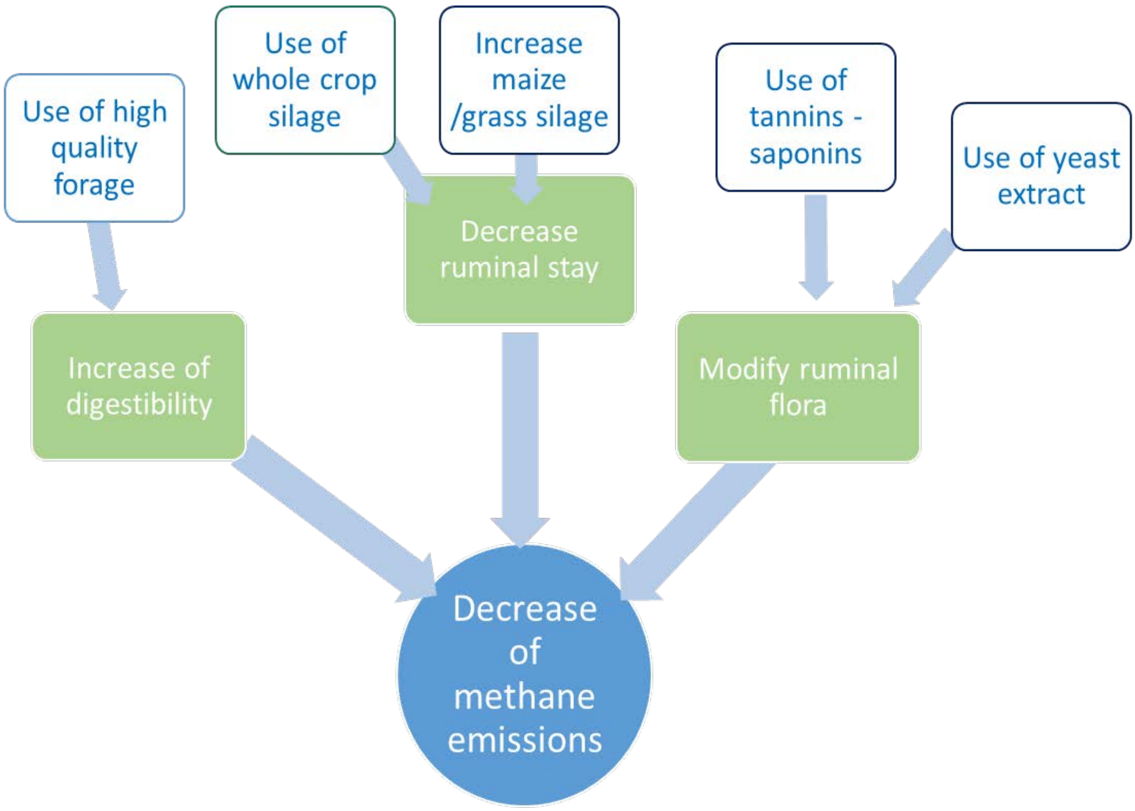


Figure 21 - Other feeding strategies described in the literature and their lever of action.

Recommendations

- The inclusion of fat in cows' diet is useful to decrease methane emissions per animal per day or per kg milk without any significant global environmental impact/kg milk.
- Extruded linseed is more effective than rapeseed and, thus, is preferred.
- To be effective, the percentage of fat has to exceed 4%, corresponding to an amount of at least 4,3 kg concentrate/cow/d of concentrate rich in extruded linseed (15%). Inclusion of 1,2% of linseed oil in the diet allows to reach the same result.
- It can be applied to cows in early lactation.
- Some extra fees are linked to the use of this kind of concentrate but they are limited (+3%) when expressed per kg milk and could be, in the future, compensated by premiums delivered for sustainable milk.
- Introduction of grazed grass induced a noticeable decrease of feeding costs.
- The climatic impact per ha was also favourable to diets including high proportion of grazed grass.

In conclusion

- Mitigation of methane emissions is possible in dairy farming through best feeding strategies.
- In some case, beneficial effect on methane emissions can be linked to deleterious effects in terms of global climate impact, zootechnical and economic performances.
- It is thus essential to get a global overview of all the potential impacts of the proposed strategies.

Abbreviations

ACS	automatic concentrate supplier
CH4	Methane
CO2	carbon dioxide
C16:0	palmitic acid
C18:0	stearic acid
C18:1	oleic acid
C18:2	linoleic acid
C18:3	linolenic acid
d	day
DM	dry matter
ECM	energy corrected milk
ELS	extruded linseed
eqCO2	equivalent CO2
FA	fatty acids
GHG	Greenhouse gas
GWP	global warming potential
H2	Hydrogen
LCA	life cycle assessment
MUFA	mono unsaturated fatty acids
ns	not significant
PUFA	poly unsaturated fatty acids
RS	Rapeseed
SE	standard error
Sig	statistical significance
VFA	volatile fatty acids

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