Alltech Optigen®
Carbon Trust Validation Report

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1 Project Overview

Alltech Inc. has commissioned the Carbon Trust to provide an independent validation opinion against ISO 14064 (part 2) regarding the predicted performance of their livestock feed additive – Optigen® (Optigen) – in terms of its ability to improve livestock performance on farms. This report summarises the terms of reference for this review (evidence base) and our opinion.

It should be noted that the FAO's Livestock Environmental Assessment and Performance (LEAP) Partnership has begun a process of writing guidance for assessing the efficacy of ruminant feed additives (FAO, 2017) and our review process may be updated on publication.

Optigen is a slow release urea product that is intended to supply nitrogen to ruminants. Alltech would like to be able to enhance their Optigen sales process with supporting opinion from a third party (the Carbon Trust) regarding its efficacy in replacing high carbon footprint products such as soya beans. The product is a non-protein nitrogen source, which concentrates nitrogen supply to the animal in order to improve ruminant efficiency. In this report, we set out the key issues, provide an opinion regarding the addition of Optigen into feeds, and summarise the evidence base used to form that opinion. We focus our opinion upon productivity and nutrition rather and also refer to the potential for reduced CH_4 emissions that come with a more efficient rumen.

2 Optigen Introduction

The section below reviews the general principles surrounding the issues which Optigen is designed to address. Section 2.1 outlines the environmental impact of Optigen, section 2.2 the carbon footprint of soybean meal, and section 2.4 explains the importance of nitrogen. Sections 2.5-2.7 reviews the function of livestock digestive systems and their importance in ruminant productivity.

2.1 Carbon footprint of Optigen

To enable comparison between the environmental impact of Optigen and soybean meal, Alltech Inc. made available calculations of the lifecycle carbon emissions of Optigen (see Figure 1 & Table 1). These calculations have been tested by the Carbon Trust and are compared in relation to the emissions of soybean meal (indicative calculations given in section 2.2.1).

Figure 1: Processes involved in lifecycle emissions of Optigen

DM (%)	CP, % DM	TDN %	Process (g CO_2/kg)	Urea (g CO_2/kg)	Coating (g CO_2/kg)	Transport (g CO_2/kg)	TOTAL (g CO_2/kg)
99	256	17.8	70	800.8	242.9	37	**1150.3**

Table 1: Summary calculations for carbon footprint of Optigen, expressed as g CO_2/kg- for full calculations see 7 Appendix

2.2 Environmental impact of soybean meal

Soybean meal is a popular source of nitrogen for farmers globally. However with increasing costs associated with its purchase and an understanding of the environmental impact that the production and transport of soybeans can have, some farmers are looking to move away from soybean as a primary source of nitrogen to their livestock.

Soybean meal is generally sourced from areas that have undergone significant land use change in order to meet demand for feeding livestock (Caro *et al.,* 2017). Areas such as the Amazon have experienced significant deforestation to clear room for grazing or crop production (FAO, 2012). Land use change emissions from soybean agriculture are estimated to cover 3.2% of global emissions from livestock (Gerber *et al.,* 2013). There are also a number of associated negative environmental impacts, including habitat loss and decreased biodiversity (Dalgaard *et al.,* 2008). Although attributing land use change emissions is a complicated process, there is a consensus that soybean meal has a particularly high footprint. Therefore reducing the levels of soybean meal in the diet of a farmer's cattle is likely to reduce the lifecycle emissions of their finished product (e.g. Lehuger *et al.,* 2009).

However, caution must be applied when considering potential (full or partial) replacement of soybean meal. If an unsuitable source of protein is provided it may have significant negative effects which could have associated negative impacts on efficiency of the rumen. Should the efficiency of the rumen decrease it can have a number of knock-on effects, including (but not limited to):

- Decreased DMI
- Reduced milk yield
- Reduced milk protein content
- Later slaughter age

The impact of any of these factors could have an associated effect on cattle methane emissions which is linked to rumen efficiency and productivity.

2.2.1 Carbon footprint of soybean meal

The carbon footprint of soybean meal can vary significantly based on whether land use change has occurred in order to allow for the cultivation of soy which is then converted into soybean meal. This also varies significantly by country/region of production. Carbon Trust has developed emissions factors for soybean meal including where it has been sourced from and whether land use change has been involved in its production. As is shown in Table 1, the emissions factor for soybean meal varies significantly dependent on whether land use change has been included.

Country/region of origin	Land Use change included?	Emissions Factor ($g\ CO_2e/kg$)
Argentina	Yes	5470
	No	210
Brazil	Yes	11650
	No	220
South America	Yes	7470
	No	260
USA	Yes	5450
	No	320
Europe	Yes	1320
	No	1320

Table 2: Table showing emissions factors for soybean meal. Derived from Alltech E-CO_2 model, Emissions Factor from Footprint Expert 4.0/Ecoinvent 2.2

2.3 Replacement of soybean meal with Optigen

Replacement of soybean meal with Optigen is not a 1:1 replacement. Optigen is significantly more concentrated than soybean meal, allowing for increased dry matter space in the rumen. When Optigen replaces soybean meal as source of nitrogen, soybean meal is effectively replaced at 1:5.5 when crude protein content is taken into account. This means that the estimated emissions factor of Optigen (1150 g CO_2e/kg) compares favourably to every emissions factor given for soybean meal production, whether land use change is included or not.

2.4 Importance of nitrogen

Cattle require sources of nitrogen in order to build amino acids which support tissue growth and milk production. This is mainly achieved through sources of protein such as soybean meal which, as discussed in section 2.2, can have a negative environmental impact, both in terms of greenhouse gas emissions and wider environmental concerns. Sources of nitrogen are generally the most expensive component of feed and therefore seeking alternatives to products such as soybean meal could be both lucrative to farmers and also reduce environmental impact.

2.5 Feed digestibility and enteric CH_4

The rumen contains a complex mixture of eaten food, bacteria, fungi, and by-products. Cattle, sheep, and other ruminants use bacteria to breakdown grass into digestible chemicals. However, a range of issues can make this a sub-optimal process. It is beyond the scope of this report to provide a review of rumen biochemistry. However, some general features are important:

- The principle aim of a farmer is to make the rumen as efficient as possible at turning feed into meat and milk without compromising health and welfare
- Rumen bacteria generate a range of by-products, some of which are digestible and some not
- By-products include energy carriers (e.g. lactate, followed by fatty acids)

- Increased bacteria activity should increase the amount of energy carriers and digestible matter but may in parallel increase the non-digestible by-products (e.g. CH_4)

There is evidence that Optigen can adequately replace soybean meal as a ruminant source of nitrogen, and in some cases can also directly enhance animal productivity. This could have an associated effect on GHG emissions by improving the efficiency of the rumen, which would leave to greater feed utilisation which is linked to reducing methane emissions (Dijkstra *et al.,* 2013).

Direct emissions benefits may be due to:

- Reduced enteric CH_4 per litre or kg DLWG
- Reduced excreted nitrogen (N) per litre of kg DLWG

2.6 Recalculating N excretion rate

The current method for calculating excreted N in Alltech E-CO_2 beef and dairy models takes account of the N content of meat and milk (i.e. N excreted = N intake – N in DLWG – N in milk – N from calf production). However, these certified models (CERT-12629, 23 August 2018) currently use fixed constants rather than actual farm average (or animal specific) parameters

2.7 Recalculating enteric CH_4 emissions

CH_4 losses from the cattle and sheep rumen can represent 2-12% of consumed energy – a significant cause of lost productivity (Tapio, Snelling, Strozzi, & Wallace, 2017). In addition, CH_4 is an important GHG and the source of existential challenge to the livestock sector from NGOs, government agencies, and academics (FAO, 2006), (Public Health England, 2014), (Garnett, 2015).

A number of organisations[1] have developed tools to estimate the carbon footprint of farming livestock, which include a number of assumptions about enteric CH_4 generation. These assumptions link existing empirical research regarding CH_4 release volumes, animal physical characteristics (e.g. weight), and the quality, quantity, and type of feed. The approach taken therefore, is to model enteric CH_4 release based upon what is known about this data – any adjustment to these calculations (e.g. CH_4 Conversion Factor) due to the use of Optigen will therefore need to be made in reference to:

- Animal weight (e.g. average Holstein Friesian cow at 650kg)
- Feed quality (e.g. digestibility)
- Feed quantity (e.g. kg dry matter intake (DMI))
- Feed type (e.g. concentrate, grazed grass, forage, etc.)

The primary factors regarding the impact of Optigen on protein uptake is the digestibility of the product within the digestive system of the ruminant animal (Figure 2). The levels of digestibility can be shown in a ruminant animal through a number of variables and be compared to productivity of control or animals fed alternative forms of protein:

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[1] Such as: Alltech E-CO_2, Promar International, Bord Bia, Cool Farm Alliance (for a UK and Ireland focus)

- Milk yield
- FCE- the amount of feed that is converted into a useful output for the animal
- DMI intake
- Body weight change

It is broadly acknowledged that dietary content can regulate the impact of protein digestibility, however making reliable adjustments across the range of ruminant diets, species, and breeds is challenging.

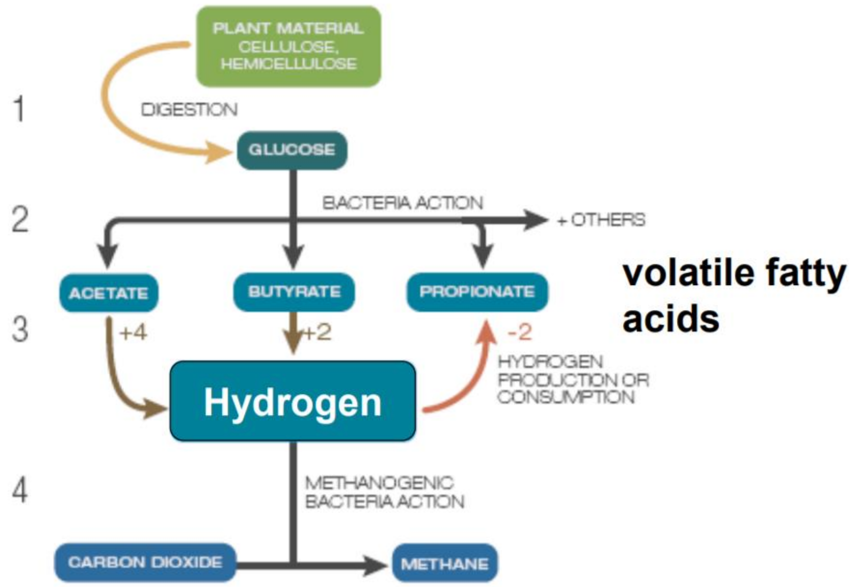

Figure 2 – Summary of rumen biochemistry *(Beauchemin & McGinn, 2011)*

3 Carbon Trust Validation Opinion

We consider that:

- Optigen has no negative effect on animal performance when used in preference to other sources of nitrogen (e.g. soybean meal)
- In some cases, Optigen can have an enhanced effect on animal performance. This can be seen through:
    - Decreased DMI per kg output
    - Increased body weight gain
    - Improved milk yield
- In terms of ruminant livestock, it is likely that enhanced animal performance will lead to a reduction in methane emissions against a valid baseline as a result of improvements in rumen efficiency.
- When soybean meal is replaced with Optigen the risk of a high carbon footprint is significantly reduced, particularly if the farmer does not know the origin of their soybean meal within their supply chain and whether land use change has been involved in its production.

Note 1:

We strongly recommend that farmers test Optigen for at least 6 weeks before committing to long-term use, due to the wide variability of farm conditions.

Note 2:

To reflect the potential importance of diet contents and alternative energy utilisation, the on-farm test should ideally include each broad type of diet used on farm (e.g. one for the winter or during finishing if concentrates predominate, and one focussed on forage when grazing in the summer).

Note 3:

For some farms it may be impractical to completely replace soybean meal with Optigen (e.g. 33% soybean meal: 66% Optigen), positive effects are seen when used in combination, although generally not as significant as a complete replacement of soybean meal with Optigen. This would also have associated effects of the upstream carbon footprint of the products.

Note 4:

There may be associated reductions in Nitrogen excretion as a result of Optigen supplementation.

Note 5:

Considering the amount of Optigen required to replace soybean meal as a source of nitrogen, the carbon footprint of Optigen (see Section 2.3) is generally significantly lower than of soybean meal, even if it is unknown whether land use change affected cultivation.

4 Carbon Footprinting of Farms

In order to provide companies with sufficient information to enable livestock carbon calculations to take account of Optigen's benefits, the following should be taken into account:

- Firstly, what level of analysis regarding benefits would a company managing a carbon calculator require?
- Secondly, what are the implications for this company in terms of data and calculation changes?

4.1 Analysis for GHG calculators

The evidence desired to enable the inclusion of Optigen in farm GHG mitigation recommendations and modelling should:

- Be based upon statistical principles, including the role of a viable control group on-farm (i.e. animals without the additive for comparison)
- Include on-farm demonstration examples
- Highlight the impact (positive or negative) on animal performance
- Include the price of Optigen per kg CO_2e saved compared to other GHG mitigation options
- Include the carbon footprint of the protein source that Optigen would be replacing for comparison (e.g. soybean meal)

Our validation opinion, summarised in section 3 above, considers that the top three bullet points have been met by the results described below. Alltech may wish to provide farmers with some additional information in order to satisfy the fourth point regarding comparable cost of mitigation. In this context, a farmer may have a GHG reduction target to achieve in a variety of alternative ways:

- Increase grazing period (free?)
- Improve genetic quality of the herd (potentially expensive but with important financial benefits)
- Agro-chemical efficiency (e.g. fertiliser reduction – free?)
- Investment in less polluting manure management facilities (expensive)

There are several free or financially beneficial options available to farmers to reduce their GHG emissions, which may be considered alongside Optigen. However, Optigen should be considered additional in its impact and, following a successful on-farm test, would be expected to enhance productivity too. Therefore, we believe it should be considered an important GHG mitigation option for a well-managed dairy or beef enterprise.

4.2 Implications for GHG calculators

The following is a non-exhaustive list of the potential changes, which could be made to existing dairy or beef carbon calculators.

- Record that the farmer is using Optigen and in what ways (e.g. all cows, for the past year). If it has only been recently adopted, then the impacts should be considered limited (i.e. only apply 50% of the potential gain), as the full effects may only be detected in farm audit data after multiple months of use.
- Review the feed and productivity data prior to starting use of Optigen to confirm any (positive or negative) change in feed efficiency, weight gain/conformity, and milk yield or quality. Data should preferably be at least monthly but annual data is suitable if Optigen has been used for a significant length of time and monthly data is unavailable.
- Review the difference in carbon footprint as a result of supplementing Optigen in preference to the other protein source (e.g. soybean meal, urea etc.)
- Reference improved feed utilisation but no increase in CH_4 in the calculations, which could take the form of:
    - Reduce assumptions about feed intake needs for a given modelled energy requirement
    - Acknowledge that the farm has taken steps to improve feed efficiency but only measure this indirectly via the improved relationship between measured feed intake and milk production or DLWG. No calculation changes are required for this approach, other than recording use of Optigen.
- Directly reduce the estimated N excretion rate, linked to increased N retention in meat and/or milk.
- Simply acknowledge that it is likely that feed efficiency will have improved and aim to measure changes in feeding and milk production data accordingly. Any changes may then be attributed to Optigen
    - The expected increase in weight gain, milk yield and/or fat/protein content may be used as a guide to understanding any changes

5 Evidence Base

5.1 Published Research

In reviewing the literature, we referred to academic publications, industry reports, and also some additional generally available material. However, we did not conduct an exhaustive review of all the publically available evidence.

This section briefly reviews a set of research papers, posters, providing a list of relevant features to enable comparison.

In general, the approach taken analysed data from in vivo (live animals in normal surroundings and their response to a changed diet containing Optigen). A range of geographies apply, although typically the similar breeds were used within species.

Section 5.2 below is a set of (non-exhaustive) academic papers and presented work describing the experimental conditions and results of on farm trials, which included the addition of Optigen. Section 5.3 and 5.4 review further papers provided to Carbon Trust in relation to the efficiency of Optigen and its effect on animal performance

5.2 Optigen vs soya

5.2.1 Abreu *et al.,* (2012)

	Report-specific information
Reference	Performance of lactating crossbreed cows on tropical pasture fed by supplements with soybean meal and Optigen or urea (Abreu *et al.,* 2012)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein-Zebu
Number of animals	21
Feed	Tropical pasture
Dose	2%, 4%, 6%
Trial period	3 x 21 days
Body weight change	Not studied
DMI	No effect ($P > 0.05$)
FCE	Not studied
Milk yield	Report-specific information

No significant effect observed in providing soya vs Optigen as source of NPN in the diet of Holstein-Zebu cows.

5.2.2 Bourg *et al.,* (2012)

	Report-specific information

Reference	Effects of a slow-release urea product on performance, carcass characteristics, and nitrogen balance of steers fed steam-flaked corn (Bourg *et al.,* 2012)	
Active ingredient	Optigen	
Geography	USA	
Fermentation location	In vivo	
Species (breed)	Angus crossbreed steers	
Number of animals	60	
Feed	Steam flaked corn based diet	
Dose	1.3% NPN	
Trial period	105 days	
	Experiment 1	Exp 2: Nitrogen Balance
Body weight change	Urea: 357-482 kg; OP: 344-489 kg	
DMI	Urea: 8.7 kg/d; OP: 8.1 kg/d	CTRL: 7.2 OP: 7.26 Urea: 7.75
FCE		

A generally positive effect on DMI was seen, DMI intake was reduced in Experiment 1 for steers fed Optigen and also compared favourably to urea intake as NPN source for Experiment 2. This is likely to lead to an increase in feed efficiency. Body weight was also not negatively impacted by the use of Optigen as a source of NPN. Overall little difference was seen between Optigen and urea supplementation as the source of NPN.

5.2.3 Neal *et al.,* (2014)

	Report-specific information
Reference	Feeding protein supplements in alfalfa hay-based lactation diets improves nutrient utilization, lactational performance, and feed efficiency of dairy cows (Neal *et al.,* 2014)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Holstein-Zebu
Number of animals	12
Feed	Alfalfa hay based
Dose	0.49% DM
Trial period	4 x 28 days
Body weight change	Non significant increase
DMI	Decrease: 5% ($p > 0.05$)
FCE	Not studied
Milk yield	Increase: 2.5% ($p > 0.05$)

Replacing soybean meal with Optigen can improve nutrient utilisation in dairy cows. This is shown by increased milk yield and decreased DMI intake, although body weight gain per day is lower than the control group. It is likely the increased supply of amino acids could lead to an increase in protein yield. In addition there is a reduction in Nitrogen excretion which would have associated environmental benefits when Optigen is supplemented.

5.2.4 Santiago *et al.,* (2015)

	Report-specific information			
Reference	Slow-release urea in diets for lactating crossbred cows (Santiago *et al.,* 2015)			
Active ingredient	Optigen			
Geography	Brazil			
Fermentation location	In vivo			
Species (breed)	Holstein-Zebu			
Number of animals	12			
Feed	Corn			
Trial period	15 days per period			
Dose	Control	34% SRU	66% SRU	100% SRU
Body weight change	Not studied	Not studied	Not studied	Not studied
DMI	18.2	18.44	18.76	17.99
FCE	0.74	0.77	0.72	0.66
Milk yield	13.39	13.88	13.44	12.05

This study suggests that complete replacement of soybean meal with Optigen can have no significant negative effect on a number of factors that are key metrics in animal performance. The greatest improvements in efficiency were seen for this at 100% Optigen.

5.2.5 Goncalves *et al.,* (2014)

	Report-specific information
Reference	Nitrogen metabolism and microbial production of dairy cows fed sugarcane and nitrogen compounds (Goncalves *et al.,* 2014)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holandes-Zebu crossbreed
Number of animals	8
Feed	70% forage, 30% concentrate
Dose	(UC) 100%; ULL 44 UC = 56% / 44% ULL, ULL 88 UC = 12% / 88% ULL
Trial period	4 x 21 days
Body weight change	No significant change
DMI	No significant change
FCE	No significant change
Milk yield	No significant change

The feeding of urea instead of soybean meal was proved to have a similar effect as a normal soybean meal based diet. This suggests Optigen can provide the necessary levels of nitrogen when compared to soybean meal.

5.2.6 Silveira *et al.*, (2012)

	Report-specific information
Reference	Partial replacement of soybean meal by encapsulated urea in commercial dairy herds (Silveira *et al.*, 2012)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	68
Feed	
Dose	160g of Optigen
Trial period	21 days
Body weight change	No significant change
DMI	Not studied
FCE	Not studied
Milk yield	Slight increase ($p = 0.62$)

Replacing soybean with Optigen did not lower performance.

5.2.7 Holder *et* al., (2013)

	Report-specific information
Reference	Effects of replacing soybean meal N with NPN from urea or Optigen® on intake and performance of receiving cattle (Holder *et al.,* 2013)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Angus crossbreed steers
Number of animals	288
Feed	Corn silage, fescue hay
Dose	0%, 0.45%, 0.9%, 1.35%
Trial period	42 days
Body weight change	No significant change
DMI	Decreased
FCE	Not studied
Milk yield	Not studied

Optigen had a higher BW gain than urea in the later stages of the trial. Indications of improved production response with Optigen intake. No adverse effect on production parameters.

5.2.8 Ferres *et al.,* 2010

	Report-specific information
Reference	Replacement of vegetable protein with Optigen® at a commercial feedlot in Uruguay (Ferres *et al.,* 2010)
Active ingredient	Optigen
Geography	Uruguay

Fermentation location	In vivo	
Species (breed)	Hereford steers	
Number of animals	312	
Feed	12.4% CP, 70% TDN	
Dose	8.9%	
Trial period	66 days	
	Control	Optigen
Body weight change (kg/d)	1.63	1.84 (p=0.011)
DMI	12.25	12.52
FCE	Not studied	Not studied
Milk yield	Not studied	Not studied

Replaced supplemental vegetable protein with Optigen and saw a significant, positive effect. Greater body weight gain. Improved feed conversion was also observed by 9.3%.

5.2.9 Corte *et al.,* 2010

	Report-specific information	
Reference	Effects of different non-protein nitrogen sources on the performance and carcass characteristics of feedlot Nellore steers (Corte *et al.,* 2010)	
Active ingredient	Optigen	
Geography	Brazil	
Fermentation location	In vivo	
Species (breed)	Nellore steers	
Number of animals	46	
Feed	78.5% concentrate	
Dose	1.8% Optigen (6% SBM)	
Trial period	66 days	
	Control	Optigen
Body weight change (kg/d)	1.59	1.46
DMI	12.25	12.52
FCE	Not studied	Not studied
Milk yield	Not studied	Not studied

The replacement of soybean meal with Optigen saw no negative performance effects. When Optigen and urea were combined it saw the most significant positive effect on cattle growth and efficiency. This was also reflected in the carcasses, where no adverse effects of these replacements were noted.

5.2.10 Agovino *et al.,* (2013)

	Report-specific information
Reference	Effect of Optigen® on finishing heifers (Agovino *et al.,* 2013)
Active ingredient	Optigen
Geography	Ireland

Fermentation location	In vivo	
Species (breed)	Heifers	
Number of animals	60	
Feed	Standard mixed rations	
Dose	0.45% Optigen	
Trial period	Not specified	
	Control	Optigen
Body weight change (kg/d)	1.18	1.41
DMI	Not studied	Not studied
FCE	N/a	Improved ($p<0.05$)
Milk yield	Not studied	Not studied

Improved performance when SBM is replaced, while also benefitting from decreased cost as a result.

5.2.11 Sgoifo Rossi *et al.,* (2013)

	Report-specific information	
Reference	Effect of Optigen® on finishing heifers (Agovino *et al.,* 2013)	
Active ingredient	Optigen	
Geography	Italy	
Fermentation location	In vivo	
Species (breed)	Charolais bullocks	
Number of animals	56	
Feed	Total mixed diet	
Dose	46 g/h/d Optigen	
Trial period	100 days	
	Control	Optigen
Body weight change (kg/d)	1.46	1.63 ($p > 0.05$)
DMI	11.9	10.64
FCE		Improved
Milk yield	N/A	N/A

No negative effect on performance as a result of Optigen supplementation. Improved metrics of body weight change and DMI are seen as a result of Optigen.

5.2.12 Goncalves *et al.,* (2007)

	Report-specific information
Reference	Optigen® II in supplements fed to Nelore beef steers receiving low quality Brachiaria brizantha hay (Goncalves *et al.,* 2007)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Nelore steers
Number of animals	8
Feed	Total mixed diet

Dose	46 g/h/d Optigen
Trial period	11 days
Body weight change (kg/d)	Increase efficiency
DMI	Decreased
FCE	Not studied
Milk yield	Not studied

Urea replacement with Optigen showed improved nutrient digestibility and no negative effect on animal performance

5.2.13 Manella *et al.*, (2007)

	Report-specific information	
Reference	Replacing vegetable protein in supplements with Optigen® II in beef steers fed sugar cane silage as the sole forage (Manella *et al.*, 2007)	
Active ingredient	Optigen	
Geography	Brazil	
Fermentation location	In vivo	
Species (breed)	Beef steers	
Number of animals	120	
Feed	Corn based	
Dose	1.8% Optigen	
Trial period	Not specified	
	Control	Optigen
Body weight change (kg/d)	496	501 (non significant increase)
DMI	Not studied	Not studied
FCE	Not studied	Not studied
Milk yield	Not studied	Not studied

Difference in diet between control and 'Optigen' diet was quite significant, not just pure Optigen replacement. No negative effect on animal performance was observed

5.2.14 Sinclair *et al.*, (2011)

	Report-specific information
Reference	The partial replacement of soyabean meal and rapeseed meal with feed grade urea or a slow-release urea and its effect on the performance, metabolism and digestibility in dairy cows (Sinclair *et al.*, 2011)
Active ingredient	Optigen
Geography	UK
Fermentation location	In vivo
Species (breed)	Holstein-Friesian
Number of animals	42
Feed	Grass and maize TMR
Dose	5.5 g/kg DM
Trial period	3 35 day periods

	Control	Optigen
Body weight change (kg/d)	0.01	0.38
DMI	22.8	22.1
FCE	N/A	Decreased compared to control
Milk yield	34.1	33.6 (non-significant decrease- $p > 0.05$)

No significant effect on diet digestibility or milk performance was observed in this study when soybean meal was partially replaced by soybean meal. Increased efficiency of Nitrogen conversion into milk protein was observed when Optigen was added, notably more effective than normal urea supplementation.

5.2.15 Kowalski *et al.,* (2010)

	Report-specific information	
Reference	On farm impact: Optigen® in diets fed high yielding dairy cows (Kowalski *et al.,* 2010)	
Active ingredient	Optigen	
Geography	Poland	
Fermentation location	In vivo	
Species (breed)	Not indicated	
Number of animals	42	
Feed	Grass and maize TMR	
Dose	5.5 g/kg DM, decreased soybean	
Trial period	90 days	
	Control	Optigen
Body weight change (kg/d)	Not studied	Not studied
DMI	0	+1.1 kg/day
FCE	Not studied	Not studied
Milk yield	34.1	+ 1.6 kg/day, $p > 0.05$

As well as increasing milk yield, this study showed no significant effect on milk composition, with a suggestion of more efficient rumen processes due to decreased levels of undigested feed in manure.

5.2.16 Garcia-Gonzalez *et al.,* (2007)

	Report-specific information
Reference	Optigen® II is a sustained release source of non-protein nitrogen in the rumen (Garcia- Gonzalez *et al.,* 2007)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Steers
Number of animals	4
Feed	Total mixed diet
Dose	0.12 g/kg/day Optigen
Trial period	24 days

Body weight change (kg/d)	Increase efficiency
DMI	Not studied
FCE	Not studied
Milk yield	Not studied

The study showed that Optigen provides a sustained source of NPN for 8 hours post ingestion. This compares favourably to urea and suggests the effects of Optigen will be considerable and long-lasting.

5.3 Additional studies (beef)

	Report-specific information
Reference	Effects of supplemental urea sources and feeding frequency on ruminal fermentation, fiber digestion, and nitrogen balance in beef steers (Alvarez Almora *et al.,* 2012)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Steers
Number of animals	8
Feed	Alamo switchgrass hay, general supplement
Dose	400 g/kg of daily DM- included Optigen
Trial period	21 days
Body weight change	Not affected
DMI	Not affected (urea vs Optigen)
FCE	Not studied
N excretion	Not affected

5.3.1 Alvarez Almora *et al.,* (2012)

Although decreased rumen ammonia concentration was found following supplementation with Optigen, there was no clear effect on animal efficiency or nitrogen utilisation. Providing a consistent (2 hourly instead of daily) dose of the supplement appeared to provide an increased digestibility of dry matter, although no significant effect was found.

5.3.2 Benedeti *et al.,* (2014)

	Report Specific Information			
Reference	Soybean meal replaced by slow release urea in finishing diets for beef cattle (Benedeti *et al.,* 2014)			
Active ingredient	Optigen			
Geography	Brazil			
Fermentation location	In vivo			
Species (breed)	Crossbred steers			
Number of animals	8			
Feed	Corn silage, corn meal; Optigen replaced SBM (low and high concentration- low 400g concentrate/kg of DM, high 800 g			
Dose	0% Optigen	33%	66%	100%
Trial period	4 x 15 days	4 x 15 days	4 x 15 days	4 x 15 days

Body weight change	No change	No change	No change	No change
DMI (kg)	8.96	8.91	8.45	8.46
FCE	Not studied	Not studied	Not studied	Not studied
N excretion				

A linear decrease of DM intake as a function of BW was detected when Optigen was added. No obvious effect was found on digestibility. Optigen increased N urinary excretion and decreased N intake, suggesting an effect on N levels and digestibility. This is linked to the decreased intake of DM as a result of Optigen supplementation, although increased urinary N loss may be due to reduced dietary N utilisation. It does show that Optigen is an adequate replacement of soybean meal.

	Report-specific information
Reference	Optigen improves performance and profitability in intensive beef cattle production (Cabrita, 2011)
Active ingredient	Optigen
Geography	Portugal
Fermentation location	In vivo
Species (breed)	Steers
Number of animals	49 Charolais x Limousine
Feed	Wheat straw and compound feed
Dose	4 kg/t of feed
Trial period	60 days
Body weight change	Increased daily weight gain
DMI	Reduced
FCE	Increased
N excretion	Not affected

5.3.3 Cabrita, 2011

Optigen improved daily weight gain while leading to a reduction in DMI, which is suggestive of positive effect of Optigen on efficiency in cattle.

5.3.4 Ceconi *et al.,* (2015)

Slow release quality of Optigen is noted in this study, in comparison to urea as the protein source. VFA concentration was not affected by Optigen although this is only indirectly linked to enteric methane production and therefore not indicative of the influence on methane emissions. No obvious difference between Optigen and other sources of protein.

	Report-specific information
Reference	Voluntary intake of low-quality hay in confined beef cattle fed non-protein nitrogen (Franco *et al.,* 2011)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Crossbreed Steers
Number of animals	4
Feed	Hay
Dose	0.6 % of feed
Trial period	Unknown
Body weight change	Not studied
DMI	Reduced
FCE	Not studied
N excretion	Not studied

5.3.5 Franco *et al.,* (2011)

Optigen, either alone or in conjunction with conventional urea was shown to increase DMI from a low quality hay food source.

	Report-specific information
Reference	Performance effects of Optigen in beef calves (Friedrichkeit & Wetscherek, 2011)
Active ingredient	Optigen
Geography	Austria
Fermentation location	In vivo
Species (breed)	Calves
Number of animals	48
Feed	Majority corn
Dose	0.05-0.17 kg/d
Trial period	56 days
Body weight change	Increased daily weight gain ($p > 0.05$)
DMI	Reduced ($p < 0.05$)
FCE	Increased
N excretion	Not affected
Body weight change	Increased daily weight gain
DMI	Reduced
FCE	Increased
N excretion	Not affected

5.3.6 Friedrichkeit & Wetscherek, (2011)

	Report-specific information
Reference	Slow-release Urea in Supplement Fed to Beef Steers (Goncalves *et al.,* 2015)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Nellore Steers
Number of animals	8
Feed	Hay and concentrate
Dose	0.6 % of feed
Trial period	11 x 4 days
Body weight change	Not studied
DMI	Reduced
FCE	Not studied
N excretion	Not studied

Increased FCE, daily weight gain and decreased DMI were all observed as a result of Optigen supplementation in growing beef calves.

5.3.7 Goncalves *et al.,* (2015)

	Report-specific information
Reference	The effects of degradable nitrogen level and slow release urea on nitrogen balance and urea kinetics in Holstein steers (Holder *et al.,* 2015)
Active ingredient	Optigen (+Synovex)
Geography	USA
Fermentation location	In vivo
Species (breed)	Holstein Steers
Number of animals	8
Feed	Hay and concentrate
Dose	15 g/gkg DM
Trial period	26 days
Body weight change	Increased for higher dose of Optigen
DMI	Reduced
FCE	Not studied
N excretion	Increased

No negative impact of using Optigen, increased digestibility when substituting regular urea. Evidence of increased efficiency.

5.3.8 Holder *et al.,* (2015)

Increasing digestible intake protein will increase N excretion due to higher urea uptake, however this may increase diet digestibility. N metabolism is generally driven by N intake.

5.3.9 Marchesin *et al.,* (2007)

	Report-specific information
Reference	REPLACEMENT OF PROTEIN AND NON-PROTEIN NITROGENWITH ENCAPSULATED UREA (OPTIGEN® II) IN NELORE MALES AND FEMALES (Marchesin *et al.,* 2007)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Nelore
Number of animals	8
Feed	Hay and concentrate
Dose	0, 25, 65, 100% Optigen
Trial period	140 days
Body weight change	Highest at 25% Optigen
DMI	Reduced
FCE	Not studied
N excretion	Not studied

Optimum urea replacement with Optigen was found to be 25%, giving the greatest increase in DLWG. In addition, complete replacement of urea with Optigen was shown to be a viable economic option at 30% replacement.

5.3.10 Miranda *et al.,* (2007)

	Report-specific information
Reference	Effect of different carbohydrate and non protein nitrogen sources in supplements on intake and in situ degradability of steers. (Miranda *et al.,* 2007)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Steers
Number of animals	5
Feed	Hay and oats
Dose	600 g/animal/day
Trial period	140 days
Body weight change	No effect
DMI	Slight decrease
FCE	Not studied
N excretion	Not studied

There was no effect noted in terms of replacing urea and soyhulls with Optigen. They all showed similar levels of DMI. No negative effect was seen on intake and ruminal digestibility.

5.3.11 Simeone *et al.*, (2009)

Report-specific information	
Reference	Replacing sunflower meal with Optigen® in high grain feedlot diets: response of calves and steers (Simeone *et al.*, 2009)
Active ingredient	Optigen
Geography	Uruguay
Fermentation location	In vivo
Species (breed)	Hereford calves and steers
Number of animals	60
Feed	High grain feedlot
Dose	42.1% N
Trial period	50 days
Body weight change	No statistically significant variation
DMI	Slight decrease
FCE	Not studied
N excretion	Not studied

Replacing sunflower meal with Optigen as the primary source of protein showed there was no negative effect of Optigen compared to sunflower meal on animal performance. No statistical significance of difference due to protein sources.

5.3.12 Wahrmund & Hersom, (2007)

Report-specific information	
Reference	Evaluation of Optigen® II addition to by-product supplements for forage-fed beef cattle (Wahrmund & Hersom, 2007)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Brahman cows and Angus steers
Number of animals	22 & 56
Feed	Hay
Dose	113 g Optigen
Trial period	50 days
Body weight change	Increase
DMI	Slight decrease
FCE	Not studied
N excretion	Not studied

Optigen was shown to be as effective a source of protein as urea. A positive effect (non-significant) was found on DMI, while it was noted that Optigen may function better with lower quality forages.

5.4 Dairy

5.4.1 Aguirre *et al.,* (2006)

	Report-specific information
Reference	Use Of A Slow Release Urea And Its Effects On Milk Yield And Composition Of Holstein (Aguirre *et al.,* 2006)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	34
Feed	Corn dominated
Dose	1% Optigen
Trial period	60 days
Body weight change	Increase
DMI	Decrease
FCE	Not studied
N excretion	Not significant

Optigen slows down solubility and N disappearance compares to soybean meal and urea. In addition Optigen supplementation resulted in higher NDF and ADF, due to the increased space given in the rumen as a result of Optigen supplementation.

5.4.2 Giallongo *et al.,* (2015)

	Report-specific information
Reference	Effects of slow-release urea and rumen-protected methionine and histidine on performance of dairy cows (Giallongo *et al.,* 2015)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	60
Feed	Corn & forage
Dose	0.4% of DM
Trial period	70 days
Body weight change	No change
DMI	No change
FCE	Not studied
N excretion	No significant increase

Supplementation of the MP-deficient diet with slow-release urea increased urinary urea-N excretion. No significant effect was observed on DMI or body weight change.

5.4.3 Inostroza *et al.,* (2010)

	Report-specific information
Reference	Effect of Optigen® on milk yield, composition, and component yields in commercial Wisconsin dairy herds (Inostroza *et al.,* 2010)
Active ingredient	Optigen
Geography	USA
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	148 average
Feed	TMR
Dose	114 g/cow/day
Trial period	70 days
Body weight change	Not studied
DMI	Not studied
FCE	Not studied
N excretion	No significant increase

Increased milk yield was observed as a result of Optigen supplementation, indicative of increased efficiency within the dairy cows studied.

5.4.4 Miranda *et al.,* (2018)

	Report-specific information
Reference	Effects of partial replacement of soybean meal with other protein sources in diets of lactating cows (Miranda *et al.,* 2018)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	8
Feed	TMR
Dose	0.75% of DM
Trial period	4 x 28 days
Body weight change	Not studied
DMI	Decreased ($p < 0.05$)
FCE	Not studied
N excretion	No significant increase

A significant decrease in DMI was measured with supplementation of Optigen, however no improvement in milk yield was recorded. There was a decrease in nitrogen intake when Optigen was added, however milk production efficiency was improved. The replacement of soybean meal with Optigen improved the efficiency of nitrogen utilization.

5.4.5 Muro *et al.,* (2011)

	Report-specific information
Reference	Field evaluation of concentrate diets formulated with Optigen® and urea as the main source of crude protein, compared with sunflower meal (Muro *et al.,* 2011)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	22
Feed	Hay
Dose	1.1% of DM
Trial period	75 days
Body weight change	Increased
DMI	Increased
FCE	Improved by 15%
N excretion	Not studied

Although DMI increased on average compared to the control, body weight gain was improved and FCE improved. It is worth noting that the diet including Optigen also included soybean meal as part of the sunflower meal replacement.

5.4.6 Santos *et al.,* (2009)

	Report-specific information
Reference	Response of lactating cows to partial replacement of soybean meal by Optigen® or urea (Santos *et al.,* 2009)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	18
Feed	TMR
Dose	1.1% of DM
Trial period	35 days
Body weight change	Increased
DMI	Decreased
FCE	Not studied
N excretion	No significant effect

Replacement of soybean meal with Optigen tended to increase the efficiency of converting feed into milk, resulting in similar milk yield with lower feed intake. No effect was seen on Nitrogen balance

5.4.7 De Souza *et al.,* (2009)

	Report-specific information
Reference	Partial replacement of soybean meal by Optigen®: Effects on milk yield and composition in lactating dairy cows (de Souza *et al.,* 2009)
Active ingredient	Optigen
Geography	Brazil
Fermentation location	In vivo
Species (breed)	Holstein
Number of animals	34
Feed	TMR
Dose	0.4% of DM
Trial period	60 days
Body weight change	Increased
DMI intake	Decreased
FCE	Not studied
N excretion	No significant effect

There was no significant treatment effect on daily production of milk, although milk yield was numerically greater with Optigen. The effect of treatment was seen throughout the 60 days of the study. This study only included partial replacement of soybean meal and not a complete replacement as some other studied have investigated.

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7 Appendix

7.1 Calculations for full lifecycle emissions of Optigen

2019 calculations adapted from workings provided by Amanda Gehman, modified by SR using updated emission factors									
Optigen	2019	[SR]							
			carbon footprint						
			g CO2/kg						
DM, %	CP, %DM	TDN, % (1)	Process (2)	urea (3)	coating (4)	transportati	total		
99	256	17.8	70	800.8	242.9	37	**1150.3**	g CO2/kg	
1	TDN calculated from NRC (2001) TDN 1x = tdNFC + tdCP + (tdFA x 2.25) + tdNDF - 7							total digestible nutrients	
	NFC, CP (true protein), NDF = 0 fat = 11								
	TDN = (11 x 2.25) - 7 = 17.75								
2	energy from natural gas and US-produced energy, overheads difficult to predict, site specific, typically small compared to emissions from ener								
	as per Kendon Jacobson (Alltech engineer) on Apr 17, 2013								
3	910 g/kg as used in model								
	urea = 910 * 0.88 (Optigen is 88% urea) =				800.8	EF from FeedPrint (Wageningen UR, 2017)			
4	use value for palm fat from model								
	palm fat = 2024 * 0.12 (Optigen is 12% coating) =				242.9	EF from Y.Schmidt (LCA 2.0, 2017)			
5	Optigen fed in UK is manufactured in Belgium								
	Artic : Belgium-Woolfox = 400km				34.1				
	Shipping Calais-Dover = 48 km				2.5				

7.2 Transport calculations

Transport emisssions		
Values from DEFRA guidelines for business reporting		
Belgium factory - Woolfox = 400km		
Serbia factory - Woolfox = 2090km		
Dover-Calais = 48km		
All artics, avg laden	0.08525	kg CO2e per tonne.km
All rigid , avg laden	0.21334	kg CO2e per tonne.km
RoRo ferry, avg	0.05166	kg CO2e per tonne.km
(kg CO2e per tonne.km = g CO2e per kg.km)		
Artic : Belgium-Woolfox = 400km	34.10	g CO2e per kg feed
Shipping Calais-Dover = 48 km	2.48	g CO2e per kg feed
Add emissions per kg Optigen	36.58	g CO2e per kg feed
Artic : Serbia-Woolfox = 2090km	178.17	g CO2e per kg feed
Shipping Calais-Dover = 48 km	2.48	g CO2e per kg feed
Add emissions per kg DEMP	180.65	g CO2e per kg feed
Transport onwards to the farm?		
Rigid truck : Woolfox to farm = 1	21.334	g CO2e per kg feed
alternatively feedprint say rule of thumb +10kgCO2e per kg feed for farm delivery		