Finnish Farmers' Adoption of Feed Additives for GHG Mitigation in Dairy Farming: Barriers and Perspectives

Adoption par les agriculteurs finlandais d'additifs alimentaires pour la réduction des émissions de gaz à effet de serre dans l'élevage laitier : obstacles et perspectives

Futtermittelzusätze zur Minderung von Treibhausgasen in der finnischen Milchviehhaltung: Barrieren und Perspektiven

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Introduction

The European Green Deal (European Commission, 2019) sets out a comprehensive strategy to achieve climate neutrality in the European Union (EU) by 2050. A key component of this initiative is the Farm-to-Fork Strategy (European Commission, 2020), which highlights the impact of food systems on climate change. The global food system is responsible for one-third of all greenhouse gas emissions (Crippa *et al.*, 2021), with a significant proportion emanating from livestock, especially from meat and dairy production. Mitigative actions taken in the cattle sector can therefore reduce the global warming effect substantially.

Finland is a northern EU Member State and dairy farming accounts for around 60 per cent of the country's agricultural emissions, contributing substantially to national greenhouse gas (GHG) emissions (Puupponen *et al.*, 2022). To mitigate climate change and achieve the EU's net-zero target by 2050 – that is, balancing greenhouse gas emissions with removal efforts – the Finnish government has established ambitious goals in its National Climate and Energy Strategy (Ministry of Economic Affairs and Employment of Finland, 2022). The strategy requires the agricultural sector to reduce GHG emissions by 29 per cent by 2035 compared to 2005 levels. The primary strategy to achieve the emissions reduction target relies on farmers adopting both existing and new climate change mitigation measures. The key measures include reducing emissions from peatlands, increasing carbon sequestration in non-organic soils, precision farming and reducing methane excretion from dairy cows. Newly emerged opportunities include using feed additives in grass-based systems to reduce methane emissions.

> "Bien que la sécurité des additifs alimentaires soit largement reconnue, leur efficacité en matière de réduction des émissions reste encore floue pour les agriculteurs."

According to the CAP plan for Finland (MMM, 2021), permanent grasslands and carbon cultivation currently play a key role in the country's agricultural contribution to climate change mitigation. Multi-species grasslands are particularly effective as carbon sinks. Conditionality requirements, such as maintaining permanent grasslands, protecting peatlands and prohibiting the burning of crop stalks, further support efforts to mitigate climate change. In addition, measures for managing manure can help reduce the release of greenhouse gases. However, policy measures specifically targeting animal diets remain limited. Conditionality measures include feed planning, which may indirectly address the climate impact of livestock feeding, while animal welfare measures encourage practices like grazing that may have additional environmental benefits. Meanwhile, Finnish dairy companies have voluntarily implemented mitigation initiatives such as calculation of carbon footprints of dairy farms, improvements in animal nutrition and carbon cultivation measures, including practices like regenerative farming, optimised grazing management, and the use of cover crops to enhance soil carbon sequestration.

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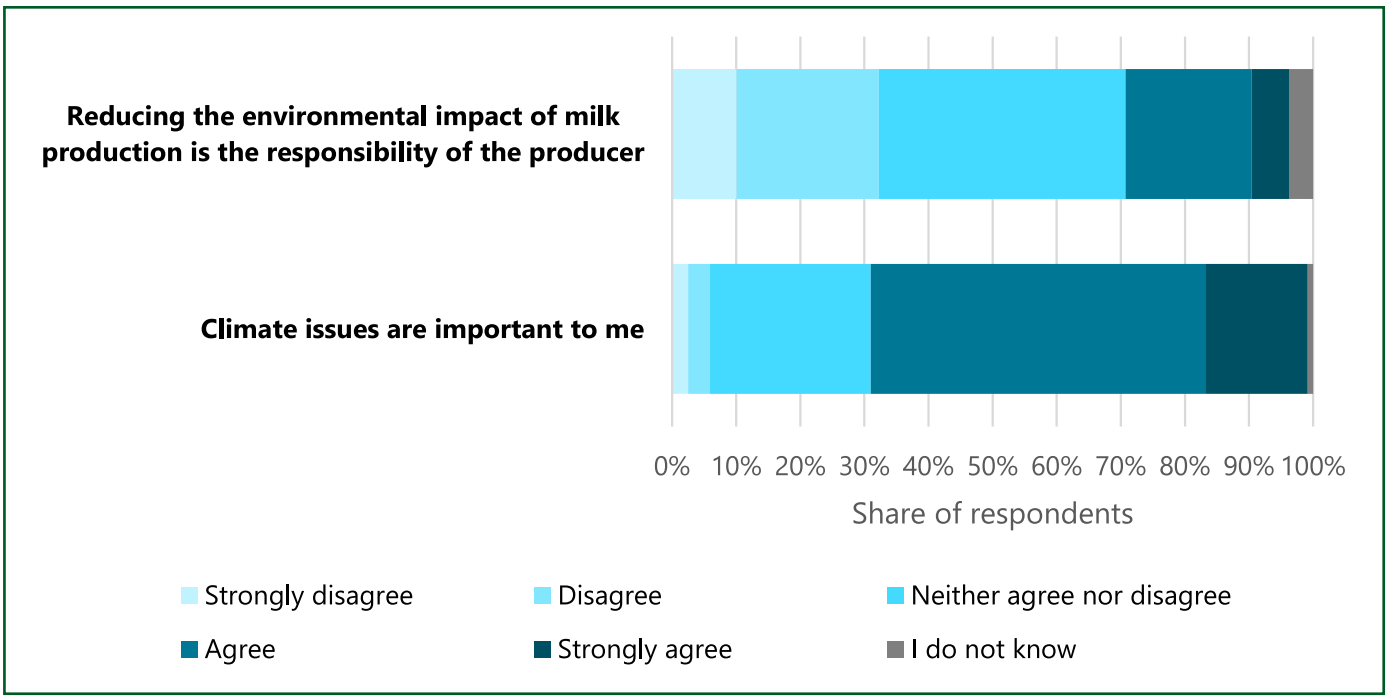
Feeding systems play a key role in how farmers manage emissions on modern dairy farms © Eetu Ahanen / Luke.

In 2022, the European Commission approved 3-nitroxypropanol (3-NOP, trade name Bovaer) as the first feed additive for cows, designed to reduce methane emissions from rumen. Trials using feed compositions from central Europe had shown that the potential reduction was up to about 30 per cent in enteric methane emissions from ruminants, measured using respiration chambers under controlled conditions (Roques *et al.*, 2024). With its promising potential, the use of 3-NOP is expected to increase in the coming years as farmers and policymakers alike seek effective solutions to reduce agricultural greenhouse gas emissions. In this context, some EU Member States, including Denmark and Belgium, have introduced new policy initiatives to promote the use of feed additives. However, for such policy measures to be successful, it is critical to understand farmers' perspectives on the adoption of emission-reducing feed additives. Key barriers, such as economic considerations, potential impacts on production, and the availability of information and support, need to be addressed to encourage widespread adoption. To contribute to this understanding, we conducted a study focused on farmers' views of feed additives aimed explicitly at reducing greenhouse gas emissions, such as 3-NOP. The practical adoption of theses additives faces several challenges, including limited information, uncertainty about their effectiveness, and cost. This study explores farmers' perceptions to help identify these barriers. By incorporating this feedback, policymakers can better support the integration of feed additives into farming practices, ultimately contributing to the achievement of climate goals set forth by the EU and individual Member States. This article aims to provide insights to facilitate this understanding, ensuring that the adoption of novel feed additives and other sustainable practices is both practical and beneficial for farmers.

Data and method

We sent an electronic questionnaire to 2,000 randomly selected dairy farmers in Finland in July 2023, with a response rate of 10 per cent (203 completed questionnaires). In addition, our study included a group of early adopters who had volunteered to participate in a farm-level 3-NOP feeding trial organised in 40 dairy farms by dairy company Valio in spring 2023. The selection of adopters was further refined through collaboration with A-Rehu, a Finnish feed manufacturer. The selected farms were Valio farms that were also A-Rehu customers and met specific criteria, including the use of a total mixed ration feeding system and a herd size of over 50 cows. Eligible farms were contacted by phone, and the majority showed a positive attitude toward participating in the pilot study. The same electronic questionnaire was sent to this group earlier, in spring 2023. Almost all of them (36) returned the questionnaire. This brought the total sample size to 239. Eight farms were removed from the random sample as they were also in the adopters' sample. The survey focused mainly on farmers' attitudes towards reducing methane emissions, mainly through the use of feed additives (3-NOP) and the role of dairy production in climate change mitigation. The study also focused on the personal, economic and regulatory factors that may influence farmers' adoption of these practices.

Figure 1: Farmers' views on climate concerns and environmental responsibility in milk production



The adopters had an average of 116 dairy cows and 176.7 hectares of arable land, while the non-adopters had an average of 64 dairy cows and 110.2 hectares of arable land. In our sample, farms, especially those that had adopted 3-NOP, were significantly larger than the national average. Finnish dairy farmers had an average of 52 dairy cows in 2023. Moreover, 27 per cent of respondent farmers were younger than 40 years, while only 3 per cent were older than 65 years. The farmers in our data were younger than the average Finnish farmer, as nearly one-fifth of Finnish farmers are older than 65 years.

In the following sections, we first present descriptive information about the results and then compare whether early adopters enrolled in the study were different from the random sample.

Farmers' opinions on climate responsibility in dairy production

The data suggest that our respondents were concerned about agricultural GHG emissions and climate change. Farmers' views were assessed with a series of statements based on a 5-point Likert scale. Figure 1 shows that 68 per cent of the respondents agreed or strongly agreed that climate issues are important. However, only 25 per cent of them thought (strongly agree and agree responses) that reducing the environmental impact of milk production is the responsibility of the producer.

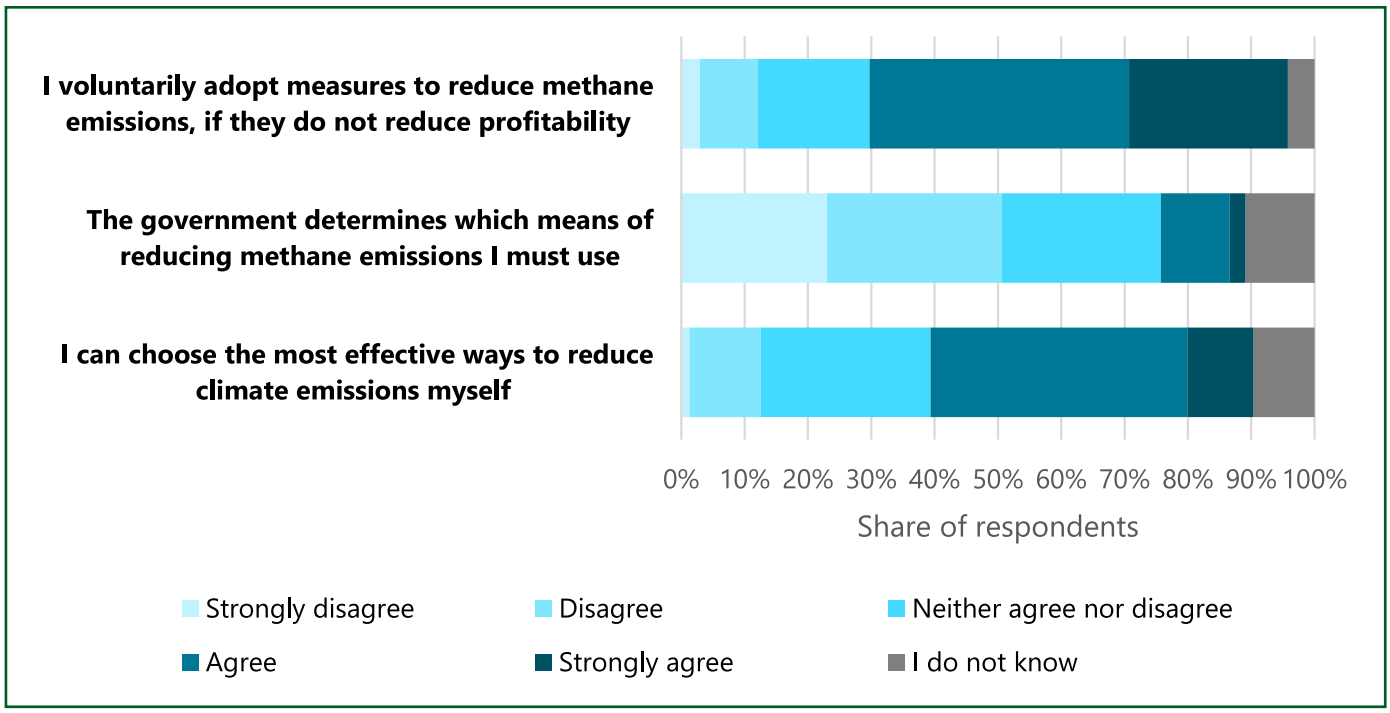
> "Obwohl die Sicherheit von Futtermittelzusatzstoffen weithin anerkannt ist, ist ihre Wirksamkeit bei der Verringerung von Emissionen für Betriebsleitende immer noch unklar."

A closer look at the attitudes of the farmers towards the reduction of methane emissions (Figure 2) shows that about half of the respondents thought that it is up to the individual farmer to choose the most appropriate methods to reduce environmental emissions. This was supported by the result that two thirds of respondents were already using voluntary means to reduce methane emissions. This suggests that they were not only confident in identifying effective methods but were also willing to implement such methods as long as they do not affect farm profitability. This confidence has most likely been built through their direct experience and knowledge of their specific agricultural practices and local conditions. This may translate into resistance to external dictates especially if farmers believe these are less effective or interfere with their independence. Moreover, half of respondents disagreed or strongly disagreed that the government should decide the methods for reducing methane emissions.

Farmers' attitudes toward farm profitability and general emissions reduction measures

While climate issues were important to two-thirds of respondents, economic considerations, especially farm profitability, were more influential in setting priorities, making environmental concerns less prominent. While about 25 per cent of the respondents disagreed or strongly disagreed that profitability should

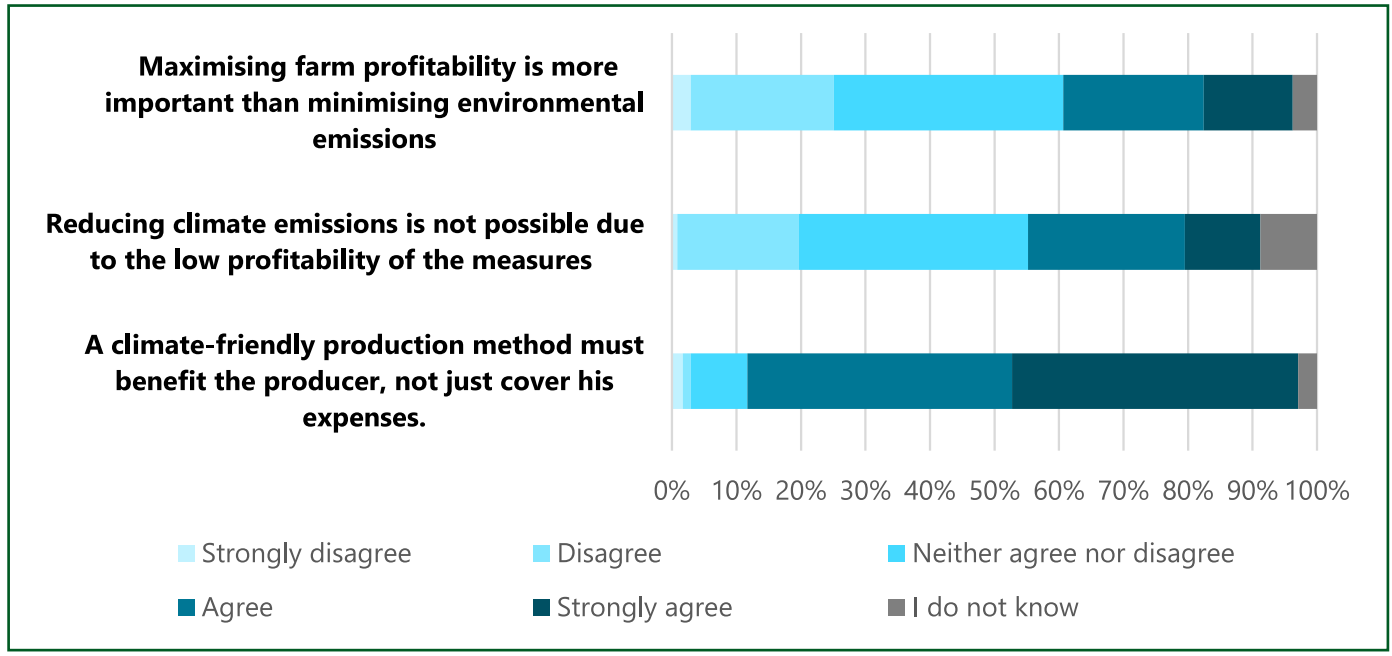
Figure 2: Farmers' attitudes toward general emissions reduction measures



come first, more than 35 per cent agreed or strongly agreed with the statement, so that a substantial portion of farmers still saw profitability as a key priority. The questions in this subsection referred to farmers' perceptions of emissions reduction efforts in general, not to the use of specific practices or technologies. Accordingly, a substantial share of respondents questioned the economic feasibility of reducing climate emissions under current practices: 36 per cent of respondents either agreed or strongly agreed that reducing climate emissions is impossible due to the low profitability of measures. This finding is not surprising, as farm management decisions are typically guided by economic considerations. This view (linking decision-making to economic factors) was dominant especially among those who indicated that their overall profitability is low.

This is also an affirmation of the consensus in the literature that it is important to promote 'win-win' strategies for profit and the environment (Che *et al.*, 2023; Pannell and Claassen, 2020). However, the high number of 'neutral' responses suggests a gap in knowledge or understanding, and that the issue involves tradeoffs and complexities. Hence there is a need to convince the farmers of the benefits of

Figure 3: Farmers' perspectives on economic viability and prioritisation in climate-friendly agricultural practices



environmentally desirable measures, given that it is their perception and not the actual benefits that govern the adoption of these measures (Chavas and Nauges, 2020). The idea of this 'win-win' strategy is consistent with our data, where a substantial majority (85.4 per cent of respondents agree and strongly agree) support the idea that environmentally friendly practices need to be economically advantageous to producers, not just break-even solutions. This suggests a preference for sustainability measures that enhance or at least maintain economic viability (Figure 3).

Farmers' perspectives on feed additives for reducing methane emissions

Figure 4 illustrates farmers' opinions on the effectiveness and safety of feed additives. The data revealed a distinct difference in farmers' perceptions between these two aspects. On one side, the majority of respondents agreed that the feed additives are safe, with two-thirds either strongly agreeing or agreeing that these additives are safe for people and the environment. This is unsurprising, because the use of feed additives is common in livestock farming, supported by extensive research and regulated to ensure safety for both the animals and the end consumers (Hutjens, 1991). In contrast, the effectiveness of feed additives in reducing climate emissions evoked more ambivalence and uncertainty among the respondents. Almost 60 per cent of the surveyed farmers neither agreed nor disagreed, or stated 'I do not know', indicating substantial uncertainty. This divergence between the two aspects may stem from variations in information dissemination or the perceived evidence regarding the safety of feed additives and their effectiveness in reducing emissions, with the latter being a relatively new issue for most of the agricultural community.

Perceived obstacles to the adoption of feed additives

To explore whether some potential barriers to adoption of feed additives that reduce methane emissions are significantly different between adopters and non-adopters, we performed the nonparametric Wilcoxon test. The test compares the median linearised scores of each subgroup and does not assume any distributional properties of the underlying variables in the analysis. The test results are shown in Table 1.

Well-educated farmers should understand the agri-environmental challenge; hence, they become more willing to adopt new and environmentally friendly management techniques (Wilson and Hart, 2000). Consistently, adopters have been found to have a significantly higher level of education than non-adopters. Studies have shown that women farmers are more environmentally sensitive and environmentally active than men, specifically in organic farming, sustainable agricultural practice and alternative agriculture (Ball, 2020; Glazebrook *et al.*, 2020). However, the findings of Table 1 do not suggest this, as variation was established between the two groups in which the adopters had a substantially lower proportion of women farmers. An explanation may be that women have a negative perception toward the use of chemical feed additives, which reduces their likelihood of use on the farm.

In general, farmers adopt new technologies based on the perceived benefits of the technology (Chavas and Nauges, 2020). Based on this assumption, the decision by farmers to adopt feed additives aimed at reducing emissions is probably influenced by a combination of perceived benefits across economic,

Figure 4: Farmers' perceptions of the safety and effectiveness of feed additives in emission reduction

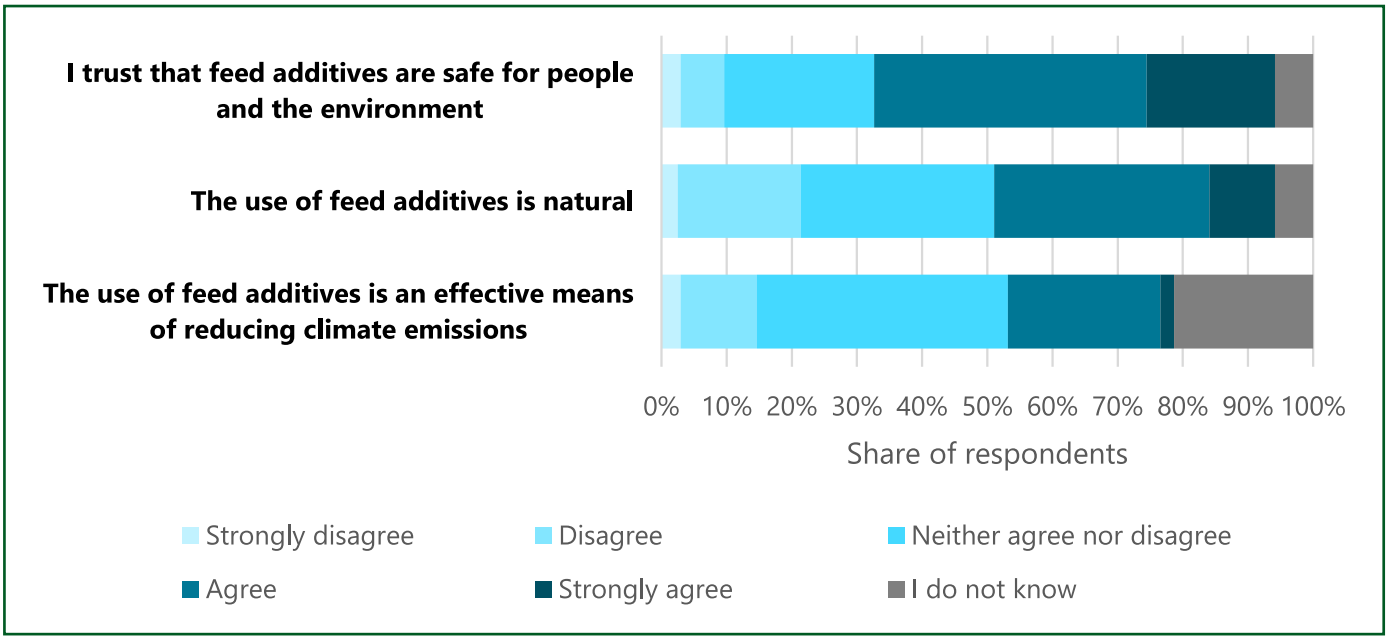


Table 1: Comparison of median scores for barriers to adopting feed additives between adopters and non-adopters using the Wilcoxon test. A higher score indicates higher importance of the barrier factor

Variables	Unit	Adopters	Non-adopters	p-value Wilcox test
Education				
Elementary school	Percentage	0	4.9	***
Secondary education		30.6	55.7	
Lower university degree		52.8	31.5	
Higher university degree		16.6	7.9	
Gender				
Female	Percentage	8.3	24.1	**
Male		91.7	75.9	
I trust the effectiveness of feed additives in reducing methane emissions.	Scale 1–5	3.6	3.1	***
I trust that feed additives are safe for people and the environment.	Scale 1–5	4.1	3.7	**
Maximising farm profitability is more important than minimising environmental emissions.	Scale 1–5	3.2	3.2	n.s.
A climate-smart production method must benefit the producer, not just cover his expenses.	Scale 1–5	4.3	4.3	n.s.
Bureaucracy prevents me from implementing climate-friendly production solutions.	Scale 1–5	2.2	3.2	***

Notes: **, *** Statistical significance at the 5% and 0.1% levels, respectively, according to a Wilcoxon test.

environmental and operational dimensions. When it comes to the environmental dimension, results in Table 1 show a statistically significant difference between adopters and non-adopters in terms of trusting the effectiveness of feed additives in reducing methane emissions. Furthermore, results also showed a significant difference between both groups regarding the statement about the 'safety of the feed additive for people and the environment'. Thus, farmers who have a lower level of perceived effectiveness and safety of the feed additives were less likely to start using them on their farms.

Monitoring individual cows helps farmers adopt new practices like methane-reducing feed additives © Yrjö Tuunanen / Luke.

Another interesting finding is the non-significance of the difference between both groups with respect to statements that underline economic issues as being crucial to the adoption of environmentally friendly farming practices. Not observing a difference in this regard may imply that adopters and non-adopters perceive the cost-benefit ratio similarly. This may also imply that, based on farmers' perceptions, the costs associated with methane-reducing feed additives are not seen as excessively prohibitive by either group. However, this does not imply that economic factors are unimportant. On the contrary, the results suggest that the economic viability of using feed additives is highly important among both groups.

The most prominent difference between the two groups was related to bureaucracy. Results indicate that non-adopters had a higher level of concern regarding bureaucratic barriers that prevent them from implementing these types of measures at the farm level. For adopters in our sample, the use of feed additive was facilitated as part of the research project, which helped to reveal that in reality there is no major farm-level bureaucracy involved in using a feed additive.

Conclusion and policy implications

This study provides valuable information on farmers' perceptions of the use of feed additives aimed at reducing greenhouse gas emissions, such as 3-NOP. It also identifies key barriers that may limit the adoption of these emission-reducing feed additives, providing critical information to support more effective mitigation strategies that incorporate feed additives. Although most farmers recognise the importance of climate issues, only a minority considered that reducing the environmental impact of dairy production is the responsibility of the producer. Yet farmers would prefer to decide for

themselves how to reduce emissions, suggesting that there may be resistance to external directives. In addition, possible conflicts between economically viable and environmentally responsible management leads to farmers prioritising profitability. Although the safety of feed additives is widely recognised, *their effectiveness in reducing emissions is still unclear to farmers, which calls for better communication, advice and education on sustainable practices*.

Several policy conclusions can be drawn from the empirical findings. If policies aim to promote the use of feed additives, an education campaign should be ensured, as higher levels of education correlate with a greater willingness to adopt new and environmentally friendly management techniques. Therefore, targeted fact-based education programmes should be developed focusing on the benefits and safety of feed additives and other sustainable practices. Workshops, seminars and online materials detailing the environmental and economic impacts will increase knowledge and acceptance of such techniques.

Financial incentives and regulatory support are essential for promoting the adoption of feed additives, *as both adopters and non-adopters consider financial benefits to be critical*. Although the feed additive studied incurs additional costs, research has shown that it does not affect cow productivity. Introducing subsidies or other financial incentives at the early stages of adoption could reduce financial risk and encourage farmers to try these techniques. Several options to provide farmers with incentives to adopt the measures exist. Subsidising the use of methane-reducing feed can be one option. However, farmers may prefer market-oriented solutions, such as a price premium. The price premium can be financed either by selling climate-friendly milk to consumers or by using the emission reductions to offset the carbon footprint within the milk value chain itself (a practice known as insetting). Farmers and industry representatives may be reluctant to introduce a carbon tax as a solution – although this is a solution that was recently agreed in Denmark (Niranjan, 2024), a tax exemption for climate-smart feeding could partially compensate for the cost increase.

Reducing the climate impact of milk production starts with changes at the feed and farm level © Yrjö Tuunanen / Luke.

> “Although the safety of feed additives is widely recognised, their effectiveness in reducing emissions is still unclear to farmers.”

Adoption rates were strongly correlated with perceived benefits of the technology, so promotional activities should clearly communicate the environmental, economic and operational benefits of feed additives. Incorporating green initiatives into these activities can be particularly effective (Buchholz and Musshoff, 2021; Ferrari *et al.*, 2019). Success stories and case studies from early adopters can demonstrate practical benefits and remove doubts about the effectiveness and safety of new additives.

The study also highlights the need to integrate gender perspectives in political intervention. The results suggest that women farmers may be concerned about the use of chemical feed additives. Policymakers should consider gender-sensitive strategies that respect and consider women farmers' views on environmental issues. This may also include creating forums for women to voice their concerns and choices about sustainable farming techniques, and ensuring extension services are gender-sensitive to these differences (Diaz and Najjar, 2019).

Finally, it is important to acknowledge the limitations of this study. The early adopter group was formed through a purposive, self-selected process, focusing on volunteers willing to trial the 3-NOP

feeding practice. This approach may not accurately reflect the demographic composition of the broader farming community, including the higher proportion of women in the sample. As a result, gender and other demographic-related insights should be interpreted with caution and cannot be confidently generalised without further research using more representative sampling methods.

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Summary

Finnish Farmers' Adoption of Feed Additives for GHG Mitigation in Dairy Farming: Barriers and Perspectives

This study offers valuable insights into farmers' perspectives on the use of feed additives (3-NOP) in reducing methane emissions, and highlights associated obstacles that may prevent the accelerated uptake of GHG mitigation measures. Our data originate from a survey of 239 Finnish dairy farmers. While most farmers acknowledge the importance of climate issues, only a small percentage consider the reduction of the environmental impact of milk production to be the responsibility of the producer. Still, the farmers would prefer to decide for themselves how to reduce emissions, which demonstrates that resistance toward external directives might exist. In addition, there is a discrepancy between economically viable and environmentally responsible management, and this makes farmers more preoccupied with profitability. Furthermore, most farmers consider the feed additives to be safe. However, their efficiency in emission reduction remains unclear to many which contributes to hesitation in adoption. Thus, improved communication and education towards sustainable practices is needed. Strengthening dialogue among researchers, advisors, policymakers and farmers can help clarify the environmental purpose of feed additives and address uncertainties about their effectiveness and safety. Targeted educational efforts should focus on practical, science-based methods for methane reduction and build confidence through transparent information and real-life examples.

Adoption par les agriculteurs finlandais d'additifs alimentaires pour la réduction des émissions de gaz à effet de serre dans l'élevage laitier : obstacles et perspectives

Cette étude donne un éclairage précieux sur le point de vue des agriculteurs sur l'utilisation d'additifs alimentaires (3-NOP) pour réduire les émissions de méthane et met en évidence les obstacles qui pourraient freiner l'adoption accélérée de mesures d'atténuation des gaz à effet de serre (GES). Nos données proviennent d'une enquête menée auprès de 239 producteurs laitiers finlandais. Si la plupart d'entre eux reconnaissent l'importance des enjeux climatiques, seul un faible pourcentage considère que la réduction de l'impact environnemental de la production laitière relève de la responsabilité du producteur. Quoi qu'il en soit, les agriculteurs préféreraient décider eux-mêmes de la manière de réduire leurs émissions, ce qui démontre une possible résistance aux directives externes. De plus, il existe un décalage entre une gestion économiquement viable et une gestion écologiquement responsable, ce qui accentue les préoccupations des agriculteurs en matière de rentabilité. En outre, la plupart des agriculteurs considèrent les additifs alimentaires comme sûrs. Cependant, leur efficacité en matière de réduction des émissions reste floue pour beaucoup, ce qui contribue à rendre les agriculteurs hésitants à les adopter. Il est donc nécessaire d'améliorer la communication et la sensibilisation aux pratiques durables. Renforcer le dialogue entre chercheurs, conseillers, décideurs de l'action publique et agriculteurs peut contribuer à clarifier l'objectif environnemental des additifs alimentaires et à lever les incertitudes quant à leur efficacité et leur sécurité. Les efforts éducatifs ciblés devraient se concentrer sur des méthodes pratiques et scientifiques de réduction des émissions de méthane et renforcer la confiance grâce à des informations transparentes et des exemples concrets.

Futtermittelzusätze zur Minderung von Treibhausgasen in der finnischenMilchviehhaltung: Barrieren und Perspektiven

Die Studie liefert wertvolle Einblicke in die Ansichten der Landwirtinnen und Landwirte über den Einsatz von Futtermittelzusatzstoffen (3-NOP) zur Reduzierung von Methanemissionen. Außerdem zeigt sie die damit verbundenen Hindernisse auf, die einer schnelleren Einführung von Maßnahmen zur Reduzierung von Treibhausgasemissionen im Wege stehen könnten. Die Daten stammen aus einer Umfrage unter 239 finnischen Milchviehbetrieben. Zwar erkennen die meisten Betriebe die Bedeutung von Klimafragen an, doch nur ein kleiner Prozentsatz ist der Ansicht, dass die Verringerung der Umweltauswirkungen der Milchproduktion in der Verantwortung der Erzeugenden liegt. Dennoch würden sie es vorziehen, selbst zu entscheiden, wie sie die Emissionen reduzieren wollen. Dies zeigt, dass es möglicherweise Widerstand gegen externe Richtlinien gibt. Außerdem besteht eine Diskrepanz zwischen einer wirtschaftlich rentablen und einer umweltverträglichen Bewirtschaftung. Das führt dazu, dass sich die Betriebsleitenden mehr mit der Rentabilität befassen. Die meisten Betriebsleitenden halten die Futtermittelzusatzstoffe außerdem für sicher. Ihre Effizienz bei der Emissionsreduzierung bleibt jedoch für viele unklar, weshalb sie nur zögerlich eingesetzt werden. Daher sind eine bessere Kommunikation und Aufklärung über nachhaltige Praktiken erforderlich. Ein verstärkter Dialog zwischen Forschung, Beratung, Politik und Betrieben kann dazu beitragen, den ökologischen Nutzen von Futtermittelzusatzstoffen zu klären und Bedenken hinsichtlich ihrer Wirksamkeit auszuräumen.

Gezielte Aufklärungsmaßnahmen sollten sich auf praktische, wissenschaftlich fundierte Methoden zur Methanreduzierung konzentrieren und durch transparente Informationen und Beispiele aus der Praxis Vertrauen schaffen.