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Presentation Paper
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The potential of feed additives to improve the environmental impact of
European livestock farming

**Secretariat
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Project basics

- Funded by European Food Safety Authority (CFT/EFSA/FEED/2012/02)
- Systematic review, undertaken 2012-2013, 1-year project, to examine if feed additives could improved the environmental impact of livestock farming.
- Review scope & boundaries:
 - Studies published post-1990
 - Farmed livestock only – excluding companion and zoo animals, marine
 - Direct beneficial effects only – excludes benefits seen via performance improvements
 - Feed supplements only – excludes nitrification & urease inhibitors
 - Livestock trials only – excludes metabolic & mechanistic modelling
 - All document types – includes peer-reviewed, unpublished, grey, industry

Rationale

- Livestock are responsible for a variety of potential polluting emissions including GHG's, ammonia, odours and losses of N, P & S via excretion.
- Feed additives can be used to improve livestock digestive processes so that nutrients are used more effectively leading to a reduction in waste products.
- Feed additives are often promoted on the basis of producer benefits (e.g. improved productivity, better livestock health) & not on their potential benefits for the environment.
- There are some exceptions to this e.g. odour control, phytase for reducing P losses.

Project Aims

To undertake a systematic review of substances and agents that when used as feed additives, may have a direct beneficial effect on the environment.

Primary review question:

Can substances/agents, used as livestock feed additives, reduce potentially polluting emissions from livestock?

Secondary review questions:

1. For which additives, and which emissions, can benefits be quantified?
2. What are the pros, cons and comparability of different experimental approaches, measurement techniques & metrics? e.g. *in vitro* vs *in vivo*.
3. Do cattle/sheep respond the same?

Methodology

- Develop the literature review and search strategy protocol.
- Undertake the literature search:
 - Refine results for relevancy based on abstract.
 - Obtain full document and screen for quality & usefulness (according to inclusion/exclusion criteria in review protocol).
 - Snowballing.
- Undertake an industry & researcher consultation process to supplement literature.
- Log bibliographical details of each manuscript along with trial results in database.
- Synthesise, interpret the data via meta analysis and report.

Review protocol

Protocol aimed to:

- Identify databases, search terms, key industry & academic contacts.
- Define inclusion/exclusion criteria to:
 - Ensure manuscripts are relevant & within review boundaries.
 - Ensure studies meet required quality standards relating to experimental design & conditions – different criteria for *in vitro*, *in vivo*.
 - Ensure each study only included once.
- Identification of data to be retrieved.
- Develop various data tags to identify data type & aid data interpretation

Generic results of review

Far more data identified than was anticipated by EFSA

- Approx 1350 manuscripts found from the primary search, reduced to 619 (461 scientific studies & 158 background articles) after duplicates removed and first relevancy screening.
- Of the 461 studies, 234 failed to meet the inclusion criteria.
- Data for 302 individual experiments was extracted from included manuscripts.
- Data for 244 substances identified, environmental benefits found for 128, of which 37 (+) are listed on Annex 1 of EU Register of Feed Additives.
- Data was identified for 4 animal groups: cattle (cows & buffalo), sheep (inc. Goats), pigs & poultry (chickens, turkeys & ducks).
- Data for 8 potentially polluting emissions identified: methane, ammonia, carbon dioxide, odour & malodorous cpds, excretion of N, P, S.

Meta analysis

- Aimed to combine results from different studies in a statistically sound manner to provide a more robust, reasoned assessment of the potential for environmental benefits. However...
- Huge variations in important study parameters (e.g. diet, dose, *in vitro* / *in vivo*, reporting metrics etc.) meant compromises required.

Approach:

- Separate data on the basis of (i) additive, (ii) species and (iii) *in vivo* / *in vitro*.
- Convert all study data to %change ($\% \Delta$) between results with feed additive & a negative control and use mean value across studies, diets and dosage.
- Assumed* that:
 - 10% reduction ($\% \Delta < -10\%$) demonstrates environmental benefit
 - 10% increase ($\% \Delta > +10\%$) demonstrates environmental burden
 - 10% to +10% equals no sound evidence either way.

* Data for a 5%, 20% thresholds also reported to EFSA

Key findings for Cattle

- At 10% threshold, 25 substances currently on Annex 1 found to reduce emissions – predominately methane & ammonia. Some substances increased emissions.
- Most benefits seen with botanical extracts e.g. essential oils, spices, vegetable oils, tannins and saponins.
- *Cinnamomum verum* showed an average decrease in methane of 71%.
- Tannic acid showed a mean decrease in ammonia of 47%.
- Some substances decreased methane and ammonia simultaneously however, some decreased one gas at the expense the other.

Key findings for Cattle

Substance (Annex 1 EU Feed Register only)	Ammonia % Δ	Methane % Δ
Linoleic acid	0	-56
Malic acid	+16	-23
Monensin	-4	-21
<i>Cinnamomum verum</i>	-14	-71
<i>Origanum vulgare</i>	-23	-50
Thymol	-11	-41
Tannic acid	-47	0
Linseed oil	+28	-28
Sunflower oil	+46	-18

Key findings for Sheep

- 21 valuable (Annex 1) substances identified.
- Most benefits seen with botanical extracts.
- Reductions in methane and ammonia.
- *Rheum officiale* showed an average decrease in methane of 75%.
- Eucalyptus oil showed average decrease in methane of 60% accompanied by a decrease in ammonia of 22%.
- Best performer for ammonia was thymol, showing a mean reduction of 46%.
- Some substances decreased methane and ammonia simultaneously.

Key findings for Sheep

Substance	Ammonia % Δ	Methane % Δ
Linoleic acid	0	-34
Monensin	-16	-32
Thymol	-46	-53
<i>Thymus vulgaris</i>	-27	-48
<i>Cinnamomum verum</i>	-32	-48
Eucalyptus oil	-22	-60
<i>Quillaja saponaria</i>	-11	-17
Coconut oil	0	-38
Sunflower oil	0	-23

Key findings for Pigs & Poultry

- Less impressive findings than with ruminants.
- Pigs – reductions in ammonia and N & P excretion seen.
- Pigs – benzoic acid reduced ammonia by 23%.
- Pigs – phytase reduced ammonia by 26%, P-losses by 21%.
- Poultry – limited benefits.
- Poultry – bentonite reduced ammonia by 41%.
- Poultry – phytase reduced P-losses by 16%.

Experimental approaches & metrics

- Sound, established well developed, repeatable standard approaches available for all emissions.
- Problems identified in the study variability regarding...
 - For *in vivo* studies – huge variations in diet, dose, diet adaptation periods, sampling periods and reporting metrics.
 - For *in vitro* studies – huge variations in incubation period, incubation temperature and reporting metrics.
 - Reporting metrics caused problems in comparisons as it was not always possible to convert data – findings vary depending on metric chosen.

Species comparison (cattle v sheep)

General impressions considering all types of emissions:

- Robust conclusions difficult due to nature of the data.
- Data for each additive not always available for both species.
- Some examples of significant differences between species responses identified:
 - e.g. fumaric acid: methane: -92% cattle, -28% sheep.
 - DL-malate: methane: -85% cattle, No effect sheep.
 - tea saponin: methane: No effect cattle, 20% sheep.
 - vegetable oils appear to increase ammonia in cattle but not sheep.

Species comparison (cattle v sheep)

More detailed study done with methane and cattle:

- Robust conclusion still difficult.
- Need to consider within-animal, animal to animal variations.
- Generally, cattle & sheep appear to respond similarly in broadest sense, i.e. where a response occurs it is seen in both species, but there are exceptions.
- Cattle appear to respond better than sheep for methane (but opposite for ammonia may be true).
- Greater similarity seen in methane reductions measured *in vitro* compared with that measured *in vivo* – maybe due to greater control over parameters.

In vitro versus *In vivo*

- *In vitro* preferred due to time, costs & animal welfare issues.
- General opinion on comparability in scientific press is divided.
- Many researchers use *in vitro* approaches to confirm *in vivo* findings.

General findings from this study:

- Difficult to reach sound conclusions due to nature of the data.
- Comparison better for methane than ammonia, for example:
 - Lauric acid, Quillaja, Yucca reduce ammonia *in vitro* but no effect *in vivo*.
 - Linseed oil reduces ammonia *in vivo* significantly but no effect *in vitro*.
- Degree of comparability seems to vary with animal type.

Conclusions

- Study was essentially a large scale scoping review.
- Data does have limitations but ...
- ... it points to the use of some feed additives as being a useful tool in reducing environmental impact of livestock farming particularly for methane and ammonia.
- Due to the data variability seen, a single study is not a good measure of the effect of a feed additive on emissions.
- Whilst experimental and measurement/analytical techniques are well established, more consistency in experimental conditions is needed.
- No sound evidence that *in vitro* and *in vivo* give the same results.
- No sound evidence that cattle and sheep respond to feed additives in the same way.
- More detailed work is needed.

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- Full report available on EFSA website – but its very, very long (1000+ pages including the annex's).
 - www.efsa.europa.eu/en/supporting/pub/440e.htm OR
 - tinyurl.com/qf5kez2
- Paper 'in press':
 - Lewis et al. (2014) The potential of feed additives to improve the environmental impact of European livestock farming: a multi-issue analysis. *International Journal of Sustainable Agriculture*.

Questions?