

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?