land-
wirtschaftliche
fakultät

UNIVERSITÄT BONN

Volatile organic compounds in silages – possible effects on intake and metabolism by ruminants and quality of ruminant products: a review

K. Gerlach, E. Katsimeni, K.-H. Südekum
Institute of Animal Science, University of Bonn

Introduction

- Meaning of ‘Volatile organic compounds (VOC)’ diverse and not clearly defined
  - The European Union:’...any organic compound having an initial boiling point less than or equal to 250 °C (482 °F) measured at a standard atmospheric pressure of 101.3 kPa.’

- VOC in silages: Origin

www.schmihing-gmbh.de/fahrsilofraese.html

Materials and Methods

- Literature review on VOC in silages
- The VOC grouped according to their chemical class
  (number of different compounds used for this study in parentheses)
  - Alcohols (34)
  - Aldehydes (14)
  - Carboxylic acids (16)
  - Esters (37)
  - Ketones (17)

→ Concentration in silages, in rumen fluid and in milk or cheese

→ Effects on rumen metabolism and productivity of ruminants

→ Possible transfer of VOC from forages into milk or cheese

Intake and metabolism: Alcohols (34)

- Most research on **ethanol** and propanol

Reference	Type of study	Animals	Ethanol g/kg DM		Correlation	Linear regression
			Range	Mean		
Brüning et al. 2018	Preference trial	Goats	0.2–17	7.7	0.17	
Daniel et al. 2013	Feeding trial	Cattle		28	n.s.	
Eisner 2007	Meta analysis	Dairy cows	18–45 3–19	13 7.8		n.s. n.s.
Gerlach et al. 2013	Preference trial	Goats	0.6–6.2 4.7–8.1	2.9 6.5	–0.33 n.s.	
Gerlach et al. 2014	Preference trial	Goats	0.9–5.6	2.3	0.78	
Hetta et al. 2007	Feeding trial	Dairy cows	1.8–16	7.0	0.48	
Huhtanen et al. 2002	Meta analysis	Dairy cows	0.4–36	12.4		n.s.
Krizsan & Randby 2007	Feeding trial	Steers	3.4–13	6.8		n.s.
Steen et al. 1998	Feeding trial	Steers	1.6–33	7.9	n.s.	

→ **Ethanol**
The effect on feed intake is variable, most times not negative

Intake and metabolism: Alcohols (34)

- Metabolised in the rumen or absorbed through the rumen epithelium and transported to the liver (Randby et al. 1999)
- Not found in faeces → complete metabolization seems plausible (Fischer et al. 2015)
- Some alcohols inhibit certain rumen microbes while others seem to stimulate their growth (Kristensen et al. 2007)

→ Alcohols seem to impact the rumen metabolism, have to be studied separately

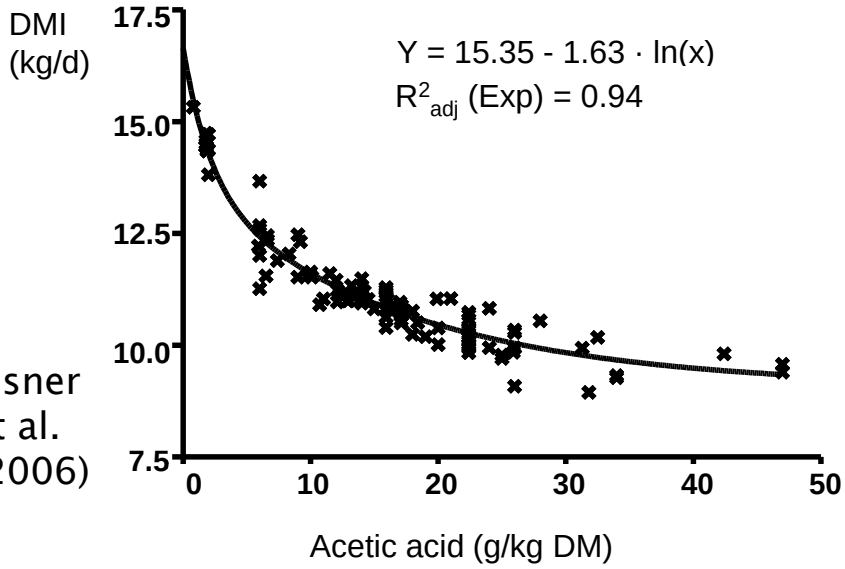
Intake and metabolism: Aldehydes (14)

- Aldehydes have frequently been analyzed and detected in silages
  (e.g., Chmelová et al. 2009, aldehyde content in farm-scale silages, mg/kg DM)

Aldehyde	Maize silages (n=8)	Grass silages (n=13)
Ethanal	26 (9–48)	30 (10–49)
Propanal	70 (51–99)	77 (54–98)
Butanal	78 (52–100)	72 (46–99)
2-Methylpropanal	29 (10–49)	26 (9–50)
Pentanal	**150 (98–200)**	**147 (105–189)**
3-Methylbutanal	78 (51–57)	76 (47–100)
Hexanal	**153 (97–196)**	**150 (104–190)**
Heptanal	24 (8–50)	23 (10–47)

- Neither detected in rumen fluid nor in faeces of ruminants
- Typically completely metabolized in the rumen (Chmelová et al. 2009)
- Exact way of degradation, further metabolism and effect on feed intake still unclear

Intake and metabolism: Carboxylic acids (16)



Eisner et al. (2006)

Effect of **acetic acid** content on dry matter (DM) intake (DMI) of wilted grass silage by dairy cows

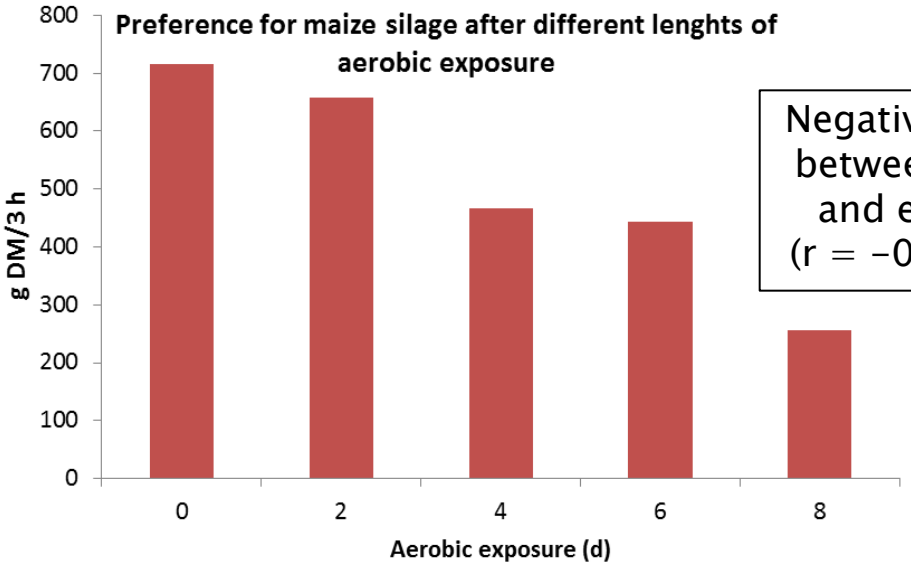
Daniel et al., Poster TH-168:
Negative impact with greater impairment of DMI with acetic acid >**1.73% of diet DM**

Propionic acid
Most times in low concentrations, 8 of 8 studies show negative impact on feed intake

An effect of volatile fatty acids on intake seems to be more likely when they are provided in combination rather than individually… (e.g., Gill et al. 1988)

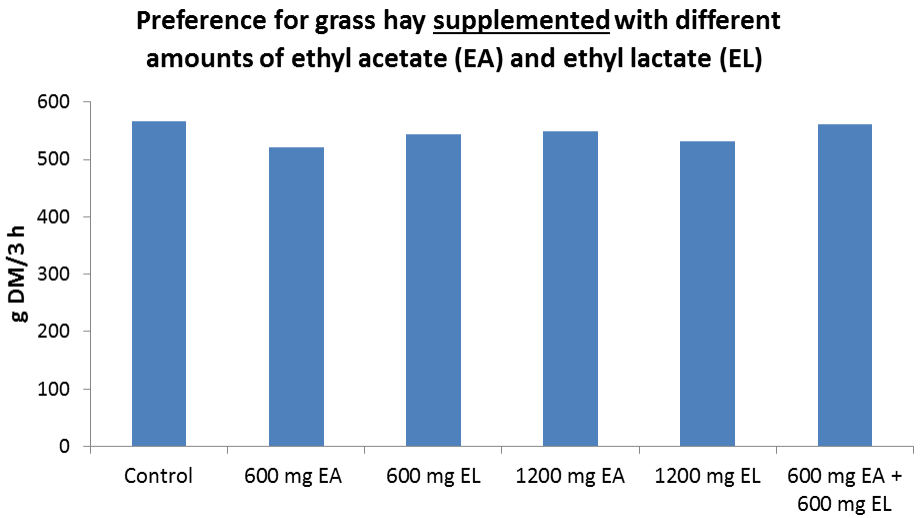
Intake and metabolism: Esters (37)

- Many esters are odorous and highly volatile
  → Contribute to the sensory characteristics of silages



Negative correlation between DM intake and ethyl lactate ($r = -0.33$, $p<0.05$)

Gerlach et al. (2013)

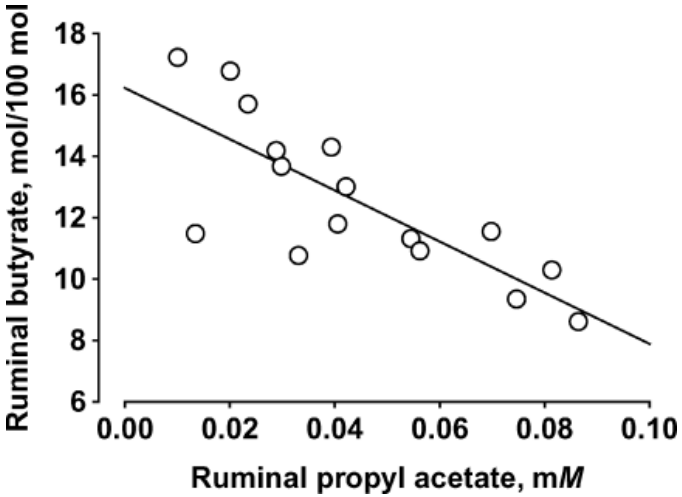


No effect of ester supplementation ($p>0.05$)

Gerlach et al. (2016)

Intake and metabolism: Esters (37)

- Formation during ensiling + synthesis in the rumen
- Ester formation as biologically important pathway of ruminal alcohol metabolism?
- Inhibition of specific microbes is discussed (Kristensen et al. 2007)



Kristensen et al. (2007):
e.g., inhibition of *Butyrivibrio fibrisolvens* responsible for decrease in ruminal butyrate?

- **Lack of literature on the effects of esters on rumen microbes or the metabolism of ruminants**

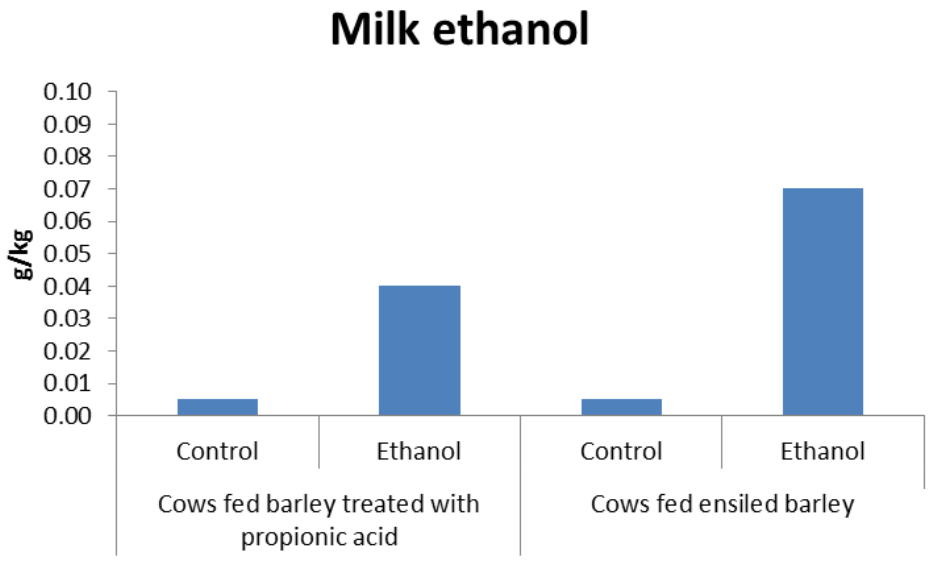
VOC and transfer to dairy products

- Honkanen et al. (1964): Transfer of VOC from feed to milk
- Two general ways of transfer

Pulmonary route

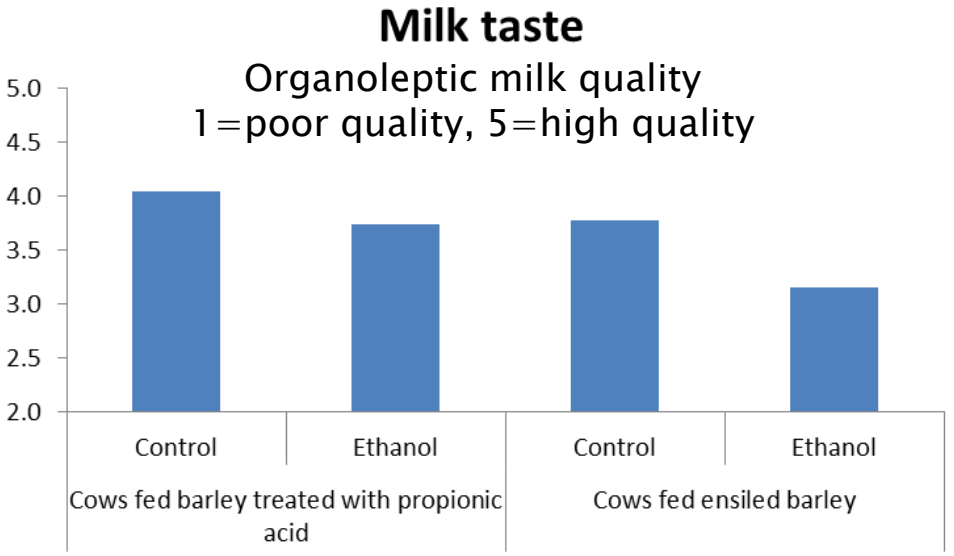
Digestive route

VOC and transfer to dairy products: Alcohols



Ethanol intake g/d

Effect of ethanol
$p<0.05$



Randby et al. (1999)

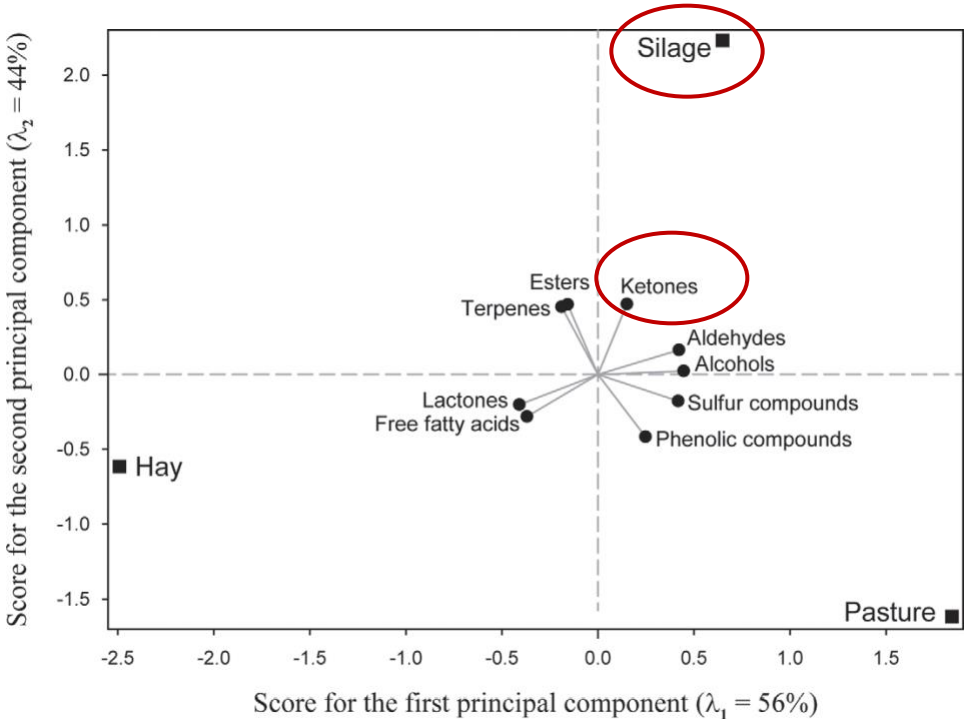
VOC and quality of dairy products: Ketones

- Increased ketone concentrations in silages resulted in higher concentrations in milk (Villeneuve et al. 2013)

  → Direct transfer from silage to milk seems probable

- Some ketones also influence milk flavour

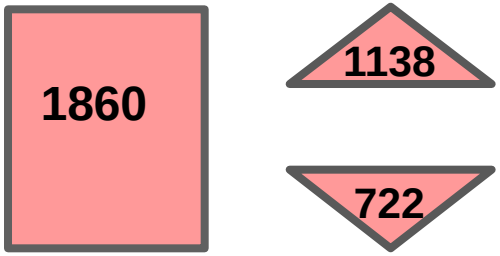
Principal component scores calculated for 3 timothy forage types and for each family of volatile organic compounds found in milk
(Villeneuve et al. 2013)



Future perspesctives – Metabolomics/Flavor profiling

- Number of VOC that can be analyzed will increase
- e.g., > 6000 compounds in lucerne silages
  (Scherer et al., Poster TU-11)
- Impact on feed intake and metabolism often still unclear
- BUT: New substances may help to answer questions that have not been answered yet

Substances differing between preferred and avoided lucerne silage ($p<0.01$)



Scherer et al., ISC Poster TU-11

Conclusions

- Numerous VOC with diverse chemical structures and diverging impact on metabolism of ruminants and dairy products
  → consider separately
- Difficulty of choosing suitable experimental design
- Specific links between variations in VOC concentration and sensory attributes of milk remain to be established (each VOC with own threshold of perception)
- Major VOC in silages have been studied in literature
  BUT: for most of the numerous other products the knowledge on formation and mode of action in ruminants is very limited!
- Innovative analytical techniques will provide new insights

Thank you!