Major contributions in 45 years of International Silage Conferences

1970 -2015

Roger Wilkins and Mike Wilkinson

We will :

- Outline the state of knowledge in 1970
- Highlight contributions to increase UNDERSTANDING of PRESERVATION and FEEDING VALUE
- Highlight contributions on INCREASING SILAGE EFFICIENCY
- Discuss future challenges

Papers presented and cited
Silage Conferences, 1970-2012

Papers and posters presented	1399
Cited in our written paper	119
Referenced in oral presentation	52
With data in presented slides	7

State of Knowledge, 1970

- Major biochemical pathways for fermentation identified
- Importance of dry matter %, water-soluble carbohydrates and buffering capacity realised
- Sources of loss identified
- With good technique, digestibility of silage similar to crop before ensiling
- Reduced voluntary intake often limits performance

Major contributions

- Understand preservation
- Understand feeding value
- Improve silage efficiency

UNDERSTANDING PRESERVATION

- **Silage fermentation**
- **Aerobic deterioration**
- **Animal and human health**

Silage fermentation: the organisms involved

Papers showing role of:

Yeasts	***Weise, 1972***
Enterobacteria	***Lindgren, 1984; Spoelstra, 1984***
Acetic acid bacteria	***Spoelstra, 1987***
Epiphytic lactic acid bacteria	***Pahlow, 1987; Muck, 1987***

Silage fermentation: plant components

- **Some bacteria have limited capacity to ferment fructans, *Seyfarth, 1993***

- **Complex effects of nitrate, *Spoelstra, 1984,* clarified by *Weissbach, 1993,* and modelled by *Kaiser, 2002***

Silage fermentation: effect of nitrate content on ensiling potential *(Kaiser, 2002)*

Calculated minimum nitrate content required for butyric acid-free silages depending on:

- **Dry matter (DM) content**
- **Water-soluble carbohydrate (WSC)/buffering capacity**
- **Clostridia spore count**

Validated for different forages by *Pahlow, 2002*

Aerobic deterioration

Not mentioned, except surface wastage, in 1970

Magnitude of losses (up to 30% in affected areas) quantified by *Honig, 1974*

Organisms highlighted:

- **Yeasts, *Weise, 1972***
- **Bacilli*, Woolford, 1976***
- **Acetic acid bacteria, *Spoelstra, 1987***

***Pahlow and Muck, 2009,* conclude 'Most often yeasts utilise lactic acid and raise pH allowing others, such as bacilli, to develop'**

Aerobic deterioration

Large effects on deterioration of:

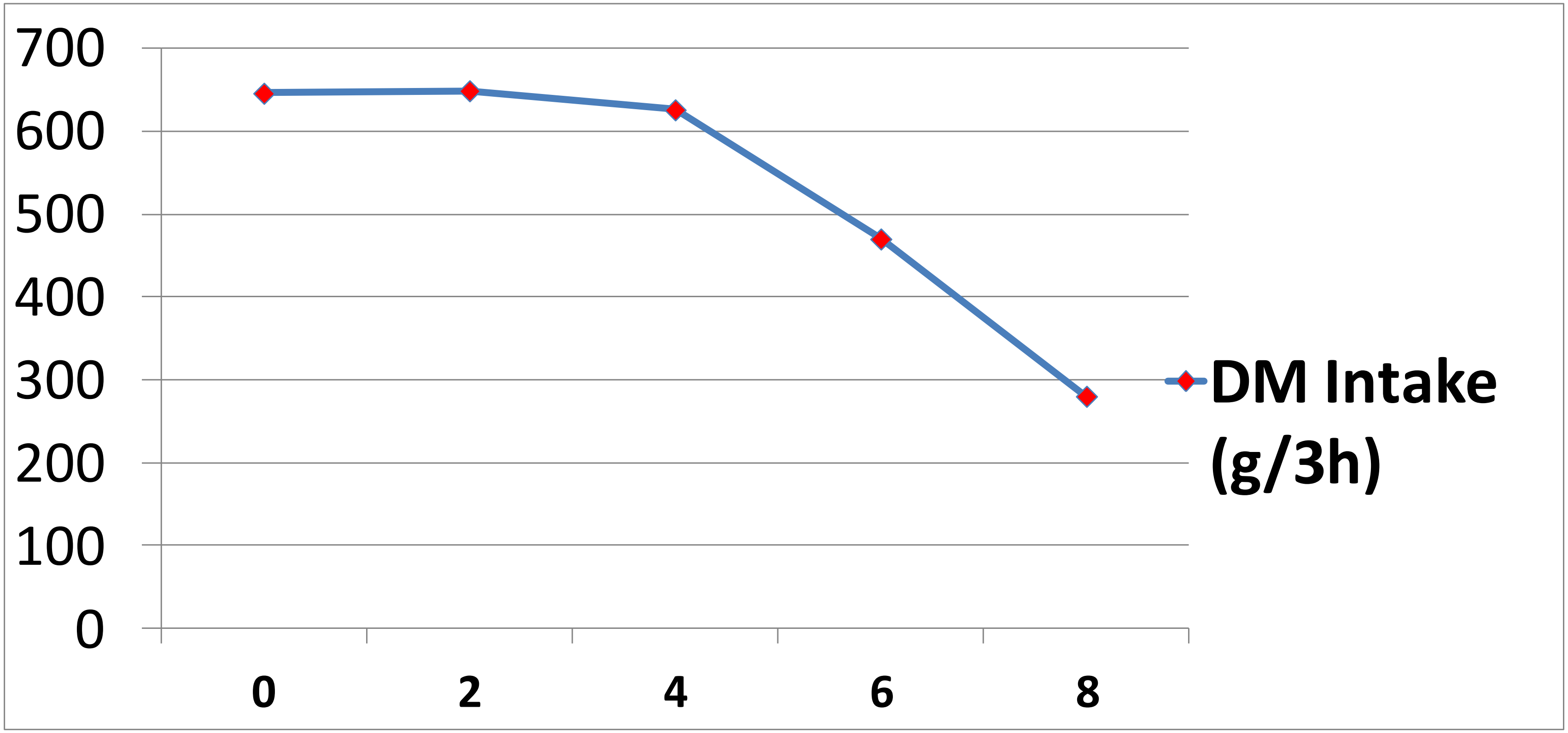
- **Extent of air permeation into exposed silo face, *Honig, 1974***
- **Silage composition (reduced by high levels of undissociated acetic acid), *Wolthusen, Rostock, 1989***

Aerobic deterioration model, *Williams, 1993*

Driven by:

- Microbial growth, including inhibitory factors
- Gas movement
- Heat transfer

Effect exposure of maize silage to air (days) on feed preference by goats, *Gerlach, 2012*



Risks to animal and human health

First reports:

- *Listeria monocytogenes* in big bale silage, *Fenlon, 1987*
- *Penicillium roquefortii* prevalent, *Auerbach, 1993*

Risks to animal and human health

Reviews by *Wilkinson, 1999,* and *Dreihuis, 2012* highlighted:

- ***E.coli***
- ***L. monocytogenes***
- ***P. roquefortii***
- ***Clostridium botulinum***

and prevalence of mycotoxins

UNDERSTANDING EFFECTS ON FEEDING VALUE

- **Intake**
- **Nitrogen utilisation**

Feed intake

Limited by:

- **Protein breakdown** ***Barry, 1976; Wilkins, 1978***
- **Total acids** ***Wilkins, 1978***
- **Physical factors (chop length)** ***Dulphy, 1976; Deswysen, 1978***

Model for prediction by *Huhtanen, 2002,* from*:*

- **Ammonia N**
- **Total acids**
- **Digestibility**

Nitrogen utilisation

Poor N utilisation from silage leads to:

- **Low N retention by animal**
- **Increased fat in carcases, *Waldo, 1978***
- **Increased loss of N to environment, *Misselbrook, 2012***

Limitations to N utilisation

Low production of microbial protein

Resulting from large quantity of non protein nitrogen and low quantity of readily available carbohydrates

Sucrose supplementation increased N retention, *Syrjala, 1972*

and microbial protein, *Huhtanen, 1987; Chamberlain, 1993*

Effect sucrose infusion on microbial N, *Huhtanen, 1987*

	No infusion	Sucrose infusion
Rumen ammonia-N	**8.3**	**5.0**
Microbial N at duodenum	**43**	**59**
Microbial N, g/kg OM apparently digested in rumen	**24**	**32**

INCREASING SILAGE EFFICIENCY

- Control or monitor crop composition
- Improve drying rates
- Use effective additives
- Improve N utilisation
- Improve silo management and sealants
- Reduce environmental impact

Improve drying rates: plastic elements for crop conditioning, *Klinner, 1981*

Additives to improve preservation and feeding value

Initial concentration on chemical additives

Technique for assessing anti-microbial spectra, *Woolford, 1972*

Clarified mode of action of formic acid

Microbial additives 1

- Importance of high application rate (10^6 / g FM), *Lingvall, 1972*
- Positive effects of *L. plantarum* on fermentation and feed intake , *summarised by Wilkins, 1996*
- But could reduce aerobic stability

Microbial additives 2

Heterolactic *L. buchneri* increased acetic acid and aerobic stability, *Driehuis, 1996*

	No additive	With *L. buchneri*
	Aerobic stability (hours)	
Grass	130	> 320
Maize	43	792
Wheat	125	250

Additives to increase digestibility

- **Session in 1976 on cellulases - Increased lactic acid, but no effect on DM digestibility**
- **In 2009 L buchneri PTA 6138 with ferulic esterase activity increased fibre and DM digestibility, but by only 1 % unit, *Bruesermeister, 2009; Dupon, 2012***
- ***Romero, 2012,* screened 18 enzymes and the best increased NDF digestibility of *Cynodon dactylon* (Bermuda grass) from 31% to 40%**

Treatments to improve N utilisation 1: Suppress fermentation in silo, *Jaakola,1993*

	Formic acid (l/t)			
	0	2	4	6
WSC in silage (g/kg DM)	3	19	37	92
Microbial N duodenum (g/day)	49	57	58	65
Microbial N (g/kg DMADR)	12.7	15.4	16.4	18.5

Treatments to improve N utilisation: 2
Plant polyphenol oxidase, *Jones, 1993*

	Trifolium pratense (Red clover)	*Medicago sativa* (Lucerne)
	Non protein nitrogen (NPN), % total N	
Herbage	14	16
Ensiled, 3 days	34	52
Ensiled, 7 days	47	79

Treatments to improve N utilisation 3
Plant tannins, *Hymes Fecht, 2005*

	Medicago sativa (Lucerne)	*Lotus corniculatus* (Birdsfoot trefoil)	
		Low tannin	Normal tannin
3.5% fat corrected milk (kg/day)	31.4	33.8	36.3
Milk protein (kg/day)	0.94	1.04	1.09

Improve silo management and sealants

High oxygen barrier films (eg ‘Silostop’):

- **Reduced surface wastage, *Delgano, 1999***
- **Reduced yeasts, moulds and clostridia, *Borreani, 2005***

Oxygen barrier film, no tyres

Effects of high oxygen barrier stretch film, *Borreani, 2012*

	Standard polyethylene	High oxygen barrier
Oxygen permeability (cm^3O_2/m^2 per 24h)	7989	32
Bale surface covered by moulds (% of total area)	3.3	0.3
DM loss (g/kg)	63	34

Bales wrapped with 6 layers; mean for *Lolium multiflorum* (Italian Ryegrass) and *Trifolium pratense* (Red Clover)

Silage systems

- **Farm-scale systems,** ***eg Lingvall, 1972; Morrison, 1982; Gordon, 1984***
- **Economic models,** ***eg Witney, 1974; McGechan, 1990; Bolsen, 2012***

Impact on environment

- **Early meetings only concern was effluent with high biological oxygen demand (BOD)**
- **First paper on methane in 1999, *Takahashi***
- **First papers on volatile organic compounds in 2009, *Mitloehner; Montes; Hafner***

Surprisingly few contributions on environmental losses of N compounds

FUTURE CHALLENGES

- Improve silage management precision – sensors and decision support models
- Effective edible sealants
- Enhance digestibility during ensiling
- Incorporate protein protection in grasses and lucerne
- Control mycotoxins
- Ensure high hygienic quality and silo safety

CONCLUSIONS 1

Benefits from Silage Conferences:

- **Rapid communication of new findings**
- **Multidisciplinary participation**
- **Building confidence and awareness leading to enhanced collaboration**

CONCLUSIONS 2

Great progress that has

IMPROVED PRACTICE FOR BENEFIT OF MANKIND

New challenges have emerged. They require sustained investment in silage R & D

and continuation of Silage Conferences!