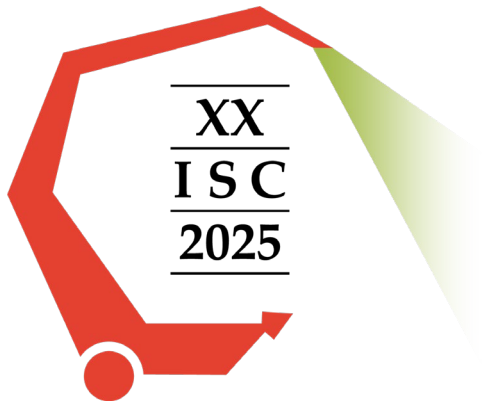




RECENT ADVANCES IN SILAGE SEALING

Giorgio Borreani and Ernesto Tabacco

Department of Agricultural, Forestry and Food Sciences (DISAFA)
University of Turin, Turin, Italy

The three pillars of a successful silage conservation

PILLARS

1. **Acidification** through carbohydrate fermentation
2. **ANAEROBIOSIS** exclude oxygen from silage mass and maintaining it during conservation
3. **Modulation of water activity** (a_w): addressing activity of different groups of microorganisms to prevent anaerobic degradation

ACTIONS

Microbiological and chemical additives

Silo building, filling and sealing

Maturity stages, field wilting, co-ensiling (dry and wet materials), adding water (dry grain)

SILAGE

HAYLAGE

Exclusion of air from silage in the early documents (1760-1888)

GIORNALE
D'ITALIA
SPETTANTE ALLA SCIENZA NATURALE,
E PRINCIPALMENTE
ALL'AGRICOLTURA, ALLE ARTI, ED AL COMMERCIO.
TOMO TERZO.



IN VENEZIA,
Appresso BENEDETTO MILOCCO in Merceria:
M DCC LXVII
CON LICENZA DE' SUPERIORI, E PRIVILEGIO.

[... The reason that promotes the degradation of the harvested plants, whether leaves or fruits, I attribute mainly to the air.]

(Baroni delli Cavalcabò, 1760.
Della maniera di conservar
fresche per tutto l'anno le foglie
d'albero)

CONSERVATION DES FOURRAGES EN SILOS.

Voici une très-grosse question soulevée par M. Vilmorin. On a recommandé de semer des fourrages dans ces derniers temps. Rien de plus utile. Mais l'eau n'est pas venue et beaucoup de semis n'ont pu avoir lieu, tandis que d'autres, ayant eu lieu, n'ont pas réussi. Il ne faut pas nous rebuter. On peut encore semer du maïs, humide, il verserait moins facilement, serait moins aqueux au moment de la récolte et pourrait par conséquent être conservé plus facilement en silos.

E. LECOUTEUX.
A M. le rédacteur en chef du Journal d'Agriculture pratique.
Paris, 28 juin 1870.

L'épaisseur de la couverture de terre ne sera pas de moins de 3 pieds, non-seulement pour intercepter le contact de l'air extérieur, mais aussi pour qu'elle agisse par son poids et chasse l'air qui se trouve interposé. Bientôt une fermentation se

[... The soil cover should not be less than “3 pieds”, not only to intercept the contact of the outside air, but also to act with its weight to expel the interposed air.]

(Vilmorin-Andrieux, 1870.
Conservation des fourrages verts en
silos Journal d'Agriculture Pratique
TOME II)

Stack
Ensilage

WALTER SCOTT
LONDON: 24 WARWICK LANE
PATERNOSTER ROW
1888

CHAPTER I.

HISTORY OF ENSILAGE.

THE genesis of ensilage is lost in the mists of antiquity. The fundamental principle of the system is the preservation of crops in their natural state by the exclusion of air. In its ancient application it was utilised mainly, if not

(Rew R. E., 1888. Stack ensilage)



Keys to Silage History

1882

1st Ensilage Congress NY

THE ENSILAGE CONGRESS.

FINAL SESSION YESTERDAY—SOME FACTS
AND FIGURES.

The second and final session of the Ensillage Congress was held at No. 55 Beekman-street yesterday forenoon. The large room which Mr. J. B. Brown had placed at the disposal of the agricultural gentlemen was well filled, and a very enthusiastic and interesting discussion took place. The principal points touched upon were the economic value of ensilage as compared with other fodder, the manner of building and filling silos, and the improved farming methods. On a

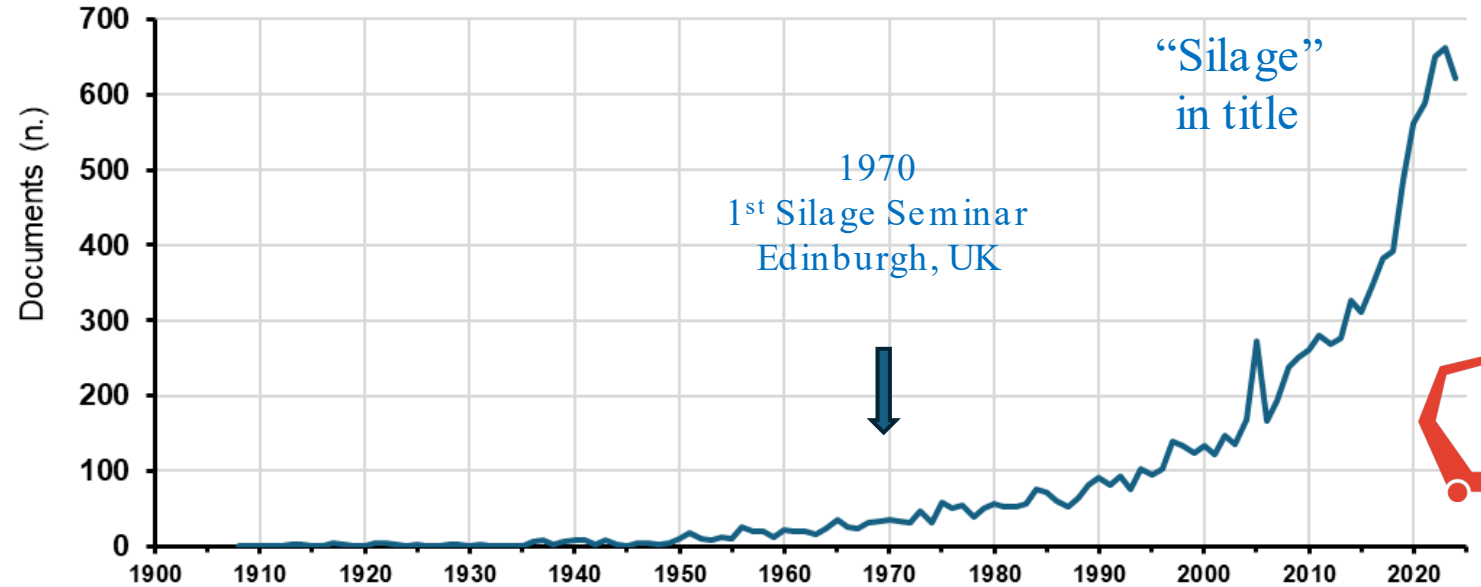
The New York Times

Published: January 27, 1882

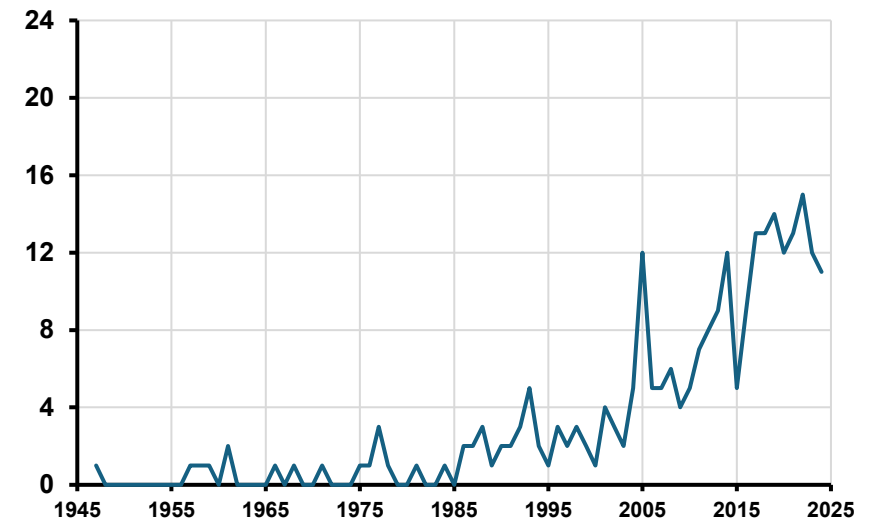
Copyright © The New York Times

Silage scientific peer review papers

Documents on scopus for "Silage" in title

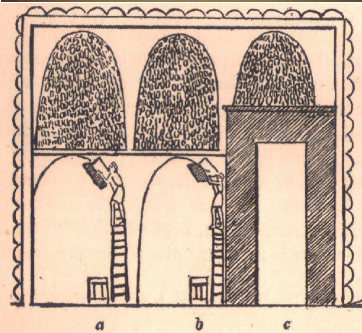


"Silage" and "farm" or
"bunker" or "sealing"
or "cover" or "plastic"
article in title



Silage an old history: sealing the key of successful

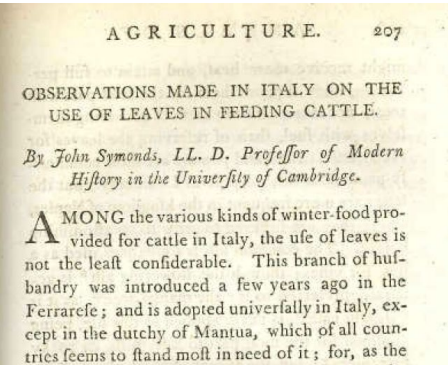
Stone silos



Silo Sealing Wood and soil

2500 b.C
Mediterranean area

Tower silos



in some parts of Italy to bury them in a pit, and to cover them with straw, upon which they lay either clay or sand; and both are equally calculated to answer the purpose. But there is a practice in

Straw plus a soil layer

1786 A.D.
Italy

Silo Gospel Hymn, 1912

If you want to save on feed, build a silo,
It will help in times of need, build a silo.
Build of concrete if you would.
Build of brick, or build of wood.
Build of anything that's good
But build a Silo.

The New York Times
Published: January 7, 1881

PRESERVING CATTLE FOOD

A SUCCESSFUL EXPERIMENT IN PREPARING ENSILAGE.

THE OPENING OF A SILO ON THE BUCKLEY FARM, NEAR PORT JERVIS—THE ENSILAGE GOUND IN EXCELLENT CONDITION—HOW A SILO IS BUILT AND FILLED.

1870 -1910
US and Europe

Sisalkraft Silos

Many conditions arise under which a temporary silo is more capacity than the owner is willing to provide for additional silage. Corn which cannot mature up more...



Experience proves that, when built in accordance with directions, this type of silo provides adequate protection for the temporary storage of silage.

For Haystack Covers—Farm Machinery Covers—For Lining Grain Bins, Hog Houses, Dairy Barns, Poultry Houses, Out Buildings, Lambing Quarters, Tool Sheds, Stock Cars, etc. For Screen Door Covers—For Protecting Berry Bushes and Shrubbery—For Wind Breaking—Curing Concrete—and for a score of other related uses.

Self demonstrating samples and full information as to farm and home uses will be mailed upon request.

SISALKRAFT

Reg. U. S. Pat. Off.



Sisalkraft is "more than a building paper." Made with kraft paper, a double coat of asphaltum rendered with coated steel sheathing combined under heat and pressure to make a strong, tough, durable sheet which resists wind and water.

1936
Illinois, US

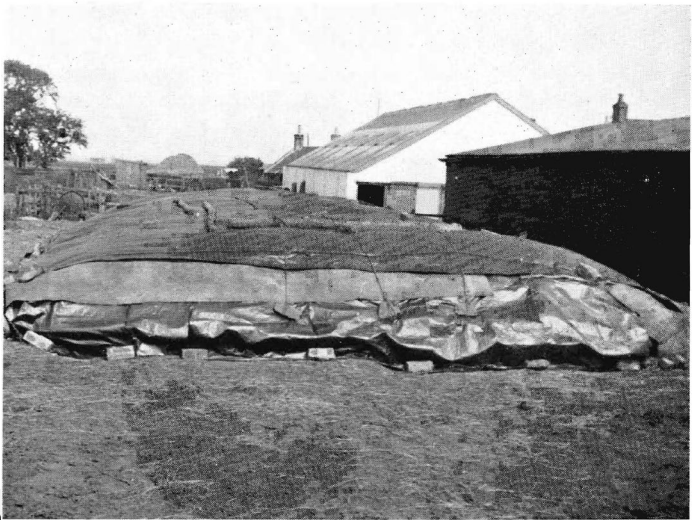


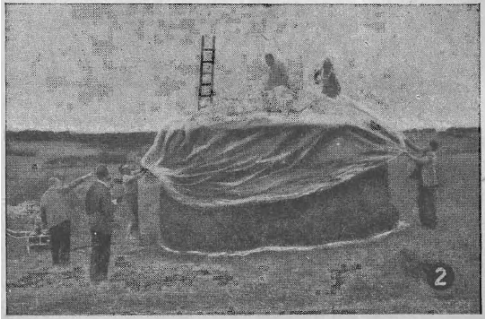
Fig. 12.—A well-finished trench silo. The covering is of sisalkraft paper and rubberized shee



1950-54
Europe and US

Plastic age and silage sealing:

40 years of undisputed success of PE films for horizontal silos



Journal of Agricultural Engineering Research
Volume 41, Issue 2, October 1988, Pages 65-73



Research paper

Optimization of plastic covers for stack silos ☆

P. Savoie *



Les films coextrudés dans l'ensilage

Coextruded films in silage

T. Daponte,
Plant and R & D manager
Hypplast NV (Belgium),
Division of Klerk's Plastic Industrie (holland)
St Lenaartseweg, 26
B 2320 Hoogstraten

« Plasticulture », n° 96 - 1992/4

Doubts and questions on oxygen permeability of plastic films?

Year	1952	1954	1957	1980
Plastic polymers	Poly-vinyl chloride (PVC 200 µm)	PE films of 100-150 µm	Neoprene-nylon blankets	Lining bunker walls with PE film
References	Anonimus (1952); Larrabee and Sprague (1957)	Staff(1957)	Gordon et al., (1961)	Ciotti (1992); Lima et al. (2017)

Savoie (1988) stated that “The optimal thickness of polyethylene films is derived as a function of storage period, silage density and dry matter content, film permeability, and the relative value of plastic and silage.

1952-1954

1988

1992

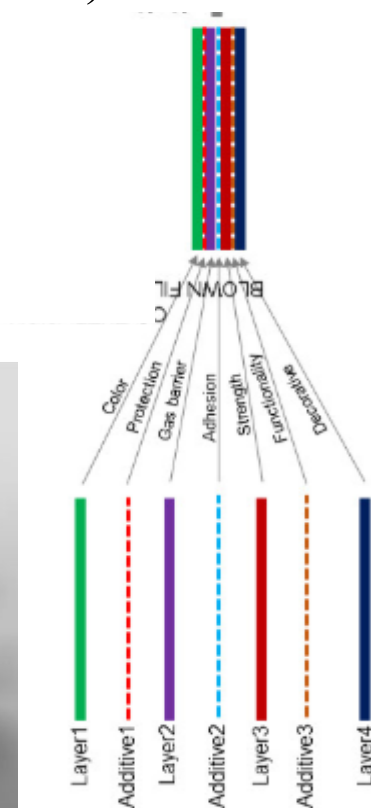
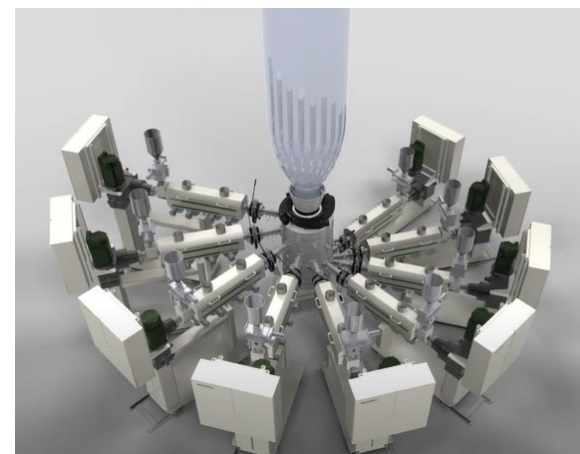
Polyethylene vs. Oxygen barrier films

In early 2000s it became clear that low-density **polyethylene (PE) films** had a too high **oxygen permeability** for silage, especially for long conservation period purposes (Degano, 1999; Borreani and Tabacco, 2005, Borreani et al., 2007; Wilkinson and Fenlon, 2014)

EVEN IF

It remains still clear that **PE films presented excellent mechanical characteristics** and a relatively low cost

New technologies in plastic film lines appeared on the market with high processing capabilities of multi-layer coextruded film (from 3, 5, 7, 9 to 11 layers)



Coextrusion of PE and PA or EVOH polymers to produce oxygen barrier films

Oxygen permeance

(cm³/m²/24 hours at 23°C, 1 atm, 65% RH)

178.000

Low density
polyethylene (LDPE)

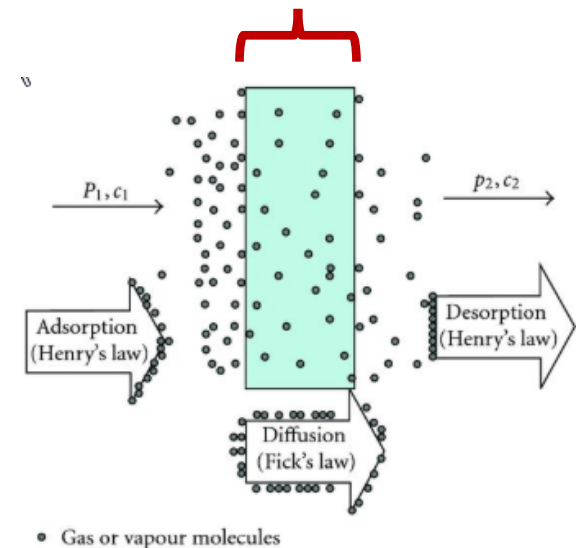
1.380

Polyamide (PA)

38

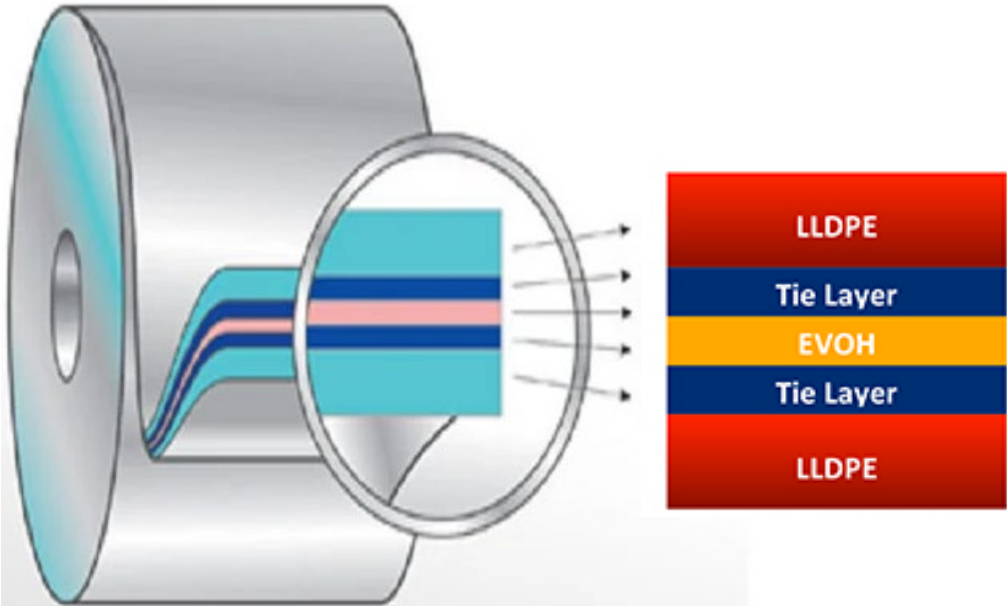
Ethylen-Vinyl-Alcohol (EVOH)

1 μm
thickness
film



Oxygen barrier and High oxygen barrier films

Film type	Thickness (μm)	Film O ₂ permeability ($\text{cm}^3/\text{m}^2/24 \text{ h, 1 bar}$)	
		at 23°C	at 50°C
Polyethylene (PE)	180	990	3000
Oxygen barrier (OB) (PE – PAcoextruded SILOSTOP®)	125	100	400
High Oxygen barrier (HOB) (PE – EVOH coextruded)	130	8.8	35



(From Borreani et al., 2007; Borreani and Tabacco, 2014)

A New Oxygen Barrier Film Reduces Aerobic Deterioration in Farm-Scale Corn Silage

G. Borreani,^{*1} E. Tabacco,^{*} and L. Cavallarini[†]

PE film

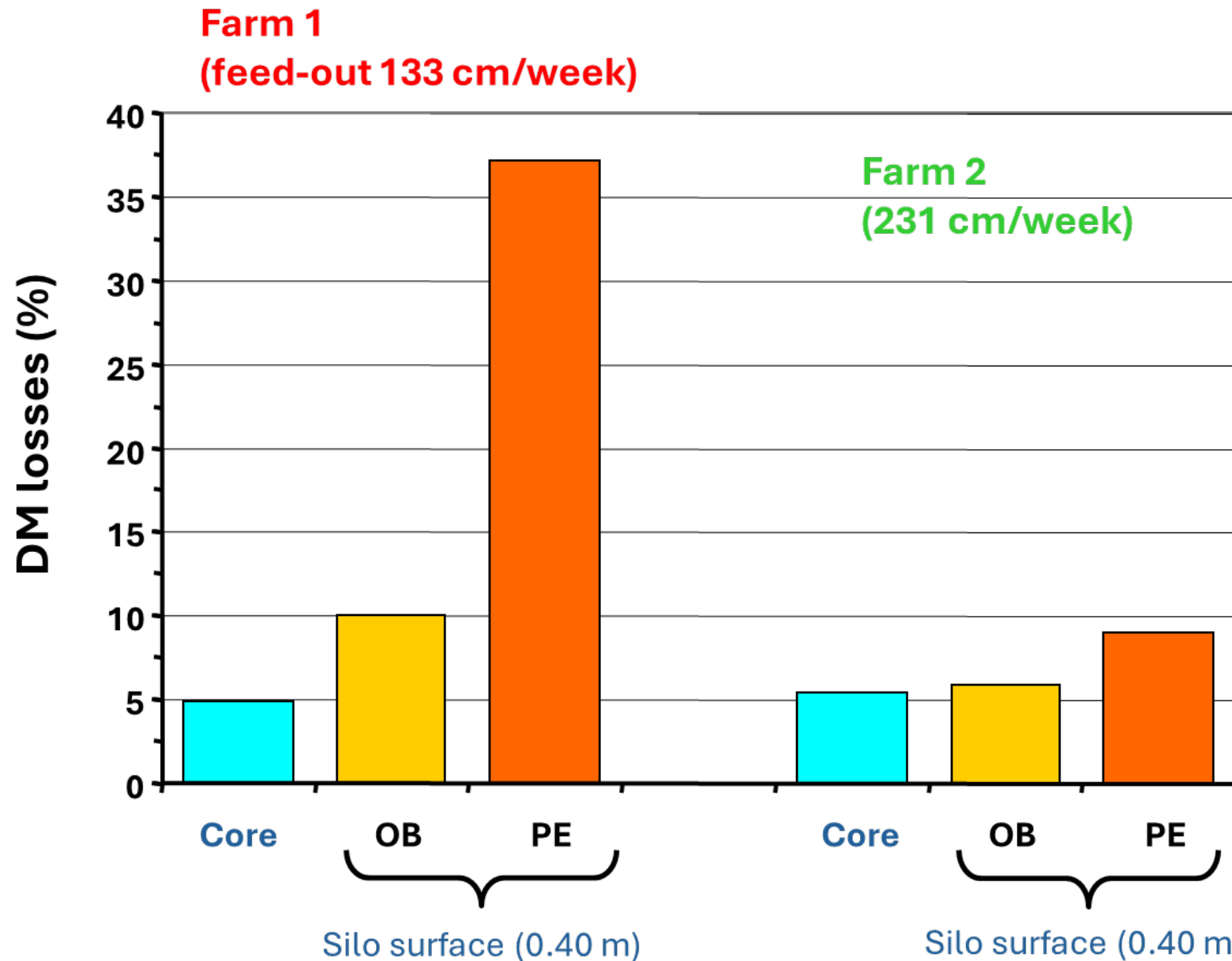
OB film



PE film

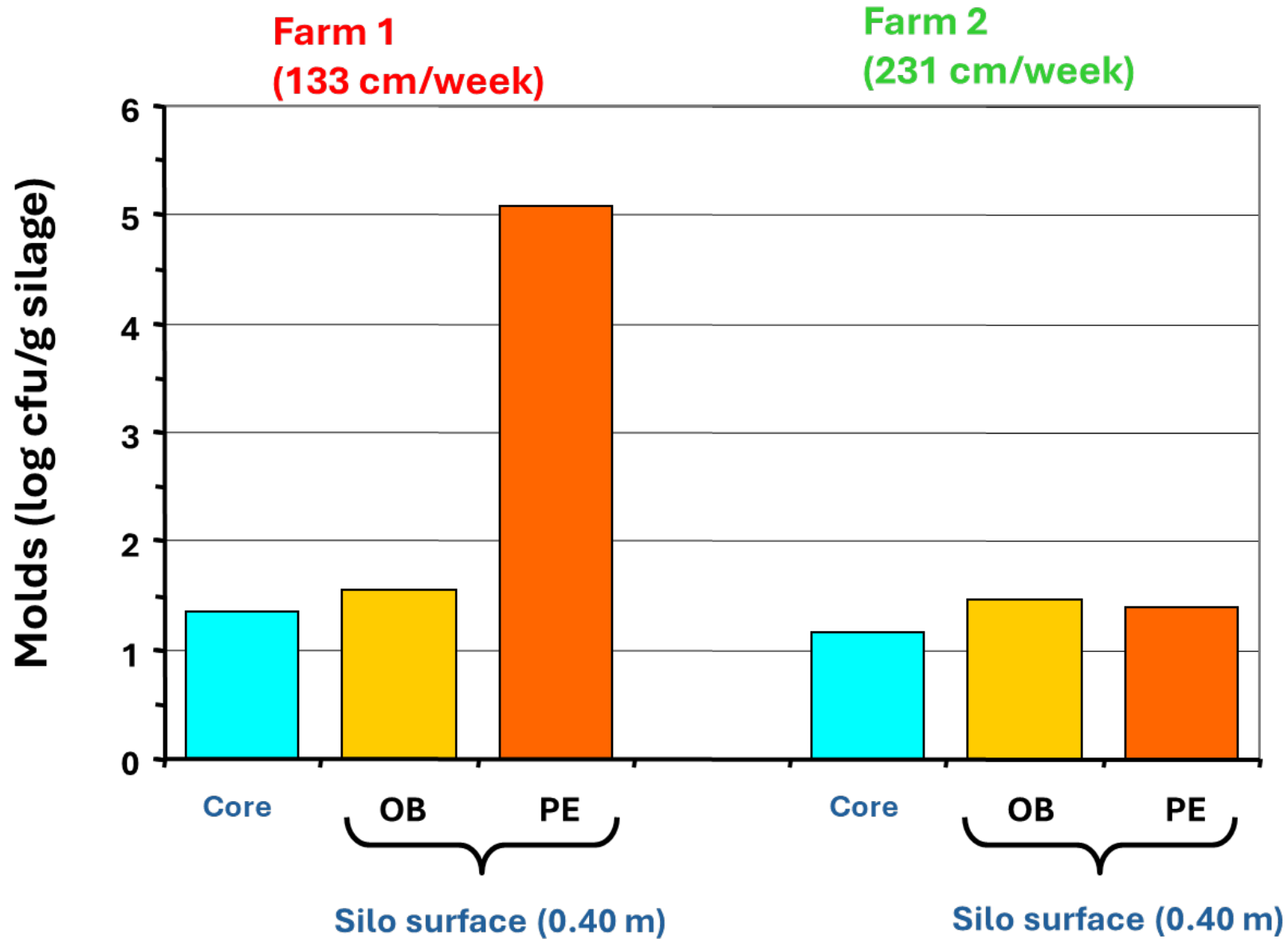
OB film

DM losses in the peripheral areas of the silo covered with PE or OB films



(From Borreani et al., 2007)

Mold count in the peripheral areas of the silo covered with PE or OB films



(From Borreani et al., 2007)



J. Dairy Sci. 97:2415–2426

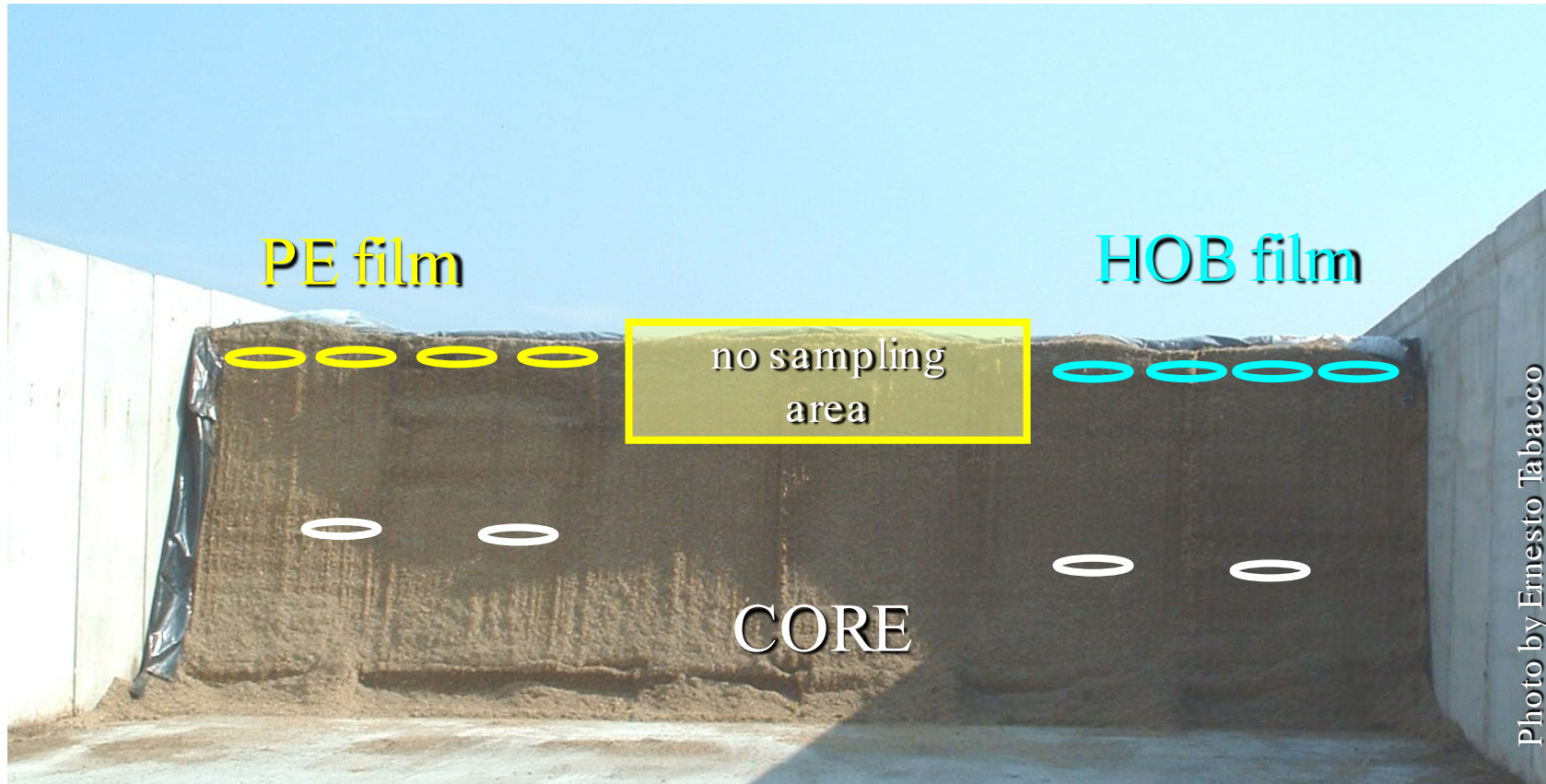
<http://dx.doi.org/10.3168/jds.2013-7632>

© American Dairy Science Association®, 2014.

Improving corn silage quality in the top layer of farm bunker silos through the use of a next-generation barrier film with high impermeability to oxygen

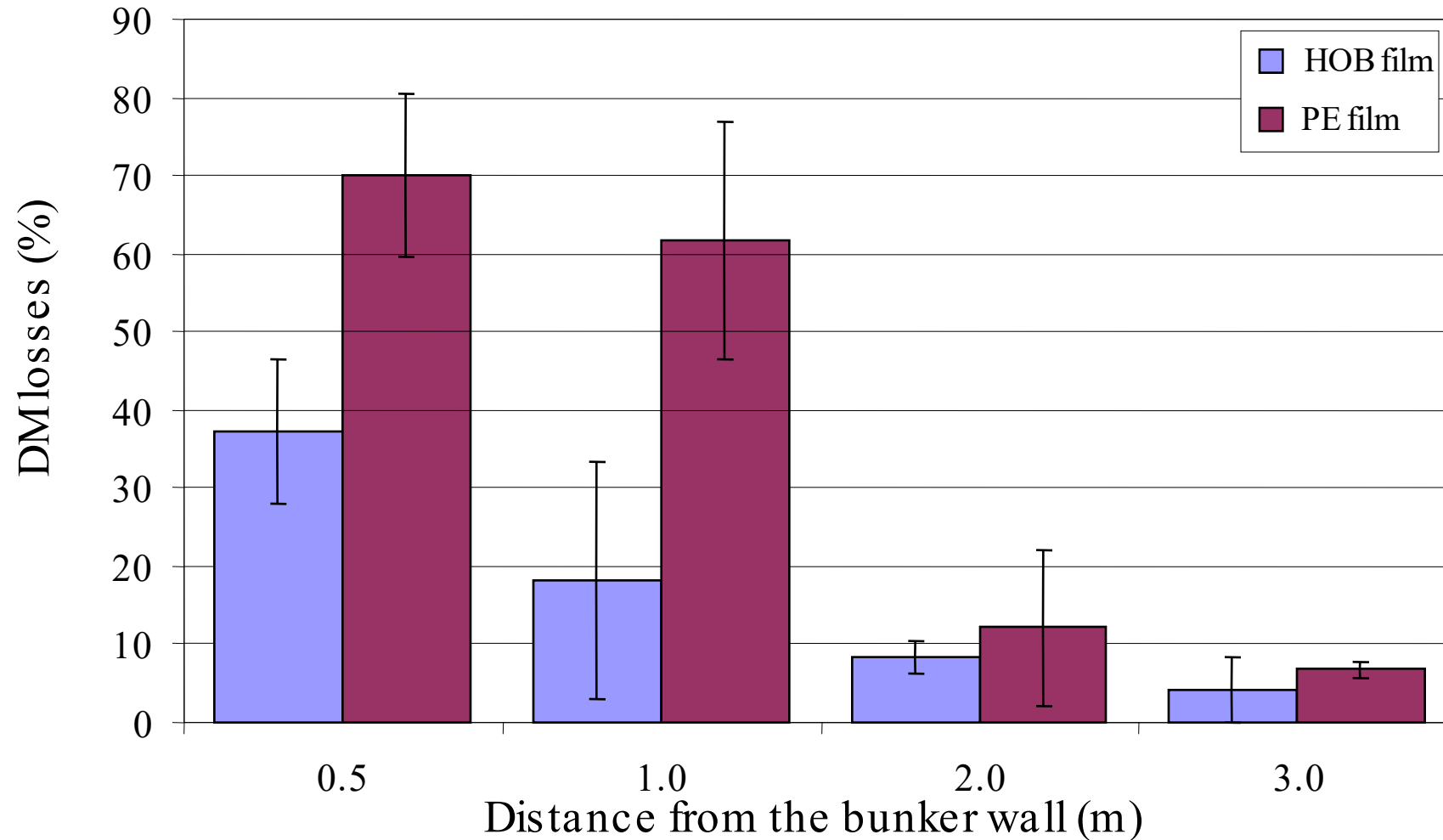
G. Borreani^{1,2} and E. Tabacco¹

Department of Agricultural, Forest and Food Sciences (DISAFA), University of Torino, Via L. da Vinci 44, 10095 Grugliasco, Italy



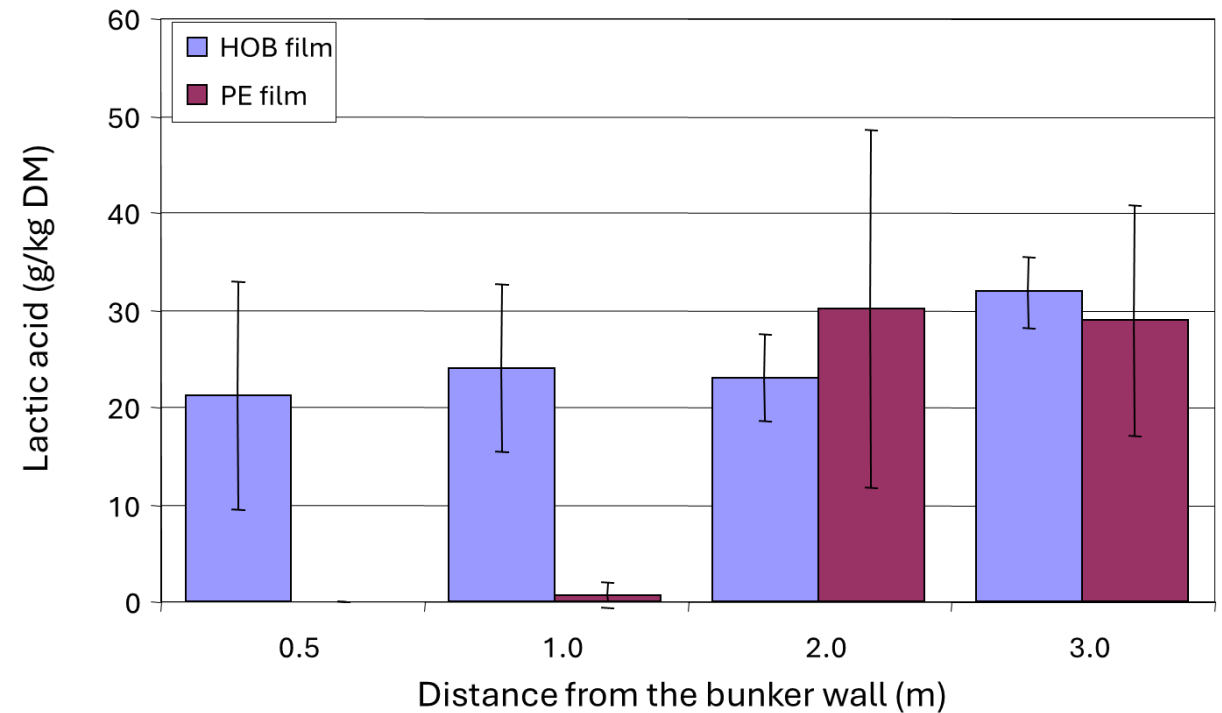
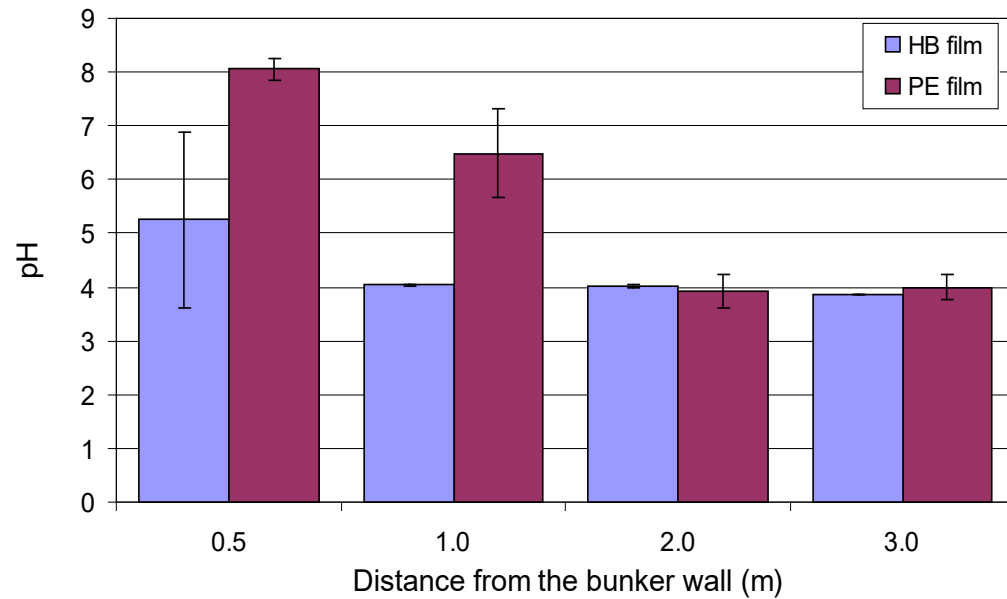
Sampling areas during experiments in commercial whole corn silage covered with HOB and PE films

DM losses in the top silo zone in relation to the distance from the bunker walls



(From Borreani and Tabacco 2014)

pH and lactic acid in the top of the silo in relation to the distance from the bunker wall

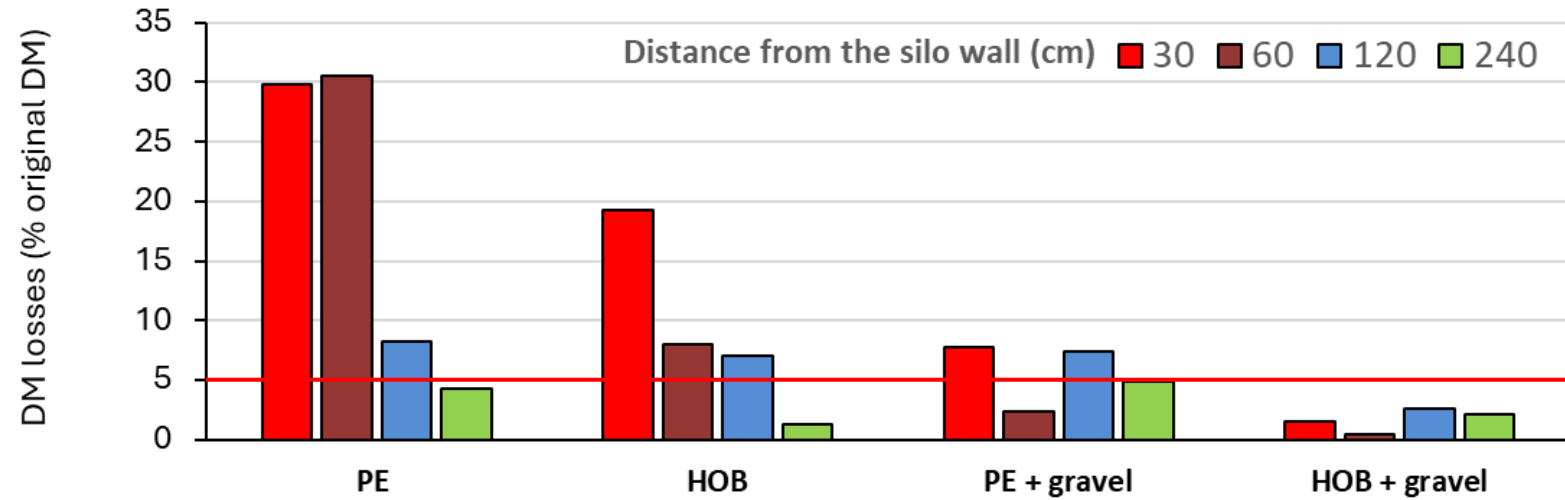


(From Borreani and Tabacco 2014)

Good plastic film - necessary, but is it enough to seal a silo?

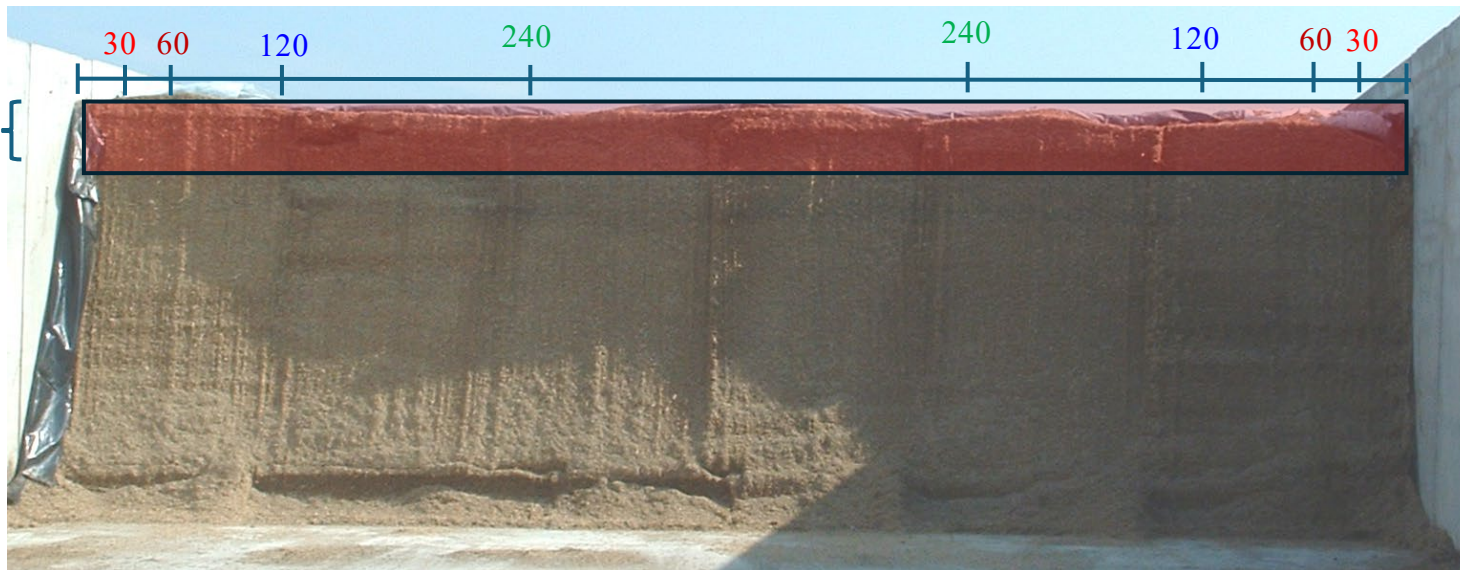


Minimizing DM losses: Synergistic effect of HOB films and uniform gravel application on silo tops

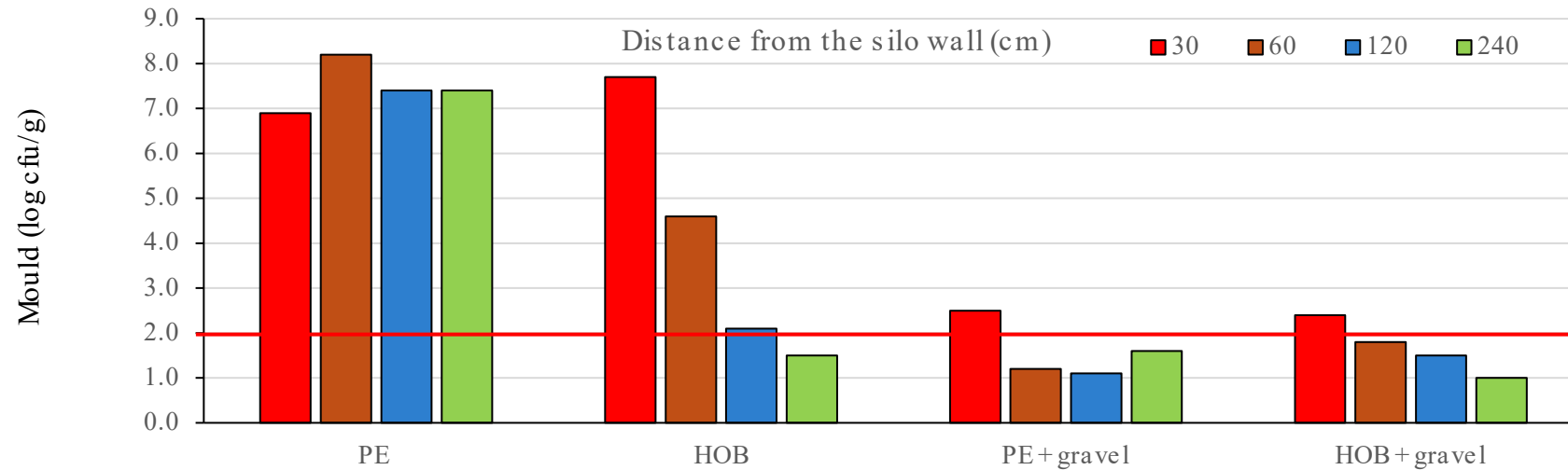


Boundary level
for stable silages

0.5 m layer



Improving microbial quality through the Combined Application of HOB films and uniform gravel application on silo tops

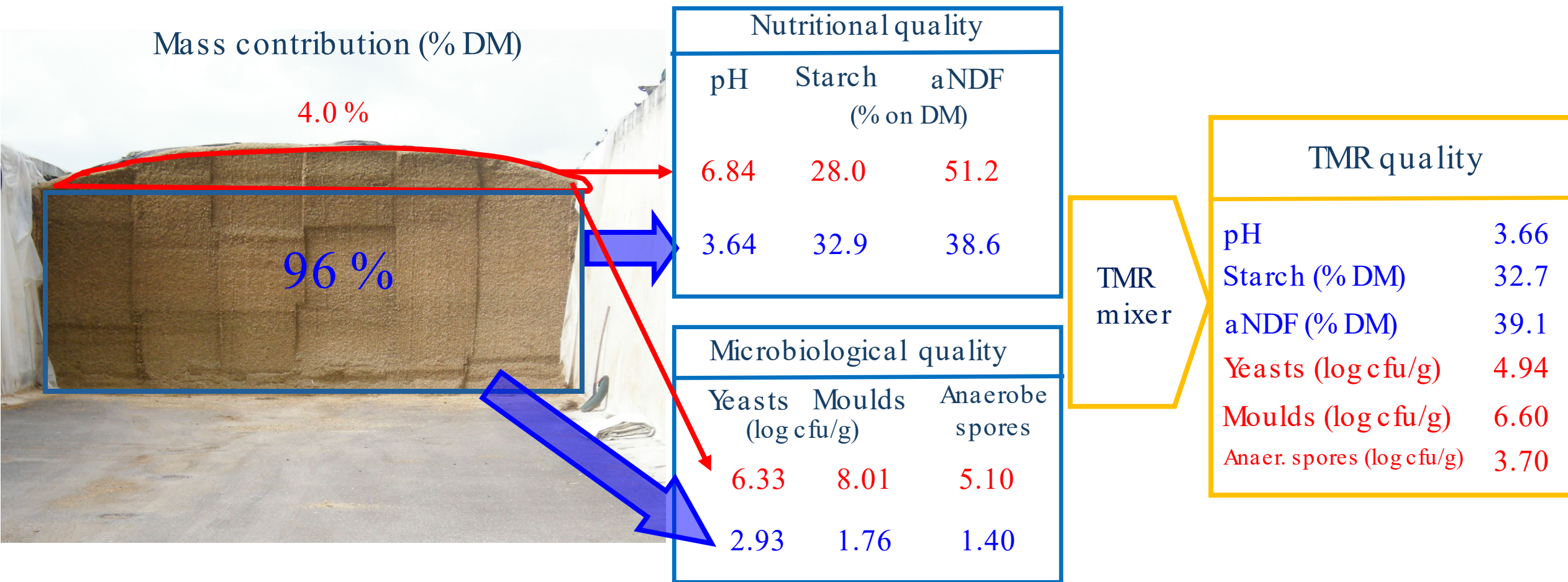


CLEAN SILAGE
100 cfu of mould/g

Towards Clean Silage



Mixing good and spoiled silage: what it means for TMR quality

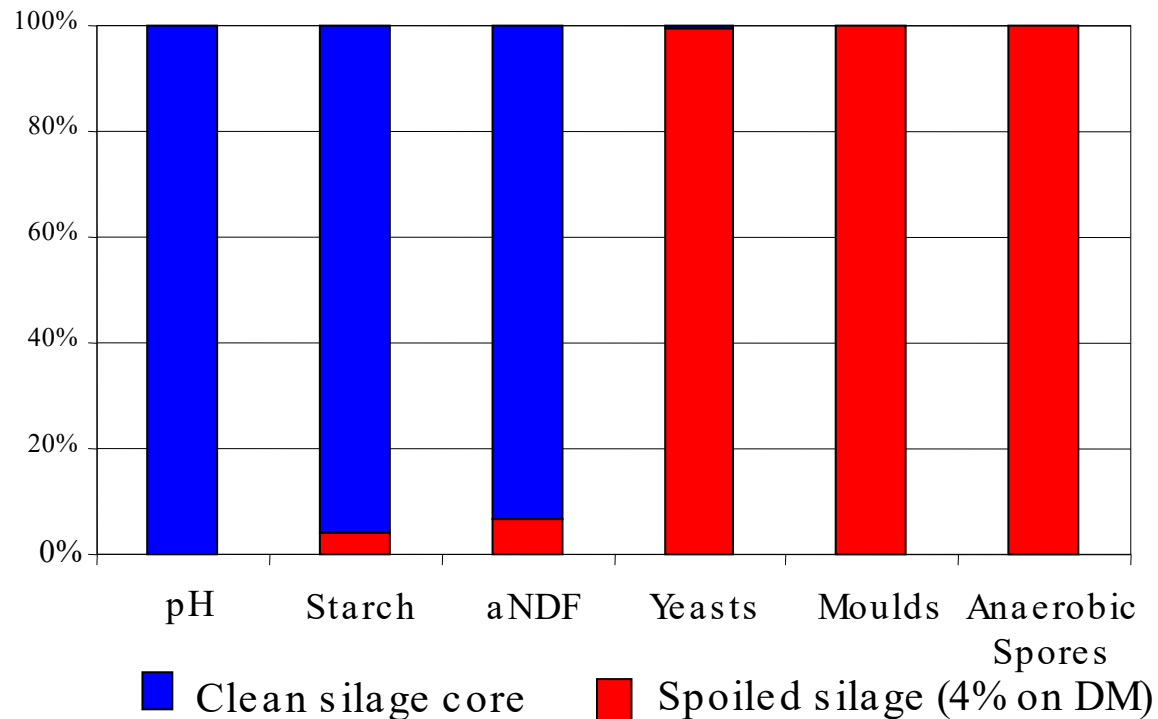


Data collected on dairy farms in northern Italy (pers. Com. Borreani and Tabacco)

Spoiled silage in feed leads to 0.9–1.4 kg less milk per cow daily

Cattlemen's Day 2000

Contribution to nutritional and microbial silage qualities

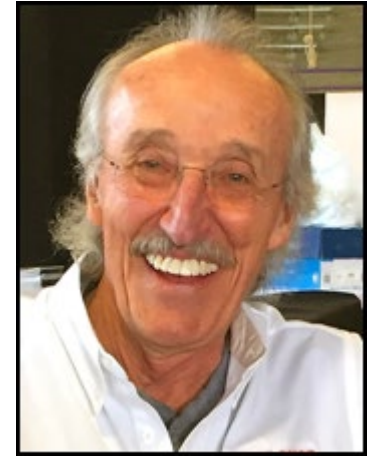


EFFECT OF LEVEL OF SURFACE-SPOILED SILAGE ON THE NUTRITIVE VALUE OF CORN SILAGE-BASED RATIONS

L. A. Whitlock, T. Wistuba, M. K. Siefers, R. V. Pope, B. E. Brent, and K. K. Bolsen

Dr. Keith K. Bolsen

May 22, 1943 - May 29, 2020



Spoiled silage in dairy cow diets can lead to:

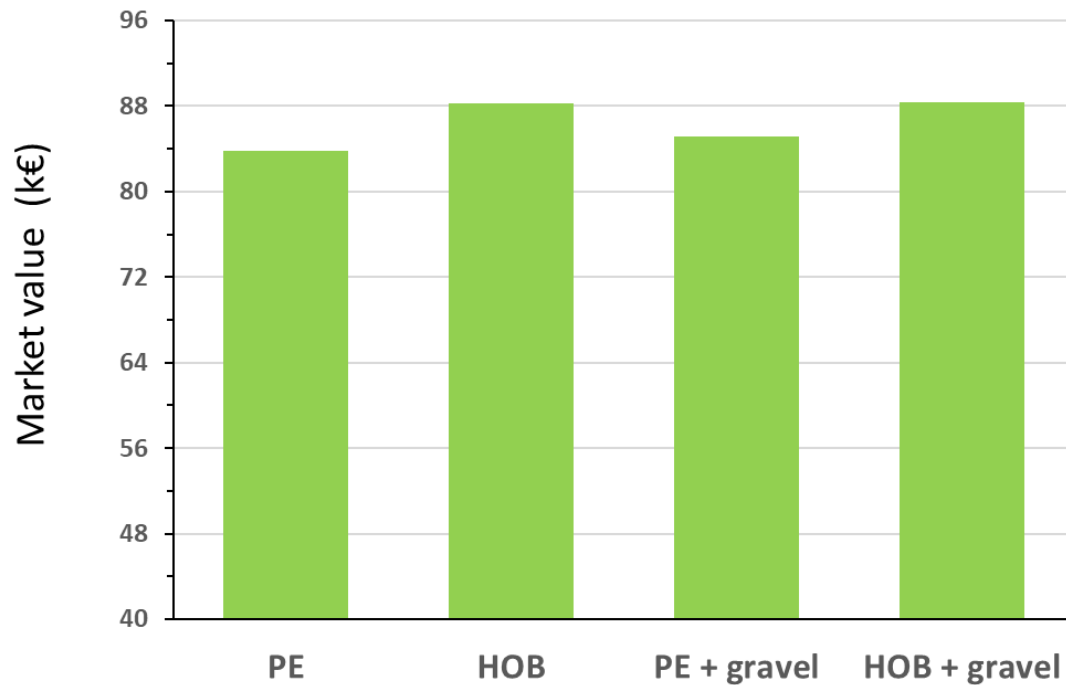
- Lower DM intake
- Greater risk of metabolic disorders
- Reduced energy availability
- Impaired fiber digestibility

Lowered milk yield up to 2.1 kg/cow/d

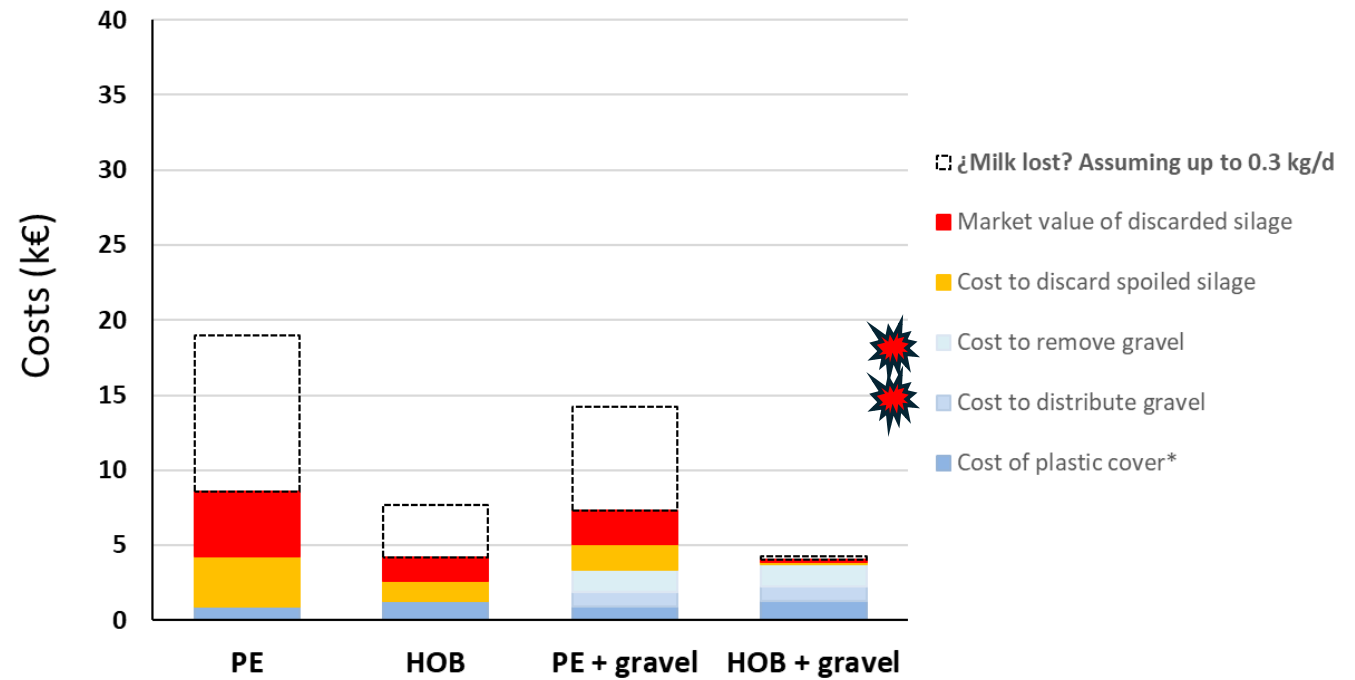
Confirmed by several authors: Hoffman e Ocker, 1997; Trevisi et al., 2003; Berger and Bolsen, 2006; Gerlach et al., 2013; Santos et al., 2014.

Market value of silage and sealing costs of a bunker silo of 1700 Mg of corn silage (Silo size: 4.0 m height, 10 m wide, 60 m long)

Market value of feed silage



Sealing costs and cost due to DM losses



Farmer perception: “...who removes the gravel?”

Researcher opinion: “Improper management of spoiled silage directly contributes to unavoidable milk loss”

An integrated approach for horizontal silo sealing is needed

- **Choosing proper plastic film:** for high mechanical and Oxygen barrier properties
- **Lining silo walls:** to protect concrete from acid corrosion and avoid the gap between silo wall modules
- **Correct distribution of plastic film over the silo:** overlapping of plastic sheets and double layer of new and old films help to increase anaerobiosis and to guarantee a perfect hermetic environment
- **Protect the cover from mechanical damages:** polypropylene nets, HDPE Woven Fabric Tarpaulin
- **Weighing down the plastic cover:** homogeneous weighing materials to maintain the contact between silage mass and sealing cover to avoid wind wave and air penetration into top layer of silage and increase silage density in the outer layer



Evaluating biodegradable film solutions for plastic waste reduction

Biologisch abbaubare Silagestretch-
folien prinzipiell möglich

Biodegradable stretch films for silage bales: basically possible

Keller, A., 2000. Agrarforschung, 7(4), 164-169.

Duration of up to 30 days!



J. Dairy Sci. 98:386–394
<http://dx.doi.org/10.3168/jds.2014-8110>
© American Dairy Science Association®, 2015.

Bio-based biodegradable film to replace the standard polyethylene cover for silage conservation

Giorgio Borreani¹ and Ernesto Tabacco

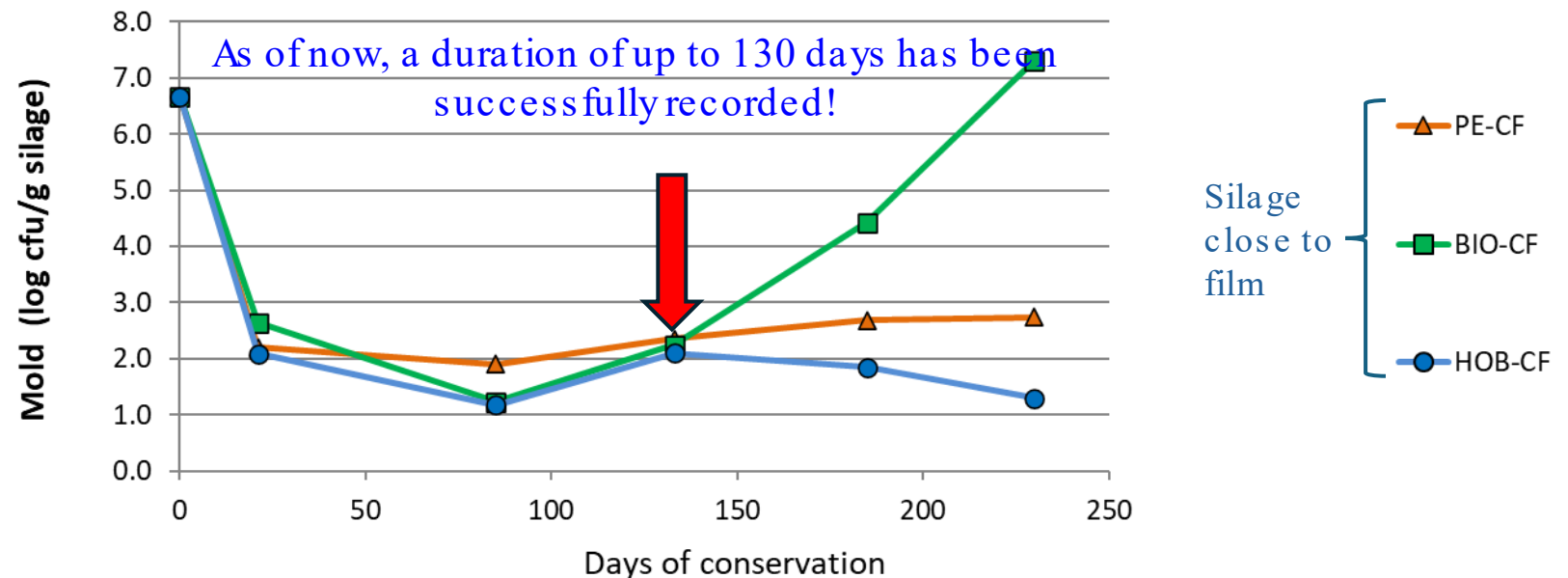


Appl. Sci. 2020, 10, 2803

Article

Feasibility of Utilizing Biodegradable Plastic Film to Cover Corn Silage under Farm Conditions

Ernesto Tabacco¹, Francesco Ferrero¹ and Giorgio Borreani¹ *



Perspectives

- Automatic sealing and weighing systems are available now by several companies. **The evaluation of manpower reductions and DM losses is necessary**
- Development of long shelf-life biodegradable films to reduce plastic waste





Photo by Ernesto Tabacco

Thank you for your attention!