ANIMALS
PEOPLE
A SUSTAINABLE
TOMORROW

HEALTHIER ANIMALS
HIGHER FOOD VALUE

MICROBES
ENZYMES
PLANTS
NUTRITION
PERFORMANCE

SILAGE INOCULANTS

SCIENCE-BASED STRATEGIES FOR HIGH-QUALITY CORN SILAGE

From Fermentation Biology to Aerobic Stability

Homofermentative vs. heterofermentative lactic acid bacteria, enzymes, microbial ecology, spoilage pathways, and practical inoculant selection for whole-plant corn (maize) silage.

IMPROVE FERMENTATION

ENHANCE STABILITY

INCREASE FEED VALUE

SUPPORT ANIMAL HEALTH

Better Silage Brighter Herds

PREPARED BY

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Ruminant Nutrition & Feed Science

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MORE THAN FEED
A HEALTHIER TOMORROW

Why Corn Silage Fermentation Management Matters

Whole-plant corn silage is preserved by controlled acid fermentation, not sterilization. The goal of every management decision — harvest timing, chop length, packing density, sealing speed, and additive choice — is the same: exclude oxygen quickly, drive pH down fast enough to stop undesirable microbes, and then keep the mass anaerobic and chemically stable until the moment it is fed. When that sequence goes well, dry matter and nutrients are conserved, starch and fiber quality are protected, and the silage remains cool and stable for hours after the face is opened to air. When it goes poorly, the consequences compound: fermentation dry matter losses rise, starch and protein are degraded by the wrong organisms, aerobic spoilage accelerates at feed-out, and intake, milk yield, and feed efficiency can all be affected — with real economic cost.

> **A key reframing:** a silage inoculant is not simply a dose of "good bacteria." As catalogued in the additive review by Muck et al. (2018), commercial silage additives span several functionally distinct categories — homofermentative LAB, heterofermentative LAB, enzymes, chemical preservatives — and different lactic acid bacteria (LAB) groups within that landscape pursue different, sometimes conflicting, biological objectives: rapid acidification versus long-term aerobic stability. Selecting the wrong group for the challenge at hand can leave the actual risk unaddressed.

What Actually Happens Inside a Corn Silage Silo

Phase 1 · Aerobic Phase (hours 0–~2 days)

Residual oxygen trapped between particles supports plant cell respiration and aerobic microorganisms. Soluble sugars are consumed, heat is produced, and this phase should be made as short as possible through fine chopping, rapid filling, and immediate, aggressive packing.

Phase 2 · Early Fermentation (days ~1–3)

Once oxygen is depleted, lactic acid bacteria proliferate rapidly, fermenting soluble sugars to organic acids. pH declines quickly. This is the window in which homofermentative inoculants exert most of their effect.

Phase 3 · Stable Anaerobic Fermentation (weeks to months)

A low, stable pH and an acid-tolerant, largely lactobacilli-dominated population hold the mass in biochemical stasis. Heterofermentative end products (acetic acid, 1,2-propanediol) continue to accumulate slowly where L. buchneri-type inoculants are present.

Phase 4 · Feed-Out / Aerobic Exposure

Opening the silo reintroduces oxygen. Lactate-assimilating yeasts activate, consume lactic acid, pH rises, heat is generated, and molds and secondary spoilage organisms follow. This is where heterofermentative inoculants exert most of their effect.

The Ensiling Pathway

> Poor fermentation management does not only cost dry matter — it changes *which* nutrients are lost. Starch and fiber quality, protein fractions, and energy value are all sensitive to which microorganisms dominate each phase (Kung et al., 2018; Borreani et al., 2018).

The Economic Stakes

DM & Nutrients

Fermentation and aerobic-phase losses both remove purchased, grown feed value before a cow ever eats it (Borreani et al., 2018).

Feed-Out Risk

Heating and mold at the face reduce intake and palatability, and can force discarding visibly spoiled silage (Kung et al., 2018).

Herd Performance

Where fermentation and stability outcomes shift, downstream effects on intake, milk yield, and feed efficiency are plausible and sometimes measurable (Oliveira et al., 2017).

These are the stakes that make the choice of bacterial group — not just "whether to inoculate" — a genuine technical decision, developed across the following pages.

Homofermentative Inoculants: Built for Speed

Homofermentative lactic acid bacteria (LAB) convert soluble sugars almost exclusively into lactic acid via glycolysis, with minimal by-product formation:

Glucose → **2 × Lactic Acid**

Because lactic acid is a stronger acid than the acetic acid produced by heterofermentative LAB, homofermentative strains drive pH down faster per unit of sugar fermented. This is their defining advantage.

Claimed benefits

- Rapid lactic acid production and faster pH decline
- Improved fermentation efficiency (more substrate retained as acid, less as heat/CO_2)
- Potential improvement in dry matter recovery during primary fermentation
- Suppression of undesirable, acid-intolerant organisms (enterobacteria, clostridia) during the early window
- Advantages when the priority is a fast, clean primary fermentation

The critical limitation

Producing more lactic acid does **not** automatically produce better aerobic stability. Lactic acid is readily metabolized by lactate-assimilating yeasts (e.g., *Candida*, *Pichia*) the moment oxygen re-enters the mass at feed-out. A silage with a large, homogeneous lactate pool and little or no antifungal acetic acid can, in practice, offer yeasts an easy energy source once air exposure begins.

Representative organisms

CURRENT NAME	COMMON OLDER NAME
Lactiplantibacillus plantarum	*Lactobacillus plantarum*
Pediococcus pentosaceus	(unchanged)
Pediococcus acidilactici	(unchanged)
Enterococcus faecium	(unchanged)

Taxonomy per Zheng et al. (2020), Int. J. Syst. Evol. Microbiol. 70:2782–2858, which reorganized the former genus Lactobacillus into 25 genera.

Answering the hard question: does homofermentative inoculation increase heating risk after opening?

The honest answer is **it depends, and evidence does not support a simple yes/no**. Mechanistically, a larger, more homogeneous lactic acid pool is a plausible substrate risk once oxygen returns (Oude Elferink et al., 2001). Empirically, the meta-analysis by Oliveira et al. (2017) found that inoculation with homofermentative and facultative heterofermentative LAB improved fermentation and dry matter recovery consistently in grasses and legumes, but the response in corn, sorghum, and sugarcane silages specifically was smaller and far less consistent — aerobic stability was not reliably improved, and was occasionally similar to or numerically worse than untreated corn silage in some trials. This does not mean homofermentative inoculants cause instability as a rule; it means their benefit is concentrated in fermentation speed and efficiency, not in aerobic stability, and a corn silage whose primary risk is feed-out heating is being matched to the wrong tool if a purely homofermentative product is chosen for that reason.

> **Practical read:** homofermentative inoculants are a reasonable choice when the dominant risk is a slow, sloppy primary fermentation (e.g., high-buffering-capacity forage, marginal packing) — not when the dominant risk is feed-out heating.

Heterofermentative Inoculants: Built for Aerobic Stability

Obligately heterofermentative LAB — above all *Lentilactobacillus buchneri* (formerly *Lactobacillus buchneri*; Zheng et al., 2020) — do not primarily ferment fresh plant sugars for their stability benefit. Instead, once a conventional lactic acid fermentation has already acidified the silage, *L. buchneri* anaerobically converts a portion of the accumulated lactic acid itself:

Lactic Acid → **Acetic Acid** + **1,2-Propanediol**

Pathway characterized by Oude Elferink et al. (2001), Appl. Environ. Microbiol. 67:125–132, building on the ensiling trial of Driehuis et al. (1999), J. Appl. Microbiol. 87:583–594.

Why this matters

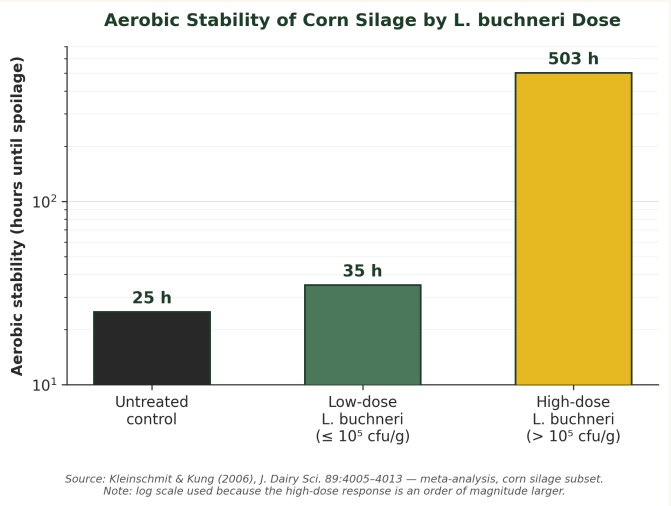
Acetic acid is a broad-spectrum antifungal compound. As it accumulates through storage, it suppresses the yeast and mold populations that would otherwise proliferate the moment oxygen re-enters the silage at feed-out. The result, demonstrated repeatedly in corn silage trials, is a longer delay before heating begins and a slower rate of heating once it starts — i.e., improved aerobic stability.

1,2-Propanediol itself is largely inert with respect to yeast growth, but its accumulation is a useful marker that the buchneri pathway is active; some strains and downstream microbial activity can further convert it to 1-propanol. Screening work by Huang et al. (2021) confirms that *L. buchneri* strains differ measurably in how much 1,2-propanediol they generate in whole-plant corn silage — another reason strain identity, not just species, drives the practical outcome.

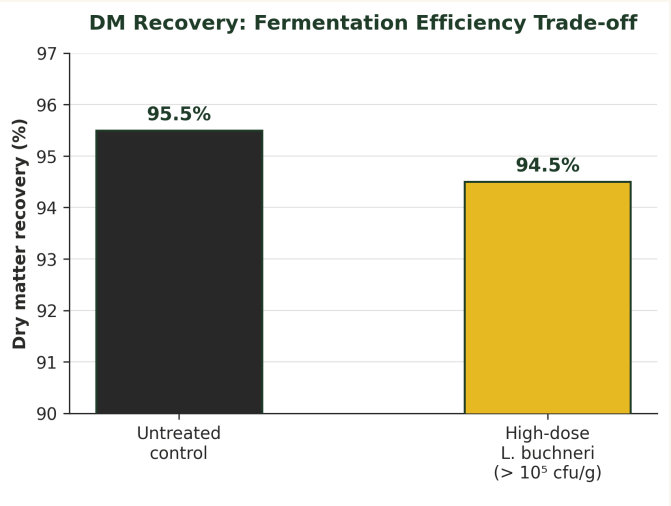
The trade-off

This pathway consumes lactic acid and releases CO_2, so it is metabolically less efficient than homofermentation and is associated with slightly higher dry matter loss *during the ensiling phase itself*. In the Kleinschmit & Kung (2006) meta-analysis, corn silage dry matter recovery was modestly lower with high-dose *L. buchneri* (94.5%) than untreated silage (95.5%) — but this small ensiling-phase cost is routinely outweighed by the much larger dry matter and nutrient losses avoided during aerobic spoilage at feed-out, when spoilage is otherwise left unchecked.

The evidence, quantitatively



Source: Kleinschmit & Kung (2006), J. Dairy Sci. 89:4005–4013 — meta-analysis, corn silage subset.
Note: log scale used because the high-dose response is an order of magnitude larger.



Source: Kleinschmit & Kung (2006), J. Dairy Sci. 89:4005–4013 — meta-analysis, corn silage subset.

Across the corn silage trials pooled by Kleinschmit & Kung (2006), aerobic stability increased from roughly 25 hours in untreated silage to about 35 hours with low-dose *L. buchneri* (≤10^5 cfu/g) and to roughly 503 hours with high-dose treatment (>10^5 cfu/g) — a dose-dependent effect running alongside a small, dose-dependent decline in dry matter recovery. This is the fermentation-efficiency-versus-aerobic-stability trade-off in numbers: a modest cost during storage, purchased in exchange for a large reduction in feed-out heating risk.

Beyond L. buchneri

Lentilactobacillus hilgardii (e.g., strain CNCM I-4785) shows a similar heterofermentative mode of action and has demonstrated comparable bacterial-community shifts and aerobic-stability benefits in high-moisture corn when paired with *L. buchneri* 40788 (Silva et al., 2021). Evidence for hilgardii used alone in whole-plant corn silage specifically is more limited than for buchneri 40788, which remains the most extensively documented strain in this class.

Take-away: heterofermentative inoculation is the biologically appropriate tool when the dominant, expected risk is feed-out heating — long feed-out faces, high ambient temperatures, low feed-out rates, or a history of visible spoilage — not a universal upgrade to every fermentation.

Homofermentative vs. Heterofermentative vs. Combination

CHARACTERISTIC	HOMOFERMENTATIVE LAB	HETEROFERMENTATIVE LAB (L. BUCHNERI-TYPE)
Primary objective	Rapid acidification / fermentation efficiency	Aerobic stability at feed-out
Main products	Lactic acid (near-exclusive)	Acetic acid + 1,2-propanediol (from lactic acid)
Speed of pH decline	Fast	Slower / unchanged in early fermentation
Lactic acid (final)	Higher	Lower (partially converted)
Acetic acid (final)	Little change	Increased, dose-dependent
CO_2 production	Minimal	Higher
Fermentation DM loss	Typically lower	Slightly higher during ensiling
Yeast suppression	Weak / inconsistent	Strong, dose-dependent
Mold suppression	Weak / inconsistent	Strong, dose-dependent
Aerobic stability	Not reliably improved (corn silage)	Substantially improved (corn silage)
Heating after opening	Risk not reduced; plausible substrate-pool risk	Delayed onset, slower rate
Best use scenario	Slow/marginal primary fermentation, high buffering capacity	Long feed-out face, heat, slow feed-out rate, spoilage history
Disadvantages	Feed-out heating risk unaddressed	Slightly higher storage DM loss; slower initial pH drop

Directional summary drawn from Kleinschmit & Kung (2006); Oliveira et al. (2017); Blajman et al. (2018, corn-silage-specific meta-analysis); Zhang et al. (2021). Magnitudes are strain-, dose-, crop-DM-, and storage-time-dependent — treat this table as a pattern, not a guarantee for any specific product.

Combination (Dual-Purpose) Inoculants

Many commercial products now pair a homofermentative species (e.g., *Lactiplantibacillus plantarum* or *Pediococcus pentosaceus*) with a heterofermentative species (*L. buchneri*), on the logic that fast initial acidification and long-term aerobic stability can be achieved in the same silage. Kleinschmit & Kung (2006) directly tested *L. buchneri* 40788 with *P. pentosaceus* R1094 in corn silage and found the combination improved fermentation characteristics without sacrificing the aerobic-stability benefit associated with buchneri.

The corn-silage-specific meta-analysis by Blajman et al. (2018) and the broader buchneri meta-analysis by Arriola et al. (2021), which explicitly compared *L. buchneri* with and without partner bacteria, both support combinations as a scientifically reasonable strategy — but neither concludes that combinations are automatically superior to a well-chosen single-species product. Effects depend on which two species are paired, their relative concentrations, and the specific fermentation and stability challenge of the forage.

What the evidence does *not* support

- That adding more bacterial species is inherently better than one well-matched species
- That homofermentative and heterofermentative strains always act independently — some evidence suggests interaction effects (e.g., the homofermentative partner can influence the timing and magnitude of the heterofermentative shift)
- That combination products remove the need to match the product to the actual risk (fermentation vs. stability)

Bottom line: combination inoculants are a legitimate, evidence-supported category for silages facing both a fermentation and a stability challenge — but “more species” is not a proxy for “more effective.”

Which Strains Have the Strongest Evidence?

Efficacy is strain-specific, not just species-specific: two products both labeled "*L. buchneri*" can behave differently in silage. The table below reports only strains with verifiable, published corn- or high-moisture-corn-silage data, and grades evidence strength rather than declaring a single "best" strain.

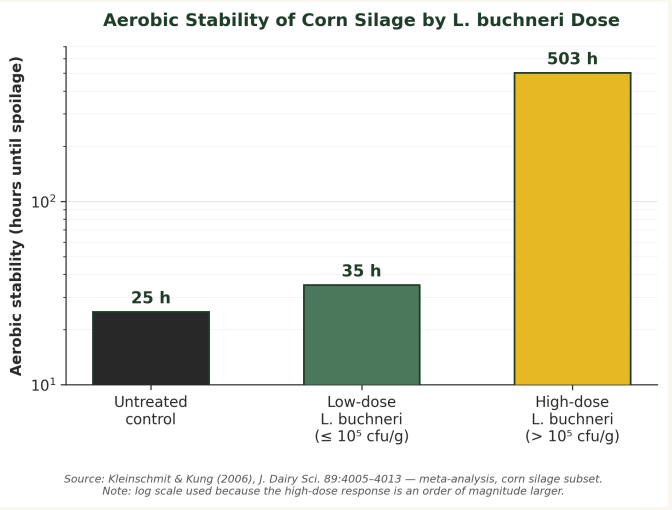
SPECIES	STRAIN	FERMENTATION EFFECT	AEROBIC STABILITY EFFECT	EVIDENCE	BEST APPLICATION
Lentilactobacillus buchneri	NCIMB 40788	Lower final lactic acid; higher acetic acid, dose-dependent	Large, repeatable improvement in corn & high-moisture corn	STRONG	Feed-out heating risk
Lentilactobacillus hilgardii	CNCM I-4785	Similar heterofermentative shift, often paired with buchneri	Improved bacterial-community stability & aerobic stability in HM corn (with buchneri)	MODERATE	Combination with buchneri, HM corn
Pediococcus pentosaceus	R1094	Faster early acidification when paired with buchneri 40788	No loss of buchneri's stability benefit in combination	MODERATE	Combination product, fast+stable
Lactiplantibacillus plantarum (generic homofermentative)	Strain-dependent	Consistent, faster pH decline across forages	Not reliably improved in corn/sorghum/sugarcane specifically	EMERGING–INSUFFICIENT (CORN STABILITY)	Fermentation-limited silages
Enterococcus faecium	Strain-dependent	Early-phase acid production, often in blends	Not established as a standalone corn-silage stability agent	INSUFFICIENT (ALONE)	Typically used in blends only

STRONG multiple independent corn-silage trials/meta-analyses agree · MODERATE consistent but fewer independent trials · EMERGING mixed/limited corn-specific data · INSUFFICIENT not demonstrated for this specific use

Sources: Taylor & Kung (2002); Kleinschmit & Kung (2006, two studies); Der Bedrosian et al. (2012); Silva et al. (2021); Blajman et al. (2018); Oliveira et al. (2017).

Does CFU/g Dose Matter?

Yes — but not as a simple "more is always better" rule. Common application targets range from roughly 10^5 to $\geq 10^7$ cfu/g of fresh forage. In the Kleinschmit & Kung (2006) meta-analysis, a clear dose threshold separated a modest response ($\leq 10^5$ cfu/g: ~35 h aerobic stability) from a dramatically larger one ($>10^5$ cfu/g: ~503 h). The practical response any given silage shows is a function of **species × strain × dose × forage characteristics × storage time** acting together — not dose in isolation.



Source: Kleinschmit & Kung (2006), J. Dairy Sci. 89:4005–4013 — meta-analysis, corn silage subset. Note: log scale used because the high-dose response is an order of magnitude larger.

The Role of Enzymes

Plant Cell Wall → Enzyme Hydrolysis → Fermentable Sugars → LAB Substrate

Cellulase, hemicellulase, xylanase, β-glucanase, and (less commonly) amylase are included in some products on the theory that partial cell-wall hydrolysis releases water-soluble carbohydrates, giving LAB more substrate and potentially improving fiber digestibility. This mechanism is biologically plausible and demonstrated in controlled enzymatic assays. However, when tested directly in whole-plant corn silage, Sheperd & Kung (1996) found that an enzyme additive did not consistently improve silage fermentation characteristics or animal performance relative to untreated silage. The evidence base for consistent, practically meaningful NDF/ADF or digestibility improvement from enzyme addition specifically in corn silage remains thin relative to the strength of evidence for LAB inoculation itself.

> **Theory vs. demonstrated effect:** plant cell walls are hydrolyzed by these enzymes in vitro — that part is settled biochemistry. Whether this translates reliably into improved fermentation or animal performance in whole-plant corn silage is a separate, and considerably less settled, question.

When Fermentation Goes Wrong

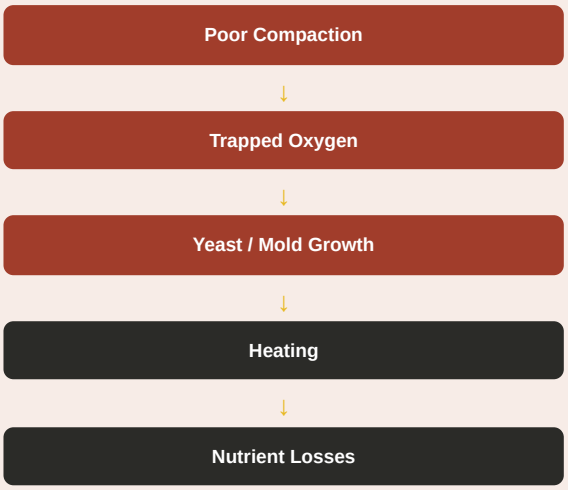
Undesirable microorganisms

Enterobacteria compete with LAB early and produce acetic acid, ethanol, and ammonia at the cost of sugar and protein quality. **Clostridia** thrive in wet, poorly acidified silage, converting sugars and lactic acid to butyric acid with heavy DM loss. **Yeasts** (lactate-assimilating types) are the primary trigger of aerobic spoilage. **Molds** follow once yeast activity has raised pH and temperature. **Acetic acid bacteria** can also contribute to aerobic instability in some conditions. **Bacillus** species, where present, are heat-tolerant and associated with secondary spoilage and, in some contexts, food-safety concern.

Undesirable fermentation products

Butyric acid (clostridial fermentation), excess ethanol (yeast activity on sugars), excess ammonia-N (proteolysis, enterobacterial and clostridial activity), excessive acetic acid when fermentation is poorly controlled, and elevated CO_2 and heat output all signal a fermentation that has drifted from the LAB-dominated pathway.

The core causal chain



Management factors that no inoculant fixes

Harvesting too wet or too dry · slow filling · poor packing density · delayed sealing · air infiltration through the plastic · poor silage-face management · slow feed-out rate relative to face area · damaged plastic · inadequate kernel processing.

Dry matter at harvest

DM concentration governs how completely a silage can be packed and how much oxygen is initially trapped. Too wet increases clostridial risk, effluent loss, and fermentation acid production; too dry limits packing density, leaves more residual oxygen, and can slow LAB activity while favoring molds. Der Bedrosian et al. (2012) found that hybrid, maturity, and DM at ensiling interact to shape corn silage composition and nutritive value, and inoculant responses (including heterofermentative inoculants) are not uniform across this DM range — low-DM corn silage in particular can show a different fermentation and aerobic-stability response to *L. buchneri* than silage ensiled nearer typical whole-plant DM targets (Filya, 2003).

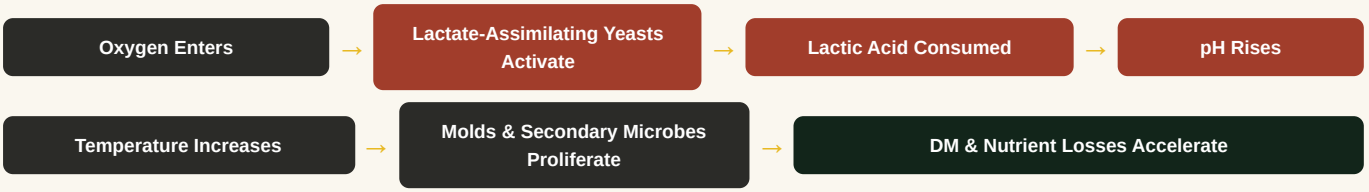
Storage time

The *L. buchneri* pathway is progressive, not instantaneous: acetic acid and 1,2-propanediol accumulate over weeks, so aerobic-stability benefits are generally weaker at 7–14 days and strengthen by 30, 60, and 90+ days of storage as the heterofermentative conversion proceeds (Driehuis et al., 1999; Der Bedrosian et al., 2012). This is a direct, practical argument against opening buchneri-treated silage too soon after ensiling and expecting the full stability benefit.

07 · FEED-OUT

The Real Enemy After Opening: Oxygen

Everything achieved during fermentation can be undone in days once the silo face is opened. The chain below is the single most consequential biological sequence in the entire corn silage system, because it determines how much of the conserved nutrient value the cow actually receives.



Downstream consequences

Once this cascade begins, losses are not limited to dry matter. Documented downstream effects include reduced energy value, depletion of residual sugars and organic acids, degradation of starch and protein quality, altered NDF digestibility, reduced palatability, and — where cows are offered spoiled or heating silage — reduced intake (Borreani et al., 2018; Kung et al., 2018). Meta-analyses linking inoculation to downstream milk yield and feed efficiency (Oliveira et al., 2017; Arriola et al., 2021; Ferraretto & Shaver, 2015) find effects that are real but variable, and generally mediated through these upstream fermentation and stability outcomes rather than acting as an independent effect of the bacteria themselves.

Mycotoxins: be precise

Visible mold and mycotoxin contamination are **not the same thing** — some molds produce no mycotoxins under the conditions present, and mycotoxins can occasionally be detected without conspicuous visible mold. Not every mold genus found in corn silage is toxigenic, and bacterial inoculants are **not** a validated method of preventing mycotoxin formation; their proven role is suppressing the yeast/mold growth that creates the conditions favorable to some toxigenic fungi, not neutralizing toxins already formed. In a corn-silage-specific investigation, Gallo et al. (2021) documented co-occurrence of regulated and emerging mycotoxins alongside fermentation quality and bacterial community measures, underscoring that mycotoxin risk should be assessed on its own terms — via testing — rather than inferred from fermentation quality or visible mold alone. Relevant fungal genera commonly discussed in corn silage include *Fusarium*, *Penicillium*, and *Aspergillus*.

Practical implication: a good inoculant program reduces the probability and severity of aerobic spoilage — it does not replace mycotoxin testing where visible mold, off-odors, or animal health issues raise concern.

Reading the Face: What to Watch For

Temperature

A face that feels noticeably warmer than ambient air is already spoiling — heat is a lagging, not leading, indicator.

Odor & Color

Sharp vinegar or alcohol notes, and visible bleaching or darkening at the face, both signal active aerobic deterioration.

Feed-Out Rate

A face advancing slower than the silage is heating is, functionally, feeding air exposure back to the herd (Kung et al., 2018).

Which Inoculant Should I Choose?

Main concern:
Rapid fermentation / preservation

↓

Consider a **homofermentative** LAB inoculant

Main concern:
Heating at feed-out

↓

Consider an ***L. buchneri*-based heterofermentative** inoculant

Main concern:
Both fermentation and stability

↓

Evaluate a scientifically validated **combination** inoculant

Silage will face frequent air exposure

↓

Prioritize **aerobic stability** over fermentation speed

High DM / difficult packing

↓

Pair inoculant strategy with **packing & face management** review

Non-negotiable: an inoculant cannot compensate for poor silage management. Poor packing, slow filling, inadequate sealing, and poor feed-out management cannot be "fixed" by applying more bacteria (Borreani et al., 2018).

Myth vs. Evidence

CLAIM	VERDICT	EVIDENCE
"More lactic acid always means better silage."	FALSE	Lactic acid is the preferred substrate for lactate-assimilating yeasts once air returns; high-dose *L. buchneri* silage has *lower* final lactic acid yet far greater aerobic stability (Kleinschmit & Kung, 2006).
"All *Lactobacillus*-type strains work the same way."	FALSE	The 2020 taxonomic reclassification (Zheng et al.) split the genus precisely because metabolic behavior differs by species and strain; evidence strength varies strain-by-strain (see p.6).
"With an inoculant, packing density matters less."	FALSE	Packing density and oxygen exclusion remain primary drivers of DM and quality loss regardless of additive (Borreani et al., 2018).
"Heterofermentative inoculants are always better."	DEPENDS	Superior for aerobic stability; not superior for fermentation speed or efficiency, and unnecessary where feed-out heating is not the risk (Oliveira et al., 2017).
"More CFU always means a better response."	DEPENDS	A clear dose threshold exists (Kleinschmit & Kung, 2006), but response is jointly determined by species, strain, forage, and storage time — not CFU alone.

Reading label rates: a product's guaranteed CFU/g applies at the labeled application rate and within its validated dose range — under-dosing (worn applicator, poor calibration, diluting beyond label instructions) is one of the most common, and most preventable, reasons an inoculant underperforms in the field.

What Does the Science Actually Say?

The strongest quantitative evidence, by source

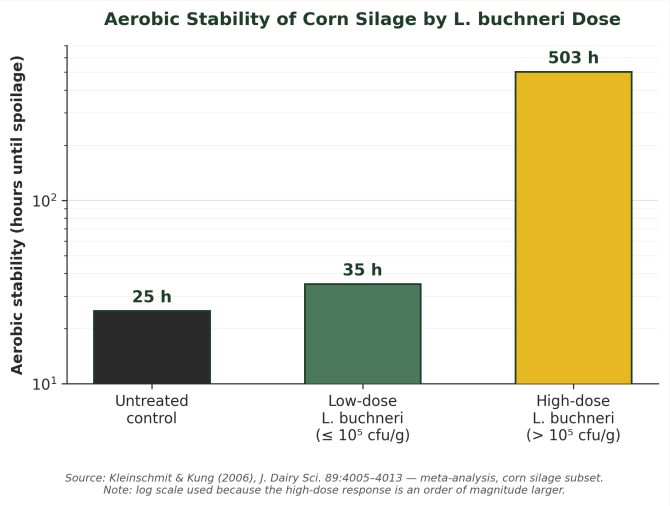
Kleinschmit & Kung (2006), *J. Dairy Sci.* 89:4005–4013 — corn silage meta-analysis: aerobic stability rose from ~25 h (untreated) to ~35 h (low-dose *L. buchneri*) to ~503 h (high-dose); DM recovery fell only slightly, from 95.5% to 94.5%, at the high dose.

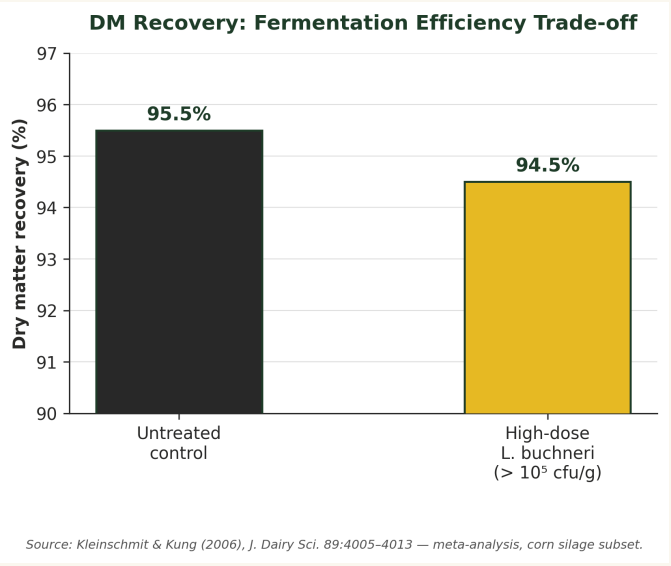
Oliveira et al. (2017), *J. Dairy Sci.* 100:4587–4603 — across forage types, LAB inoculation reliably improved fermentation and DM recovery in grasses/legumes; the response in corn, sorghum, and sugarcane silage was smaller and inconsistent.

Arriola et al. (2021), *J. Dairy Sci.* 104:7653–7670 — confirms *L. buchneri*'s aerobic-stability benefit with or without partner bacteria, moderated by dose and strain combination.

Blajman et al. (2018), *J. Appl. Microbiol.* 125:1655–1669 — corn-silage-specific meta-analysis directly comparing homofermentative and heterofermentative LAB.

Ferraretto & Shaver (2015), *J. Dairy Sci.* 98:2662–2675 — meta-analysis linking corn silage hybrid/management factors to intake, digestion, and lactation performance.

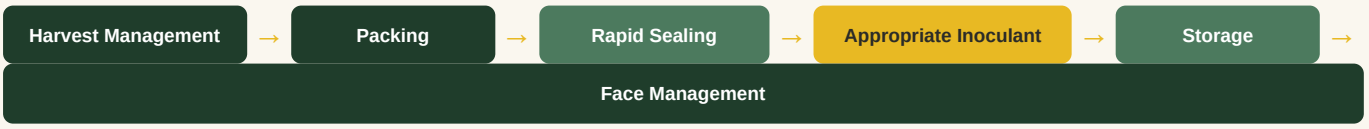




Every numerical value above is drawn directly from the cited source; see the reference list for full bibliographic details.

The Final Take-Home Message

The best inoculant is not necessarily the product containing the greatest number of bacterial species. The appropriate inoculant is the one whose strain, dose, and metabolic function match the specific challenge of the silage — a slow, inefficient fermentation calls for a different biological tool than a silage that heats badly at feed-out, and no product does both jobs equally well by default.



Inoculants are tools for steering fermentation biology in a chosen direction — they are not substitutes for sound harvest, packing, sealing, storage, and feed-out management. Excellent management consistently outweighs inoculant selection; the two are complementary, not interchangeable.

"Match the biology to the risk — fermentation speed and aerobic stability are two different problems, and, at the strain level, two different solutions."

20 Questions, 20 Evidence-Based Answers

1. Biological difference between homo- and heterofermentative? Homofermentative LAB convert sugars almost solely to lactic acid; heterofermentative *L. buchneri*-type LAB additionally convert lactic acid to acetic acid + 1,2-propanediol.

2. Better for rapid pH decline? Homofermentative LAB — lactic acid is the stronger acid and is produced faster.

3. Better for aerobic stability? Heterofermentative (*L. buchneri*-type), via acetic acid's antifungal action.

4. Why does L. buchneri improve aerobic stability? It generates acetic acid, which suppresses the yeasts that trigger spoilage on air exposure.

5. Why is acetic acid important? It is a broad-spectrum antifungal compound that restrains yeast and mold growth.

6. What role does 1,2-propanediol play? A co-product of the buchneri pathway; largely a marker of pathway activity, with some further conversion to 1-propanol.

7. Can excess lactic acid contribute to instability? Yes, indirectly — it is a ready substrate for lactate-assimilating yeasts once oxygen returns.

8. Does inoculation reduce DM losses? It can reduce feed-out losses substantially (heterofermentative types), at the cost of a small increase in ensiling-phase loss.

9. Does response change with corn silage DM? Yes; DM at ensiling affects packing, oxygen exclusion, and the fermentation/stability response to inoculation.

10. Does inoculant dose matter? Yes — a clear dose threshold has been documented, though response also depends on strain and forage.

11. Are combination inoculants superior? They are a reasonable strategy for dual challenges, not automatically superior to a well-matched single-species product.

12. Do enzymes improve effectiveness? Mechanistically plausible, but controlled corn silage trials have not shown a consistent fermentation or performance benefit.

13. Which strains have the strongest evidence? *L. buchneri* NCIMB 40788 has the strongest, most repeated corn-silage evidence base.

14. How important is storage duration? Important — the buchneri pathway is progressive; full benefits generally need 30+ days.

15. Can inoculants prevent yeast and mold growth? They can substantially suppress it (heterofermentative types) but cannot eliminate the possibility.

16. Can inoculants prevent mycotoxins? No — they are not a validated mycotoxin-prevention method; testing is required when risk is suspected.

17. What happens when inoculated silage meets oxygen? The same spoilage cascade begins, but effective heterofermentative treatment delays its onset and slows its rate.

18. Does better fermentation raise milk yield or feed efficiency? Sometimes; effects are real but variable and mediated through fermentation/stability outcomes, not guaranteed.

19. When is inoculation economically justified? When the risk it targets — slow fermentation or feed-out heating — is genuinely present on that farm.

20. When does management matter more than inoculant choice? Always as the foundation — harvest DM, packing, sealing speed, and face management set the ceiling on outcomes.

> These answers summarize positions developed in full, with citations, on pages 2–10 of this report.

REFERENCES

Verified Sources

Every citation below was individually verified against publisher, PubMed, or Crossref records during preparation of this report (title, journal, volume/pages, and DOI confirmed). No source in this list is invented, approximated, or cited second-hand without confirming the original publication. APA-style formatting.

1. Kleinschmit, D. H., & Kung, L., Jr. (2006). A meta-analysis of the effects of *Lactobacillus buchneri* on the fermentation and aerobic stability of corn and grass and small-grain silages. *Journal of Dairy Science, 89*(10), 4005–4013. https://doi.org/10.3168/jds.S0022-0302(06)72444-4

2. Kleinschmit, D. H., & Kung, L., Jr. (2006). The effects of *Lactobacillus buchneri* 40788 and *Pediococcus pentosaceus* R1094 on the fermentation of corn silage. *Journal of Dairy Science, 89*(10), 3999–4004. https://doi.org/10.3168/jds.S0022-0302(06)72443-2

3. Oliveira, A. S., Weinberg, Z. G., Ogunade, I. M., Cervantes, A. A. P., Arriola, K. G., Jiang, Y., Kim, D., Li, X., Gonçalves, M. C. M., Vyas, D., & Adesogan, A. T. (2017). Meta-analysis of effects of inoculation with homofermentative and facultative heterofermentative lactic acid bacteria on silage fermentation, aerobic stability, and the performance of dairy cows. *Journal of Dairy Science, 100*(6), 4587–4603. https://doi.org/10.3168/jds.2016-11815

4. Arriola, K. G., Oliveira, A. S., Jiang, Y., Kim, D., Silva, H. M., Kim, S. C., Amaro, F. X., Ogunade, I. M., Sultana, H., Pech-Cervantes, A. A., Ferraretto, L. F., Vyas, D., & Adesogan, A. T. (2021). Meta-analysis of effects of inoculation with *Lactobacillus buchneri*, with or without other bacteria, on silage fermentation, aerobic stability, and performance of dairy cows. *Journal of Dairy Science, 104*(7), 7653–7670. https://doi.org/10.3168/jds.2020-19647

5. Blajman, J. E., Páez, R. B., Vinderola, C. G., Lingua, M. S., & Signorini, M. L. (2018). A meta-analysis on the effectiveness of homofermentative and heterofermentative lactic acid bacteria for corn silage. *Journal of Applied Microbiology, 125*(6), 1655–1669. https://doi.org/10.1111/jam.14084

6. Muck, R. E., Nadeau, E. M. G., McAllister, T. A., Contreras-Govea, F. E., Santos, M. C., & Kung, L., Jr. (2018). Silage review: Recent advances and future uses of silage additives. *Journal of Dairy Science, 101*(5), 3980–4000. https://doi.org/10.3168/jds.2017-13839

7. Kung, L., Jr., Shaver, R. D., Grant, R. J., & Schmidt, R. J. (2018). Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. *Journal of Dairy Science, 101*(5), 4020–4033. https://doi.org/10.3168/jds.2017-13909

8. Borreani, G., Tabacco, E., Schmidt, R. J., Holmes, B. J., & Muck, R. E. (2018). Silage review: Factors affecting dry matter and quality losses in silages. *Journal of Dairy Science, 101*(5), 3952–3979. https://doi.org/10.3168/jds.2017-13837

9. Driehuis, F., Oude Elferink, S. J. W. H., & Spoelstra, S. F. (1999). Anaerobic lactic acid degradation during ensilage of whole crop maize inoculated with *Lactobacillus buchneri* inhibits yeast growth and improves aerobic stability. *Journal of Applied Microbiology, 87*(4), 583–594. https://doi.org/10.1046/j.1365-2672.1999.00856.x

10. Oude Elferink, S. J. W. H., Krooneman, J., Gottschal, J. C., Spoelstra, S. F., Faber, F., & Driehuis, F. (2001). Anaerobic conversion of lactic acid to acetic acid and 1,2-propanediol by *Lactobacillus buchneri*. *Applied and Environmental Microbiology, 67*(1), 125–132. https://doi.org/10.1128/AEM.67.1.125-132.2001

11. Zheng, J., Wittouck, S., Salvetti, E., Franz, C. M. A. P., Harris, H. M. B., Mattarelli, P., O'Toole, P. W., Pot, B., Vandamme, P., Walter, J., Watanabe, K., Wuyts, S., Felis, G. E., Gänzle, M. G., & Lebeer, S. (2020). A taxonomic note on the genus *Lactobacillus*: Description of 23 novel genera, emended description of the genus *Lactobacillus* Beijerinck 1901, and union of Lactobacillaceae and Leuconostocaceae. *International Journal of Systematic and Evolutionary Microbiology, 70*(4), 2782–2858. https://doi.org/10.1099/ijsem.0.004107

12. Filya, I. (2003). The effect of *Lactobacillus buchneri* and *Lactobacillus plantarum* on the fermentation, aerobic stability, and ruminal degradability of low dry matter corn and sorghum silages. *Journal of Dairy Science, 86*(11), 3575–3581. https://doi.org/10.3168/jds.S0022-0302(03)73963-0

13. Taylor, C. C., & Kung, L., Jr. (2002). The effect of *Lactobacillus buchneri* 40788 on the fermentation and aerobic stability of high moisture corn in laboratory silos. *Journal of Dairy Science, 85*(6), 1526–1532. https://doi.org/10.3168/jds.S0022-0302(02)74222-7

14. Der Bedrosian, M. C., Nestor, K. E., Jr., & Kung, L., Jr. (2012). The effects of hybrid, maturity, and length of storage on the composition and nutritive value of corn silage. *Journal of Dairy Science, 95*(9), 5115–5126. https://doi.org/10.3168/jds.2011-4833

15. Silva, E. B., Smith, M. L., Savage, R. M., Polukis, S. A., Drouin, P., & Kung, L., Jr. (2021). Effects of *Lactobacillus hilgardii* 4785 and *Lactobacillus buchneri* 40788 on the bacterial community, fermentation and aerobic stability of high-moisture corn silage. *Journal of Applied Microbiology, 130*(5), 1481–1493. https://doi.org/10.1111/jam.14892

16. Ferraretto, L. F., & Shaver, R. D. (2015). Effects of whole-plant corn silage hybrid type on intake, digestion, ruminal fermentation, and lactation performance by dairy cows through a meta-analysis. *Journal of Dairy Science, 98*(4), 2662–2675. https://doi.org/10.3168/jds.2014-9045

17. Zhang, F., Miao, F., Wang, X., Lu, W., & Ma, C. (2021). Effects of homo- and hetero-fermentative lactic acid bacteria on the quality and aerobic stability of corn silage. *Canadian Journal of Animal Science, 101*(4), 761–770. https://doi.org/10.1139/cjas-2019-0170

18. Gallo, A., Ghilardelli, F., Atzori, A. S., Zara, S., Novak, B., Faas, J., & Fancello, F. (2021). Co-occurrence of regulated and emerging mycotoxins in corn silage: Relationships with fermentation quality and bacterial communities. *Toxins, 13*(3), 232. https://doi.org/10.3390/toxins13030232

19. Huang, Z., Wang, M., Ke, W., & Guo, X. (2021). Screening of high 1,2-propanediol production by *Lactobacillus buchneri* strains and their effects on fermentation characteristics and aerobic stability of whole-plant corn silage. *Agriculture, 11*(7), 590. https://doi.org/10.3390/agriculture11070590

20. Sheperd, A. C., & Kung, L., Jr. (1996). An enzyme additive for corn silage: Effects on silage composition and animal performance. *Journal of Dairy Science, 79*(10), 1760–1766. https://doi.org/10.3168/jds.S0022-0302(96)76543-8