

THE CHEESE SCHOOL

Science of Artisan Cheeses Conference · Somerset · 18-19/08/2026

Encouraging Healthy Rind Development in Mould-Ripened Cheeses

*Rapid, healthy Geotrichum establishment — environmental conditions, timing and flora balance
— with a look beyond bloomy rind to combined Penicillium-Geotrichum and washed rinds.*

Ivan Larcher

Dairy Technologist

From first bloom to full flora balance

01

Why the rind matters

The thin, uniform bloomy rind as a quality hallmark — and why it's hard to repeat

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Meet the flora

Geotrichum, Penicillium camemberti and yeasts — who does what, and in what order

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Environment & timing

Temperature, humidity, airflow, salt and dosage — the levers you actually control

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Keeping wild moulds out

Competitive exclusion, hygiene, and troubleshooting common rind faults

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Beyond bloomy rind

Combined Penicillium-Geotrichum rinds, washed rinds, lactic vs rennet washing regimes

THE CHALLENGE

A thin, even rind is easy to describe, hard to repeat

The definition of a well-made bloomy-rind cheese is very subjective . What is the norm ? What is beautiful or not ?. Cheesemakers need to know which “family” of rind they are targeting : more rustic and uneven or more commercial and regular ? Then getting there consistently, batch after batch, is where artisan production gets hard.

- Uneven or patchy coverage across the batch

- Wild moulds (grey, black, blue-green) outcompeting the inoculated flora

- Rind too thick, ropy, or ammoniated by the time it ships

- Slip-skin under a thin rind before the core has caught up

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Flannel Flower — a mature Penicillium + Geotrichum rind

A LITTLE HISTORY

Brie, then and now

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The Brie of the 1880s

Marie-Jules Justin, c. 1885

A thick, grey-brown, wrinkled natural rind — a farmhouse Brie ripened on ambient, uncontrolled flora.

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Brie as we know it today

Stabilised soft cheese, modern production

A smooth, bright, tight white felt — selected *Penicillium*-dominant cultures and controlled ripening rooms.

DIVERSITY OF TECHNOLOGIES

LACTIC



MIXED



STABILISED



		TYPES		
		LACTIC	MIXED	STABILISED
MILK	Raw milk	++	(+)	–
	Thermised/pasteurised milk	(+)	+	++
LACTIC ACID BACTERIA	Mesophilic	Lactococci	++	–
		Leuconostocs	(+)	–
	Thermophilic	Streptococci	(+)	++
COAGULATION	Renneting T°C	20-28°C	28-34°C	32-40°C
	Renneting pH	6.00-6.30	6.10-6.30	6.40-6.55
	Coagulant ml/100L (520mg/L chymosin)	4-12 ml	16-25 ml	25-40 ml
	Total coagulation time	14-36h	30 min-2h	20-30 min
IN VAT/MOULD	Cutting	no	Ø 2-3 cm	Ø 0.7-1 cm
	Stirring	–	+	++
	Drainage	+	++	+++
CHEESE COMPOSITION AT THE DEMOULDING	Fat on dry basis	0-75 %	30-60%	50-65%
	Moisture on a fat-free basis	74-85%	69-72%	68-71%
	Ca/fat-free dry matter	< 0.4%	0.8-1.7%	1.8-2.3%
	pH	≤ 4.45	4.65-4.85	4.95-5.20
	Residual sugars	≥ 18g/kg	10-15 g/kg	2-6 g/kg
RIPENING CULTURES	<i>Geotrichum candidum</i>	++	+	–
	<i>Penicillium camemberti</i>	+	++	+++
	Both Geo. + PC	++	+++	+++
	Corynebacteria	+	++	+
	<i>Penicillium roqueforti</i>	–	++	+
BEST BEFORE	From the end of cheese making	2 to 9 weeks	6 to 10 weeks	7 to 15 weeks

Table 1. Soft cheese diversity. Source: Bernard Mietton – ENILRIO Poligny (France).

What healthy establishment looks like on the wheel



Even, tight coverage

A full, uniform coat across the whole wheel — no bare patches, no wild colour.

Photos: Flannel Flower, Long Paddock Cheese
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Fine, wrinkled texture

The characteristic Geotrichum-driven brain-like wrinkling under a thin Penicillium felt.



Rind-to-paste transition

A thin, well-anchored rind sitting cleanly over a paste that hasn't slipped or over-ripened.

THE PLAYERS

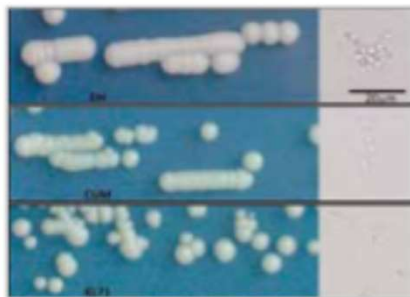
Three groups build the rind, in sequence

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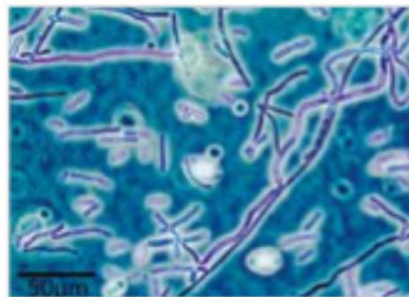
Organism	Arrives	What it does
Yeasts (<i>Debaryomyces</i> , <i>Kluyveromyces</i> , <i>Candida</i> ...)	First (draining through salting)	Colonise the surface early; consume lactate and deacidify the rind, opening the door for moulds to grow
<i>Geotrichum candidum</i>	Very early (1-2 days)	Establishes ahead of <i>Penicillium</i> ; deacidifies and neutralises the surface; suppresses <i>Mucor</i> and other wild moulds by competitive exclusion
<i>Penicillium camemberti</i>	Follows <i>Geotrichum</i> (days 3-10+)	Forms the visible white felt; drives the proteolysis/lipolysis behind classic bloomy-rind flavour and texture



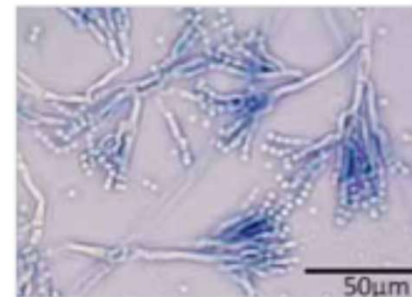
Geotrichum + Penicillium
rind, mature



Yeasts.



Geotrichum candidum.



Penicillium camemberti – mycelium and conidia.

Yeasts: the overlooked first responders

Yeasts colonise the cheese surface earliest of all — during whey draining, after moulding and before salting — reaching 10^6 – 10^8 cfu/cm² within the first five days and holding that level through ripening. Inside the paste, populations run 100-1,000× lower.

Deacidification

Lactate catabolism raises surface pH, opening the door for mould and bacterial growth.

Sugar assimilation

Consumes residual lactose and galactose left on the rind surface.

Limited lipolysis

Modest fat breakdown compared to moulds, except species like *Yarrowia lipolytica*.

Gas & aroma

Some species (*Kluyveromyces*) ferment lactose into gas, creating “micro-persillage”; amino acid breakdown yields alcohols, esters and aldehydes.

Proteolysis

Caseinolytic, aminopeptidase and carboxypeptidase activity — varies by species and strain.

Synergy with *Geotrichum*

Yeast growth favours *Geotrichum candidum*, which in turn suppresses undesirable wild moulds.

Main yeasts used in cheeses (apart *Geotrichum*) :

- *Kluyveromyces lactis* / *marxianus*
- *Debaryomyces hansenii*
- *Candida colliculosa* / *catenulate*
- *Cyberlindnera jadinii* (ex *Candida utilis*)
- *Trichosporon oviforme*
- *Yarrowia lipolytica*
- *Saccharomyces cerevisiae*

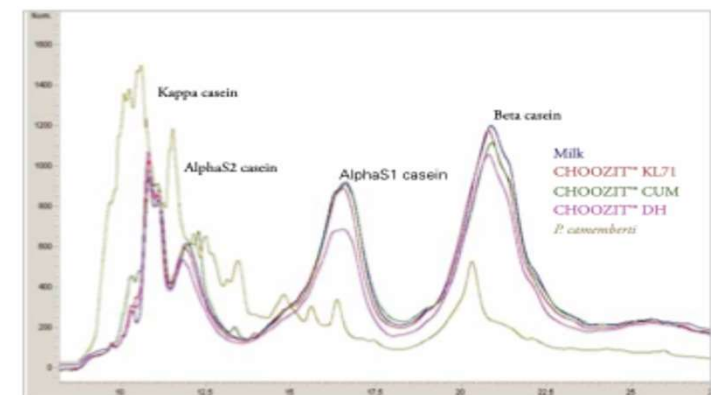


Figure 11. Proteolytic profile of milk (24h/25°C, HPLC analysis).

Why Geotrichum earns its head start

- **Fast off the mark**

Colonises the surface within 1-2 days of manufacture — well ahead of *Penicillium camemberti*.

- **Neutralises the surface**

Metabolises lactate and amino acids at the rind, raising pH — the deacidification that lets *Penicillium*, yeasts and bacteria establish afterward.

- **Genuine competitive exclusion**

Several *Geotrichum* strains actively inhibit growth and sporulation of *Mucor* and other wild moulds — this is a real biological head start, not just a race.



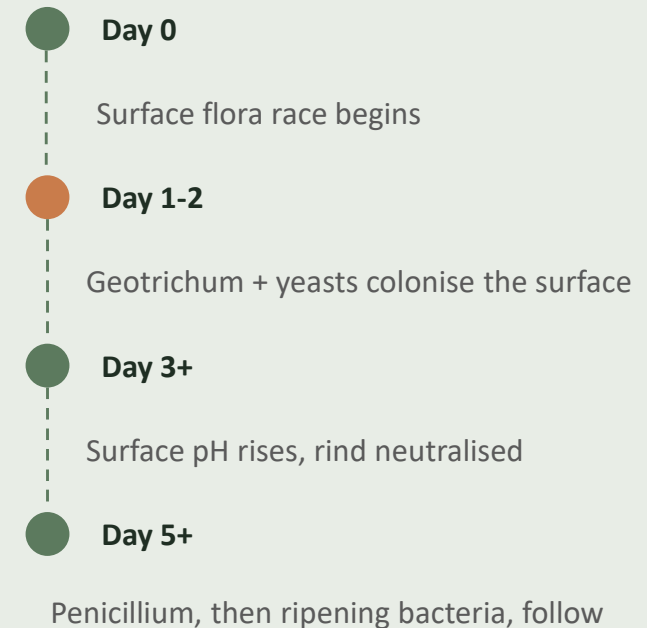
CHOOZIT™ GEO 15 (type 1)

CHOOZIT™ GEO 13 (type 2)

CHOOZIT™ GEO 17 (type 3)

Sources: TM 2106-1e; *Geotrichum candidum* literature (ASM/AEM, *Frontiers in Microbiology*)
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ESTABLISHMENT TIMELINE



Four levers, one goal: fast, even establishment

Temperature

Geotrichum's optimum is 25-30°C; Penicillium's is closer to 20°C. That gap is exactly why a warm start followed by a cool finish works so well. A proper ageing can only be done if one control precisely the temperature evolution : from warm room 28*c to cold ageing 8*c, in various phase.

Humidity / Aw

High RH drives early growth. Penicillium and yeasts tolerate high Aw well; Geotrichum is far more salt-sensitive, so how you salt matters as much as how humid the room is. Later on the RH will influence weight losses and rind's mouthfeel.

Airflow / O₂

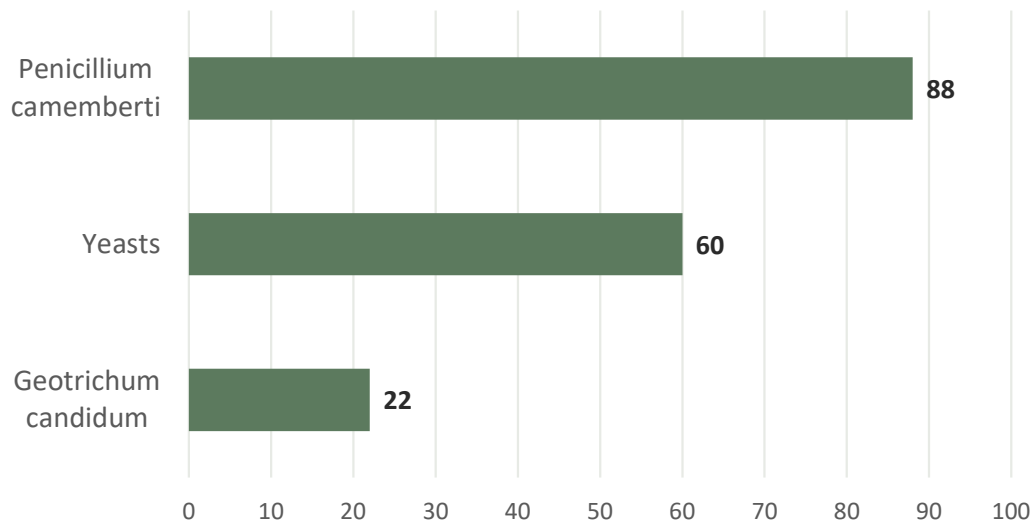
Oxygen-rich, well-renewed air favours yeasts, Geotrichum, Penicillium and Brevibacteria, but can also favor excessive PC development, this one turning yellowish and developing undesired mushroom and styrene flavors.

Strains, Dosage & timing

The strains will influence directly the final aspect as well as the flavour profile. Rigorous selection will permit to deliver the outcomes targeted. Higher inoculation accelerates the apparition of yeasts, Penicillium and Geotrichum. Inoculate the milk for early implantation, and/or spray the surface after salting for even coverage.

Salt is a flora-balance tool, not just a preservative

RELATIVE SALT TOLERANCE (qualitative index)



Geotrichum: significant decline above 1-2% NaCl. Yeasts and especially Penicillium camemberti tolerate a much wider range.

PRACTICAL IMPLICATION

Light, even salting protects *Geotrichum*'s early window.

Because *Geotrichum* needs salt to diffuse in gradually rather than sit concentrated on the surface, heavy or uneven dry salting can suppress it in patches — exactly where wild moulds find their opening.

Penicillium camemberti and yeasts are far more robust across the same range, so they can tolerate salting choices that *Geotrichum* cannot.

When salting goes wrong, Geotrichum pays first

Salt quantity and timing don't just season the cheese — they decide whether *Geotrichum* gets the runway it needs before *Penicillium* takes over. Both faults below follow directly from getting one of these wrong.



Incomplete rind coverage

Heavy or uneven salting inhibits *Geotrichum* locally, leaving bare, pale paste exposed at the centre while only a thin rim of rind closes at the edge. *Penicillium* will eventually take over but this lack of surface protection will favor contaminants development.

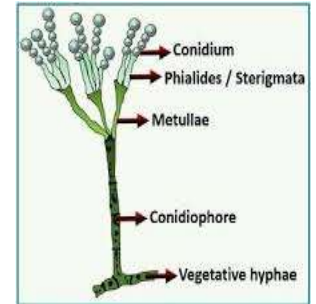


Weak, patchy *Penicillium* growth

For this batch of cheeses salted in brine, cheeses were not submerged so the floating side of the cheeses are undersalted, allowing an excessive growth of *Geotrichum*, limiting the *Penicillium* development.

THE BIOLOGY : PENICILLIUM CAMEMBERTI

Penicillium camemberti is the other well-known member of the *Penicillium* family. It is widely used in the production of “Bloomy” soft cheeses, such as Camembert, Brie, Coulommiers but also traditional versions of Saint Marcellin or Pouligny Saint Pierre. Although it is commonly assumed that *P.camemberti* is delivering a white fluffy velvety rind, some varieties of *P.camemberti* can show grey-green colors.



In fact the *Penicillium camemberti* family includes 3 species : *P. biforme*, *P. camemberti* and *P. fuscoglaucum*. All 3 species are found in cheesemaking environment but the first 2 are specific to cheese (soft cheeses for *P.camemberti* and semi-hard cheeses for *P. biforme*) while *P. fuscoglaucum* is found in all natural environments.

At the beginning of the 20th century (evidences reported in 1905), a white mutant was generated in the cheese industry from a grey-green fungus, initially named *P. commune* (now split into 2 species, *P. biforme* and *P. fuscoglaucum*). The Brie type cheeses produced then was covered with a grey-green fungi and not with a white thick velvet.

P. camemberti specie is then also divided into 2 varieties: *P.camemberti* var. *camemberti* (delivering a white fluffy rind) and *P.camemberti* var. *caseifulvum* (grey-green velvety rind), both varieties being strong competitors against others fungi although the *camemberti* variety being stronger than *caseifulvum*.



Commercial Brie



Camembert de Normandie

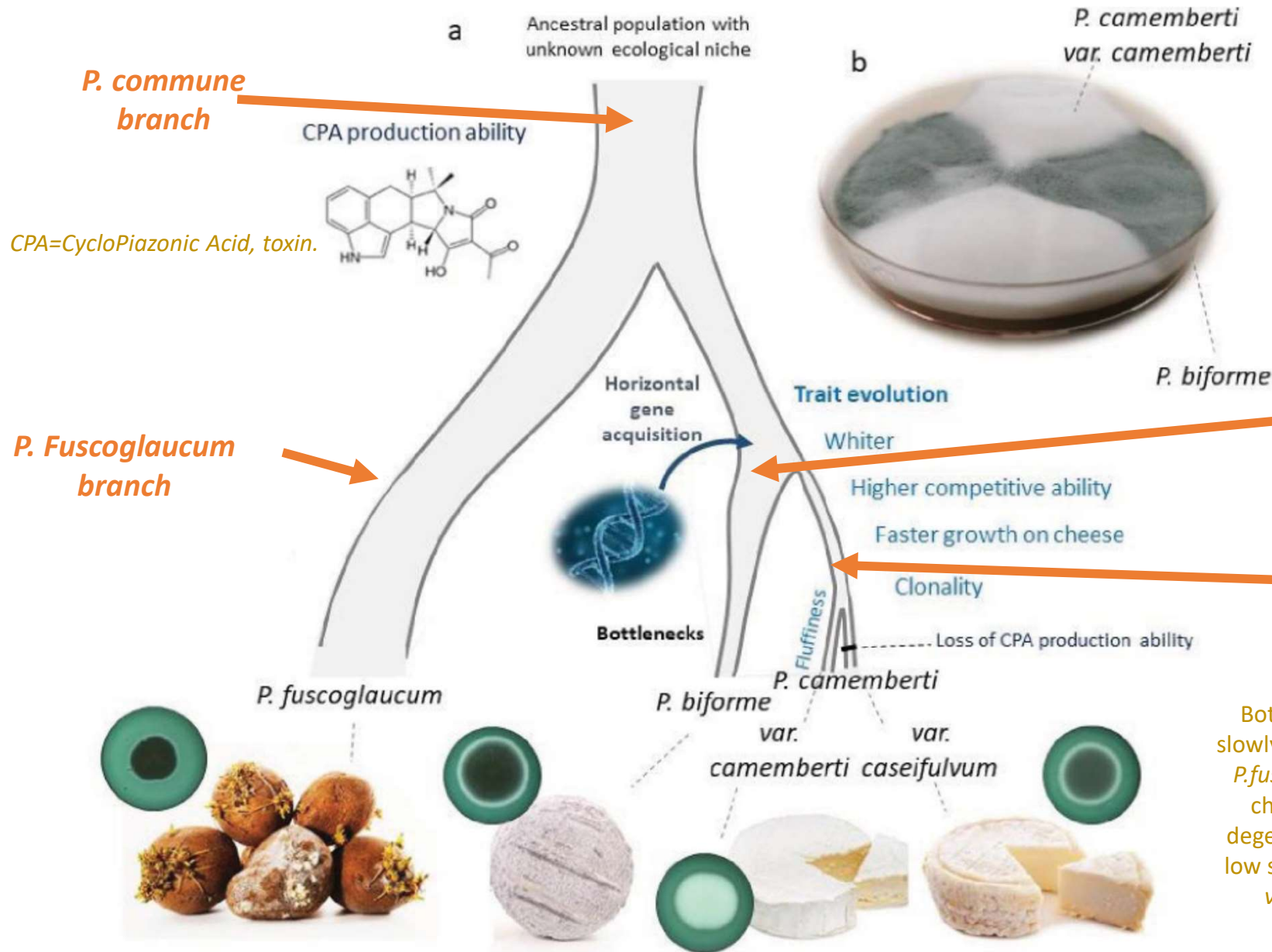


Rigotte de Condieu



Pouligny Saint Pierre

GENEALOGY



Source : Domestication of the Emblematic White Cheese-Making Fungus *Penicillium camemberti* and Its Diversification into Two Varieties
Jeanne Ropars et Al. - 2020

Both *P. camemberti* varieties grow more slowly in harsh conditions than *P. biforme* or *P. fuscoglaucum*, suggesting adaptation to cheesemaking environment has led to degenerations, one of them being the very low spore production level in *P. camemberti* var. *camemberti*, raising concerns in cheesemaking industry.

Penicillium camemberti: what it brings to the rind

Moulds are aerobic fungi that grow on the cheese surface, forming a filamentous, felt-like covering. *P. camemberti* var. *camemberti* strains are selected for whiteness, aroma, lipolytic/proteolytic potential, and growth pattern — **radial** (fast, thin cover) versus **vertical** (slower, thicker, stronger competing power).

Appearance

Colour, mycelium length and density of the rind are highly strain-dependent.

Neutralisation / deacidification

Uses lactic acid as a carbon source, raising surface pH — proteolysis accelerates sharply once pH > 5.0.

Proteolytic activity

Endo- and exopeptidases release free amino acids, catabolised to ammonia and volatile compounds; can debitter the paste.

Lipolytic activity

Far more extensive than in other cheese types. Lipases stay ~50% active at 2°C while proteases are inactive — why cold ageing builds flavour with less paste breakdown.

Aroma production

Releases methyl ketones, secondary alcohols, esters, aldehydes, volatile amines and ammonia — the aromatic signature of bloomy soft cheeses.

Interactions with other microbes

Fast growth suppresses *Mucor* and other coloured *Penicillium*. The pH rise it drives promotes acid-sensitive coryneform / red-smear bacteria.

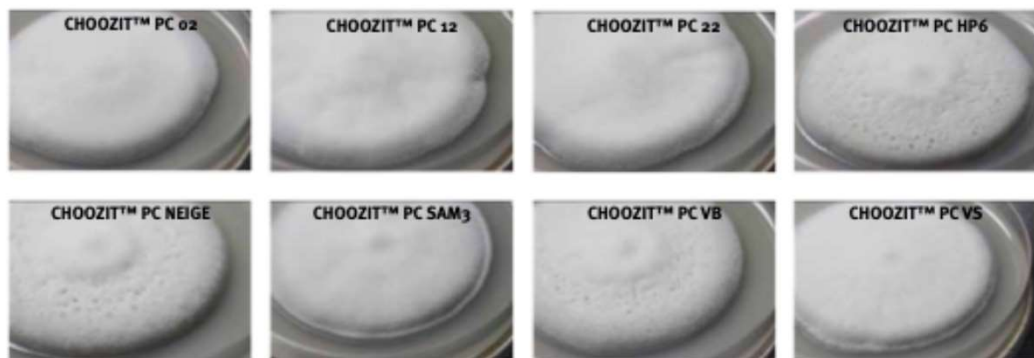


Figure 14. Appearance of CHOOZIT™ PC products.

THICKNESS OF THE MYCELIUM	LOW	LOW TO AVERAGE	AVERAGE	AVERAGE TO HIGH	HIGH
CHOOZIT™ PC 02					
CHOOZIT™ PC 12					
CHOOZIT™ PC 22					
CHOOZIT™ PC HP6					
CHOOZIT™ PC NEIGE					
CHOOZIT™ PC SAM3					
CHOOZIT™ PC VB					
CHOOZIT™ PC VS					

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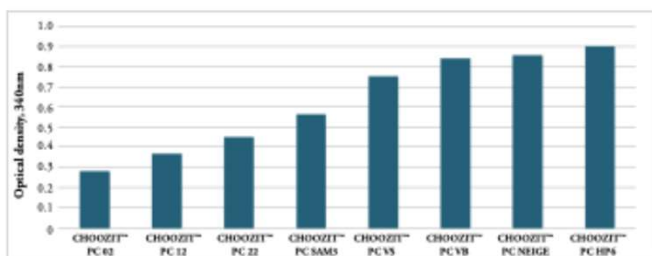
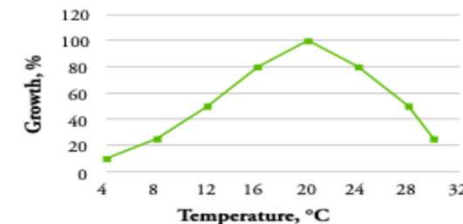
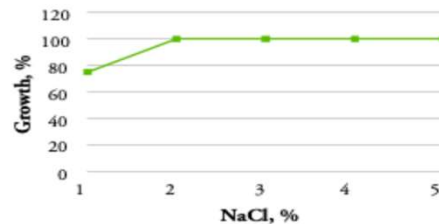
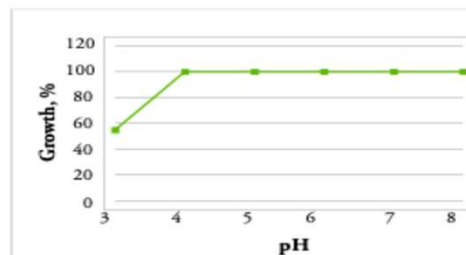


Figure 18. Total proteolysis.



Major characteristics of *Penicillium camemberti* – Source Dupont.

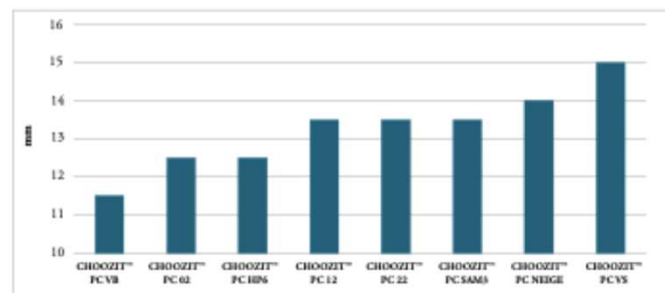
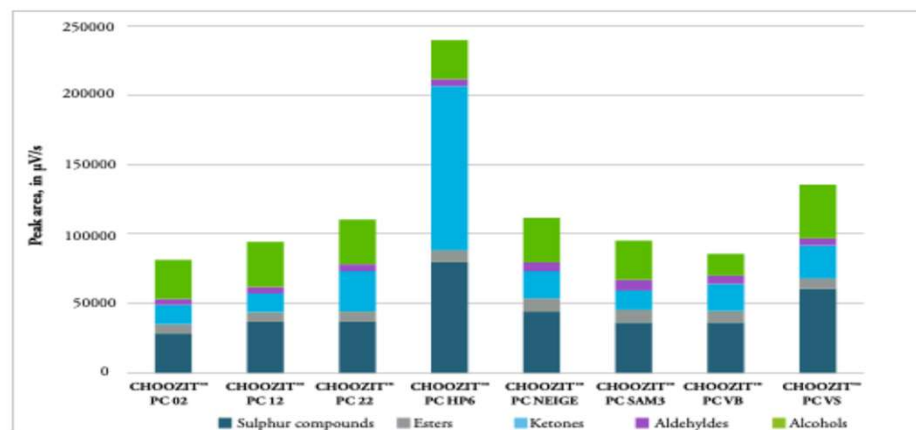
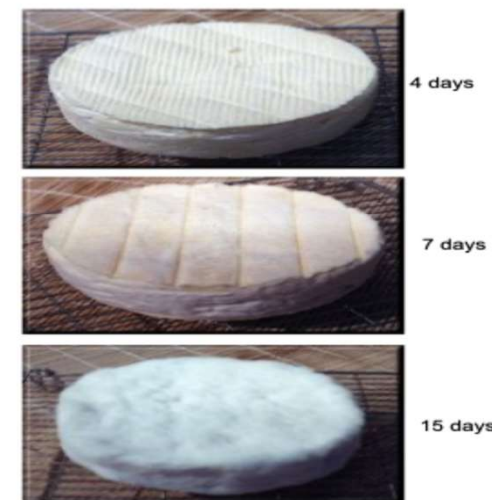


Figure 19. Lipolysis.



Volatile compounds – aroma production - Source Dupont.

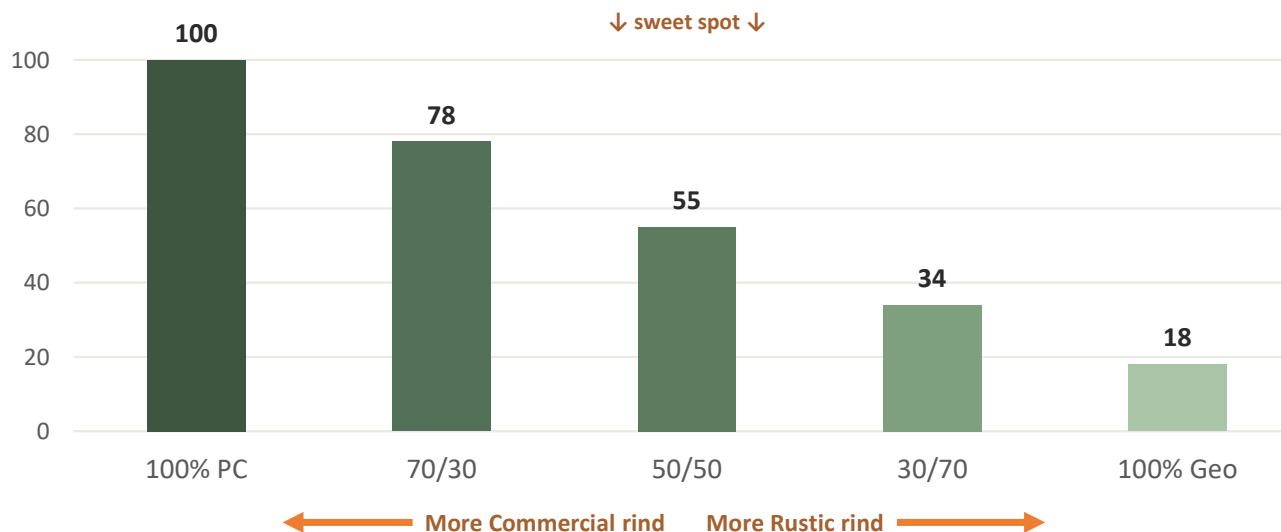


Abstract from Dupont Technical Memorandum – Solutions for white surface ripened cheeses.

The Penicillium : Geotrichum ratio shapes the rind

Optimal combinations sit around **30-50% Penicillium / 50-70% Geotrichum**. At this balance: faster surface flora development, better protection against pollutants, a finer and thinner cover, better ageing stability, less bitterness, fewer mushroom/ammonia off-notes.

RIND THICKNESS, BY PC:GEOTRICHUM RATIO (illustrative index)



Inoculation timing

In the milk, before renneting

Earliest implantation

As a surface spray, after salting

Even coverage; corrects gaps

Source: DuPont-Danisco TM 2106-1e §3.2/§7.1; CHOOZIT™ Ripening Cultures. Thickness values are an illustrative index of the described trend, not lab measurements.
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Three ratios, three rinds



Flannel Flower

Geotrichum-dominant

Loose, wrinkled, matte coat — fast establishment, thin cover typical of a Geo-heavy blend.

Same biology, different balance — compare this against the PC:Geotrichum ratio on the previous slide.
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Brie de Meaux

Mixed Geotrichum / Penicillium

The traditional combined rind: visible wrinkling still shows through a light, even felt.



Stabilised Brie

Penicillium-dominant

Smooth, taut, bright white felt — the dense, uniform cover typical of a PC-heavy blend.

The hastener: a warm, humid head start

Right after salting, most successful bloomy-rind schedules run a short, deliberately warm and humid *hastener* stage before the cheeses ever see the cold ageing room. This is the window where yeasts and *Geotrichum* get their head start.

Two field-tested presets:

Traditional rind:

23°C · 85% RH · 1-2 days, delayed dry salting

Commercial rind:

16°C · 85-90% RH · 24-48 hours, salting in brine prior hastener.

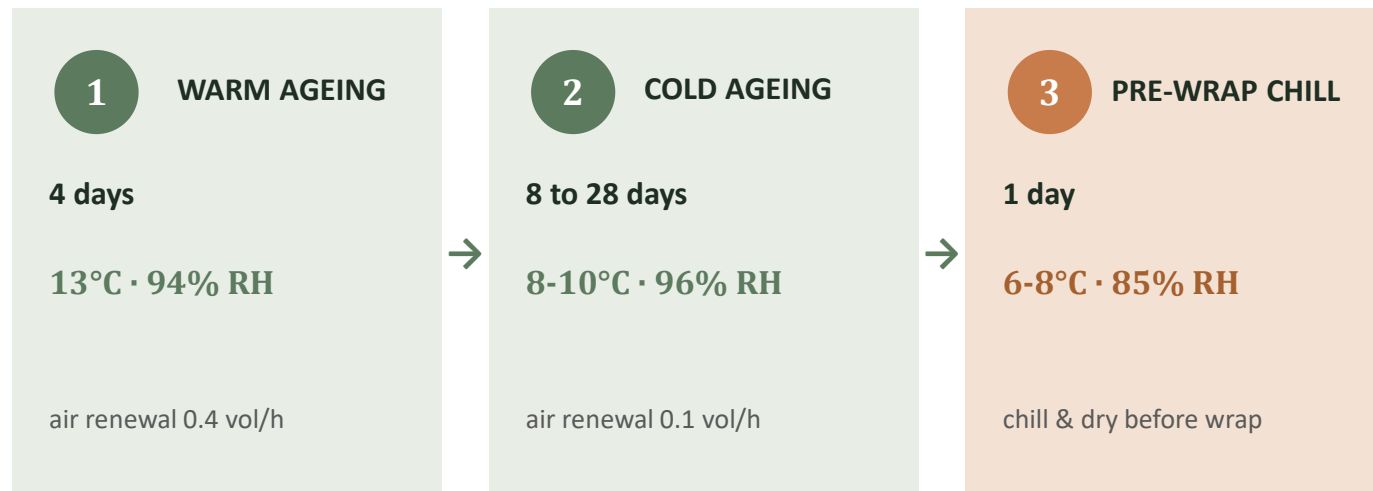
Exact figures depend on cheese format and milk technology — treat these as calibration starting points, not fixed recipes.

WHY IT WORKS

- Warmth pushes yeast and *Geotrichum* growth rates well above wild-mould background levels
- High RH prevents the surface from crusting before flora can establish
- A short duration keeps *Penicillium* in check until *Geotrichum* has its foothold

The salting moment is a powerful tool to promote Geo growth over PC : the sooner you salt, the more PC oriented, the later you salt the more dominant the Geo.

Step the room down as the rind matures



Throughout: turn the cheeses every other day.

Why cool and dry the room down? Cooling slows *Penicillium* relative to *Geotrichum* early, keeping the coat even. Dropping RH and drying the surface just before wrap prevents free surface moisture — exactly the condition that invites wild mould and slip-skin. After wrapping, a minimum of ~10 days cold storage at 4-6°C finishes aroma development.



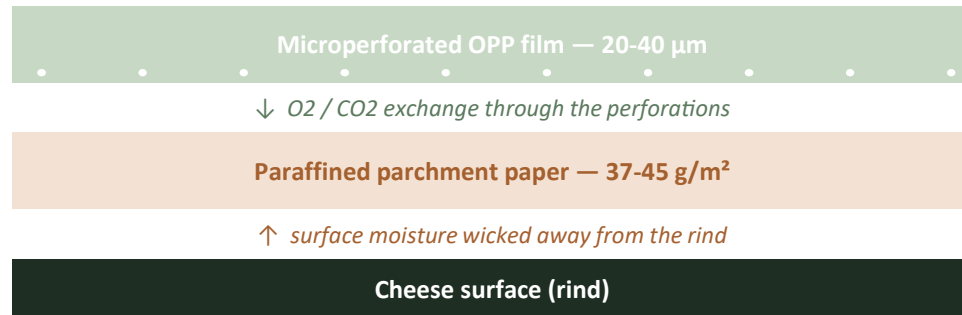
PACKAGING & SHELF LIFE

Packaging paper: engineering the rind's breathing room

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Bloomy rinds need packaging that breathes just enough: sufficient O₂ for *Penicillium* and *Geotrichum* to stay active, not so much that ripening runs away — plus enough moisture wicking to avoid a soggy rind without drying it out.

TWO-PLY WRAP, CROSS-SECTION

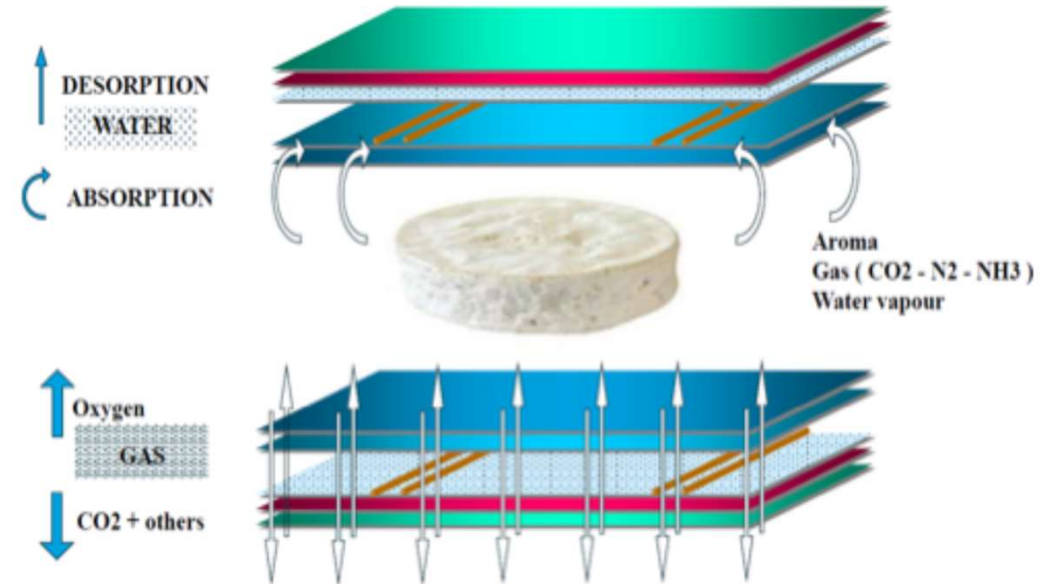


Shiny (film) side out · dull (paper) side against the rind

Why each layer matters

- **Outer film — controls the exchange**
Microperforation size and density set exactly how much O₂ reaches the surface — too little starves the mould, too much races the ripening.
- **Inner paper — manages moisture**
Wicks the light exudation naturally released by the paste, keeping the rind from sitting in its own moisture without drying it out.
- **Paraffin — protects the rind on opening**
Stops mould filaments growing into the paper fibres, so the wrap releases cleanly without tearing the felt.

Source: Amcor / CEFQ “Le Papier d’Emballage” packaging seminar; industry cheese-wrap technical sheets.
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PACKAGING & SHELF LIFE

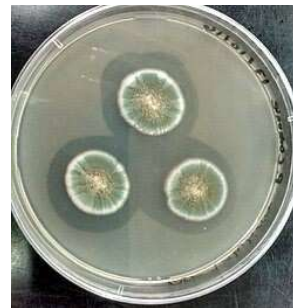
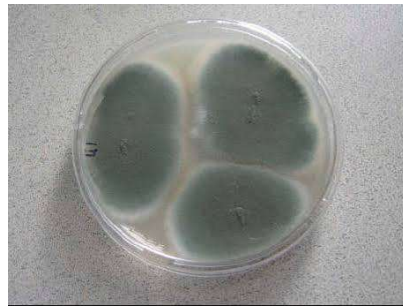
Insufficient chilling before wrapping: condensation between rind and paper.

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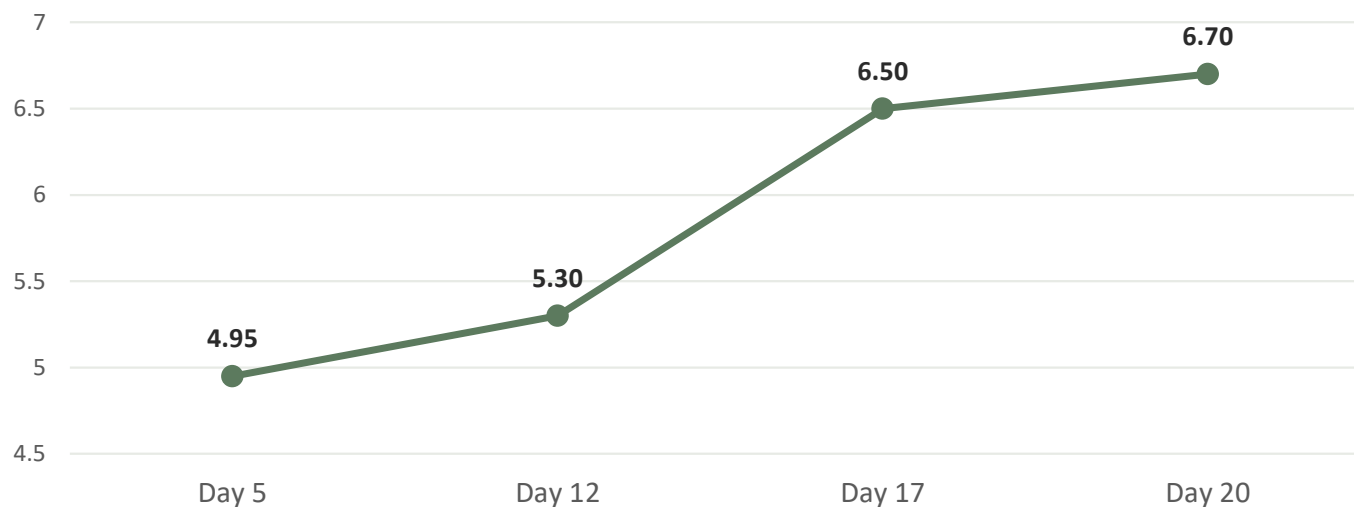
Out-compete, don't just clean up after

- ✓ Regularly check ambiance with routine tests on PDA petri-dishes, allowing you to assess the presence and eventual dominance of contaminants in your processing environment
- ✓ Keep the hastener warm & humid, then cool and dry on schedule — don't let it drift
- ✓ Salt lightly and evenly, possibly later — protect Geotrichum's window rather than starving it
- ✓ Dose enough Geotrichum/yeast to win the early colonization race,
- ✓ Provide clean, filtered, oxygen-rich airflow rather than stagnant humid air
- ✓ Always prefer microbial competition rather than permanent sanitation : yeast/Geo/PC are your best friends to fight undesired contaminants.



Encouraging Healthy Rind Development in Mould-Ripened Cheeses

Track pH to know whether you're on schedule

**Day 5**

Acidophilic flora — yeasts and Geotrichum active

Day 12

Geotrichum + Penicillium camemberti growth

Day 17

Micrococcus & B. linens growth

Day 20

Full surface maturity — ready for wrap / storage

If pH stalls low past day 5-7, Geotrichum/yeast establishment was too slow. Check hastener conditions and salting evenness before blaming the mould inoculum itself.

Source: Ivan Larcher, Brie-type ripening cycle data. pH values are approximate midpoints of the observed range.

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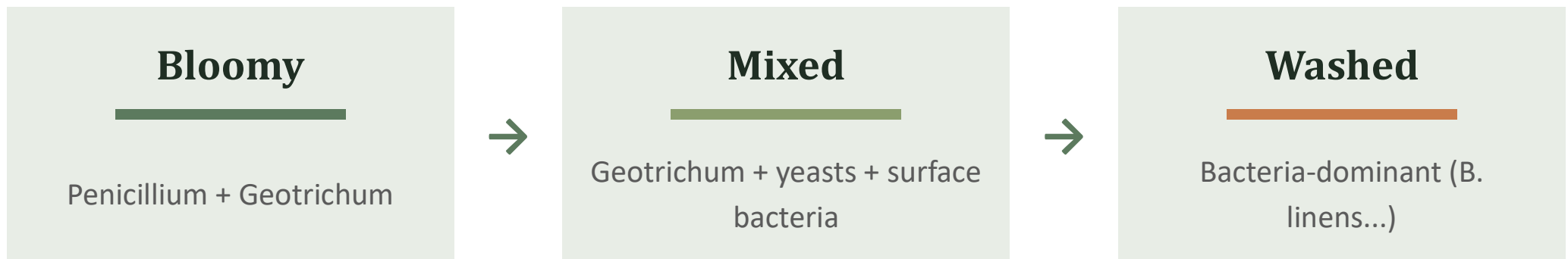
Beyond bloomy: surface-ripened cheeses more generally

*Combined Penicillium-Geotrichum rinds · washed rinds · how washing differs between
lactic and rennet-set cheeses*



Geotrichum + Penicillium: also the opening act for smear-ripened cheeses

The same PC:Geo logic scales up. In mixed-rind and eventually washed-rind cheeses, *Geotrichum candidum* and yeasts still open the show — they establish first, neutralise the surface, and stimulate the desirable, acid-sensitive flora (like *Brevibacterium linens*) that follows.



Same opening chapter — Geotrichum + yeasts — different ending, depending on how far the surface pH is allowed to climb.

WASHED RINDS

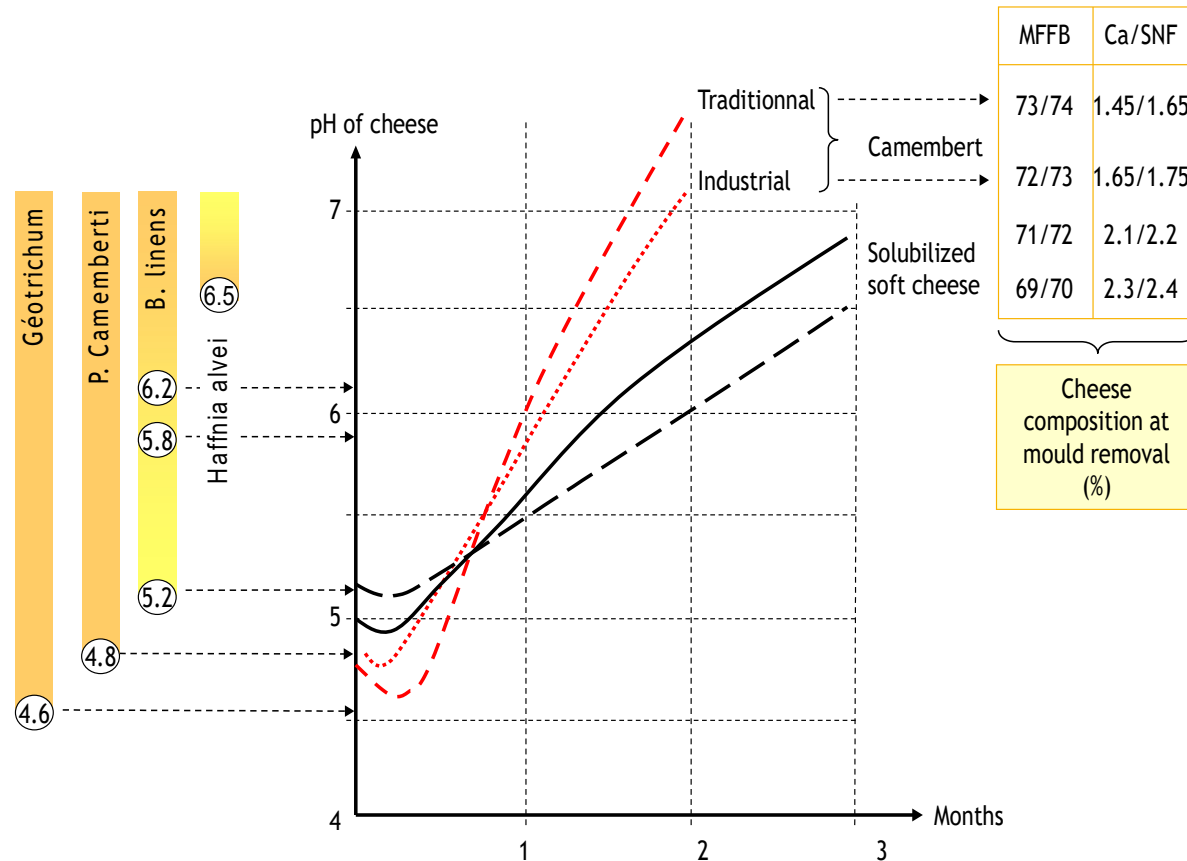
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Washing hands the rind from mould to bacteria as pH climbs

EXAMPLE WASHING REGIME

25 days at 11°C / 95% RH · washed every day week 1 then twice a week with ~3% salted water · chill before wrap

Washing raises surface pH and humidity together, deliberately pushing the flora past *Geotrichum* and *Penicillium* and into the acid-sensitive bacteria that give washed rinds their colour and aroma.



Adapted from B. Mietton / S. Roustel —
order of appearance as ripening progresses;

WASHED RINDS

What goes in the washing solution (the “morge”)



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Component	Role	Typical spec
Water	Base solvent — must be free of contaminants	UV-treated, boiled/pasteurised, or bottled
Salt	Selects halophilic flora, controls surface moisture, curbs unwanted moulds	3-5% for soft washed rinds; up to 10% for hard cheeses
Flora	Builds the smear: colour, aroma, proteolysis and lipolysis	B. linens (“red ferment”) + Geotrichum candidum, Debaryomyces hansenii, Micrococcus
Nutrients	Feed the flora while the solution rests before use	Pasteurised milk or sweet whey
Acid (optional)	Checks unwanted mould growth, favours acid-loving yeasts	White vinegar (~5 mL/L), lactic acid, or acid whey — target pH 5.0-5.2

REGIONAL VARIATIONS

Époisses — salted water + marc de Bourgogne · Langres — + marc de Champagne · Livarot — + cider · Maroilles — + beer

Sources: ACTALIA Produits Laitiers / MREPACA technical sheet; French washed-rind cheesemaking tradition.
Encouraging Healthy Rind Development in Mould-Ripened Cheeses

Why washing timing differs by curd type



Lactic-curd washed cheeses

e.g. Époisses-style

- Demoulding pH ≤ 4.65 , low mineralisation, fragile/crumbly curd
- Surface starts far from the pH washing bacteria need — Geotrichum/yeast deacidification has more work to do first
- Washing typically starts later and gentler: more diluted brine, lower frequency at first



Mixed / rennet-set washed cheeses

e.g. Munster, Livarot

- Demoulding pH 4.80-5.2+, higher mineralisation, firmer curd
- Surface starts closer to the range washing bacteria already tolerate
- Can be washed earlier and more assertively — sturdier curd, shorter runway to B. linens

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Principle, not recipe — always calibrate against your own curd's demoulding pH and structure.

Five things to check before you blame the mould

- 1 Speed wins.** Fast Geotrichum/yeast establishment (1-3 warm, humid days) is your best defence against wild moulds — competitive exclusion, not cleanup.
- 2 Salt evenly, lightly, later.** Geotrichum is salt-sensitive; protect its window.
- 3 Step the room down.** Warm/humid hastener → cooling bloom → dry before wrap. Drift at any stage shows up on the rind.
- 4 Watch pH, not just the calendar.** It tells you whether flora succession is on schedule.
- 5 One opening chapter, many endings.** Geotrichum + yeasts carry through to mixed and washed rinds — master it once, apply it everywhere.

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Questions?

Thank you for joining the session.

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