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Impact of cows' feeding systems on summer butter fatty acid profile, colour, and rheological properties

From pasture to plate: can the feeding system be read in butter?

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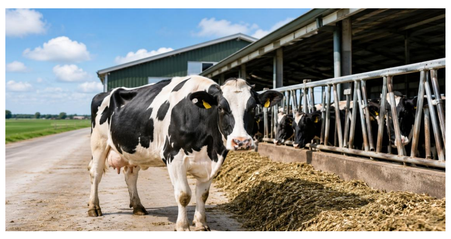
Background and objective

Cows' breeding and feeding systems can affect the nutritional and technological quality of milk and dairy products. We tested whether butter produced under different summer feeding systems carries a measurable fatty-acid and physicochemical signature.

Objective **Relate fatty-acid composition to colour and rheological traits of butter from three production contexts.**

Study design: 31 summer



Lowland TMR

9 samples • 3 production plants
Intensive dairy herds fed corn silage-based TMR.

Mountain hay TMR

11 samples • 4 mountain plants
Cream from dairy herds fed hay-based TMR

Alpine grazing

11 samples • 5 small artisanal plants
Cream from alpine-grazing dairy herds.

Core comparison

Feeding/production system (alpine grazing vs TMR) was evaluated separately from the geographical label (mountain vs lowland).

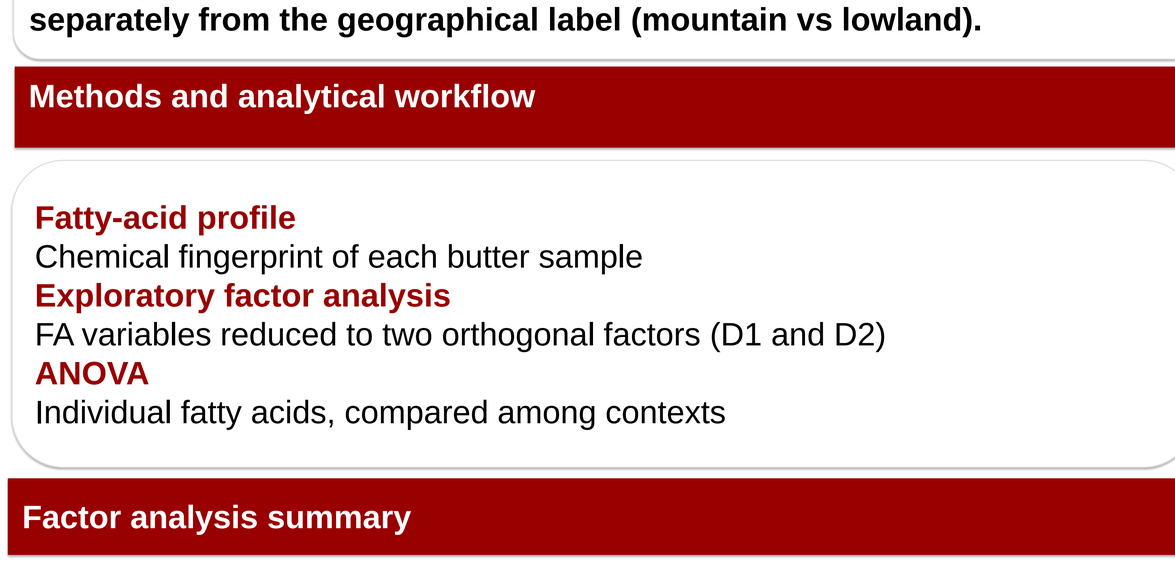
Methods and analytical workflow

Fatty-acid profile
Chemical fingerprint of each butter sample
Exploratory factor analysis
FA variables reduced to two orthogonal factors (D1 and D2)
ANOVA
Individual fatty acids, compared among contexts

Factor analysis summary

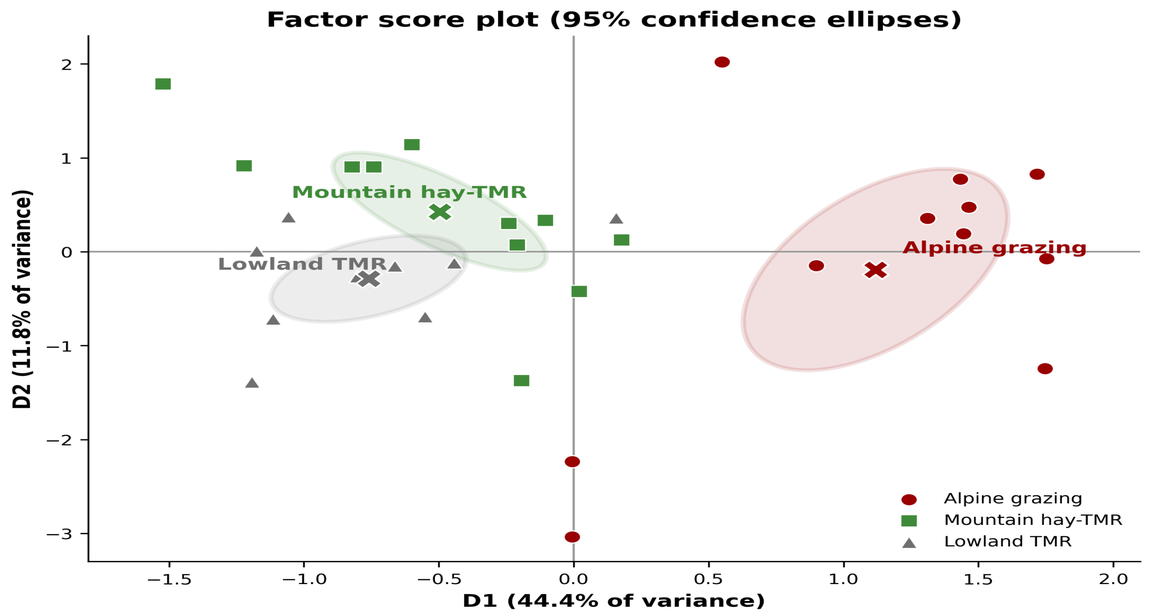
D1 = 44.4% • D2 = 11.8%
Total explained variance = 56.2%
D1 captured the main production-system gradient; D2 described a weaker secondary variation.

What drove D1 separation?



Interpretation
Negative D1 loadings: medium-chain saturated FA (C6:0–C16:0) and higher contents in TMR-based butter. **Positive D1 loadings**: C18:0, major C18:1 isomers, trans-vaccenic acid and CLA and higher contents in alpine-grazing butter.

Score plot: production-system separation



Butter from alpine grazing systems shifted towards positive D1, with limited overlap with the two TMR-based groups.

D2: what was the secondary gradient?

D2 was mainly associated with C15:0 on the positive side and with palmitoleic acid (C16:1n9) and linoleic acid (C18:2n6c) on the negative side.
Therefore, D2 captured additional within-summer variability, especially a mountain-specific sub-pattern, rather than the main alpine-grazing vs TMR contrast.

ANOVA confirms the fatty-acid signature

Fatty acid	Coordinates of factors	Alpine grazing	Mountain hay-TMR	Lowland TMR	P	Pattern
Main D1 markers: medium-chain saturated FA						
C6:0	D1 −	2.30 b	2.53 a	2.48 ab	0.028	lower in alpine
C8:0	D1 −	1.14 b	1.34 a	1.34 a	<0.0001	lower in alpine
C10:0	D1 −	2.04 b	2.88 a	2.91 a	<0.0001	lower in alpine
C12:0	D1 −	2.33 b	3.30 a	3.40 a	<0.0001	lower in alpine
C14:0	D1 −	9.21 b	11.5 a	11.2 a	<0.0001	lower in alpine
C16:0	D1 −	27.4 b	31.4 a	33.2 a	<0.0001	lower in alpine
Main D1 markers: long-chain / bioactive FA						
C18:0	D1 +	10.7 a	9.64 b	9.51 b	0.002	higher in alpine
C18:1n9ct	D1 +	24.1 a	20.1 b	20.0 b	<0.0001	higher in alpine
C18:1n11 trans	D1 +	4.25 a	2.56 b	1.77 b	<0.0001	higher in alpine
CLA (C18:2 c9t11)	D1 +	1.11 a	0.613 b	0.380 b	0.003	higher in alpine
Secondary D2 markers						
C15:0	D2 +	1.03	1.09	1.11	0.369	n.s.
C16:1n9	D2 −	1.61 a	1.49 b	1.62 a	0.016	mountain lower
C18:2n6c	D2 −	2.79 a	2.33 b	2.55 ab	0.008	mountain lower

Different letters within rows indicate significant differences among production contexts; n.s. = not significant.

Key message from ANOVA
The factor-analysis signature was statistically confirmed: alpine-grazing butter had lower levels of medium-chain saturated FA and higher levels of long-chain/bioactive FA.

Physicochemical relevance

The fatty-acid signature translated into measurable colour and texture differences.

Greater yellowness
consistent with a visually distinctive alpine-grazing product

Shorter melting latency
faster response in the melting test

Lower spreadability
a texture difference relevant to consumers and processing

Take-home message

**The production system was the dominant driver of summer butter quality.
Alpine grazing shifted the fatty-acid profile towards long-chain and bioactive fatty acids, including trans-vaccenic acid and CLA.
Geographical origin alone was a secondary source of variation compared with the feeding/production system.**

Why it matters for mountain farming

The results support the valorization of alpine dairy systems through measurable pasture-to-product attributes.

Grassland → **Feeding** → **Butter quality**

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