Intrinsic quality according to farming systems in beef

The INTAQT project investigated the relationships between the level of intensification of farming systems and beef quality on 55 highly diverse farms across five countries (France, Spain, Switzerland, the UK, and Italy).

Beef farming systems strongly influence certain intrinsic beef quality traits, particularly n-3 fatty acid content and the n-6/n-3 fatty acid ratio.

In contrast, fat and protein contents, most mineral contents, and technological and sensory traits vary considerably within each farming system, with no clear trends associated with intensification. Food safety is maintained across all systems.

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Beef is an integral part of European diets and a major source of affordable, high-quality animal protein and micronutrients. Regardless of the production system, beef is indeed naturally rich in minerals (such as iron), and vitamins, making it an important component of healthy and sustainable diets. Consumers, retailers and policymakers increasingly expect production systems that combine efficiency with high-quality products, while grass-based, organic and PDO systems are gaining importance.

Although the effects of beef production systems on productivity are well documented, much less is known about their impact on the overall intrinsic quality of beef, including its safety, nutritional value, technological properties and sensory characteristics.

Understanding these relationships is essential to help producers optimize management practices — such as the balance between grass, maize silage and concentrates in cattle diets — while maintaining competitiveness, protecting the environment and meeting societal expectations.

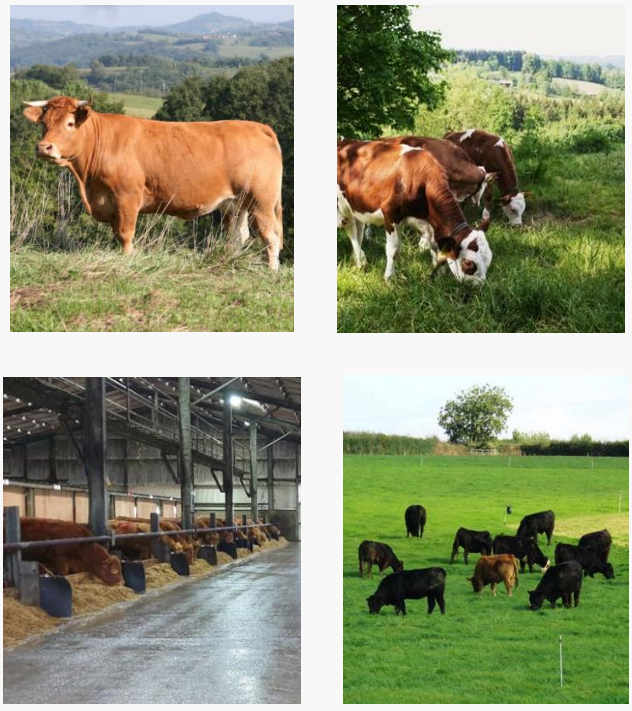

Fig 1: Illustration of the diversity of beef farming systems

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Animals originated from N = 55 fattening beef farms set in five European countries: Switzerland (N = 20), Spain (N = 5), France (N = 10), Italy (N = 10) and the UK (N = 10). Farms were categorised into six classes according to the level of intensification of the farming systems studied [inputs to animals (concentrates…) and inputs to land (nitrogen, pesticides)], as described by Caumette et al. (2026). The main characteristics of these six classes (Fig. 2) are:

1. Swiss (CH) suckler beef farms operating grass-based systems with little or no concentrate.
2. French (FR) suckler beef farms with beef cull cows (grass-based systems with moderate to high levels of supplementation).
3. Swiss (CH) suckler beef farms raising young dairy-beef crossbred cattle and finishing them at up to 23 months of age on grassland, with no or minimal feed supplementation.
4. UK medium-input farms raising beef cattle on grassland from 12 to 27 months of age, with grazing animals receiving moderate levels of concentrate supplementation.
5. Swiss (CH) medium-input farms finishing cattle of mixed genetic backgrounds indoors from 9 to 16 months of age, with moderate levels of concentrate supplementation.
6. High-input indoor fattening farms in Italy (IT), Spain (ES) and Switzerland (CH), relying on high levels of concentrates and maize silage in the diet and finishing cattle by 14 months of age.

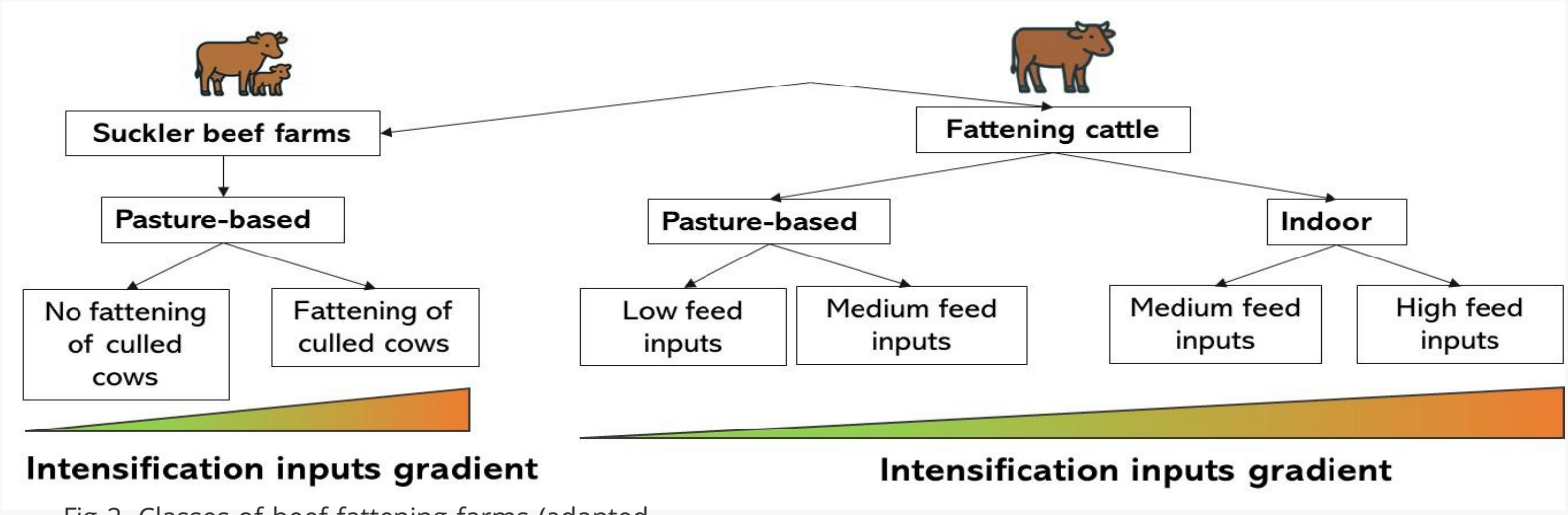

Fig 2. Classes of beef fattening farms (adapted from Caumette et al., 2026).

A total of 497 beef samples from the *Longissimus thoracis and lumborum* muscles, collected between the 8th and the 9th rib, were included in the study. Samples were collected from the 55 studied fattening beef farms set in five different European countries. Each farm contributed between 5 and 10 animals, sampled during two distinct slaughter periods (summer, winter) carried out between 2022 and 2023. For some biochemical analyses, muscle samples collected from animals within the same farm and slaughter period were finely ground in liquid nitrogen and pooled before analysis.

The analyses included the following traits:
- **Safety traits:** Heavy metals, Mycotoxins, Plant toxins, organic pollutants (dioxins/PCBs/PFAS), Resistant bacteria.
- **Sensory and technological traits**: Sensory test with untrained consumers, Color, Shear force, Marbling, Ultimate pH, Connective tissue, Lipid oxidation, Key metabolites and protein markers.
-**Nutritional value**: Protein, Fat, Fatty acid composition, Histidine dipeptides, Minerals (iron, zinc), Trace elements, Vitamins A, B3, B5, B6, B9, B12, D, E.

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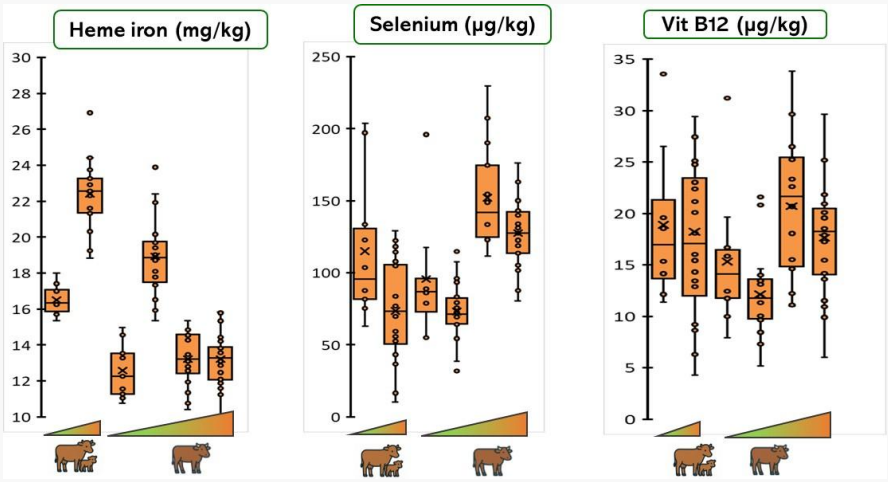
Most quality traits varied among farm types without a clear intensification-gradient trend. In contrast, some specific **nutritional** quality traits (n-3 and n-6 fatty acid contents and the n-6/n-3 ratio) showed marked and consistent differences along farms types.

None of the analysed **contaminants** exceeded regulatory thresholds.



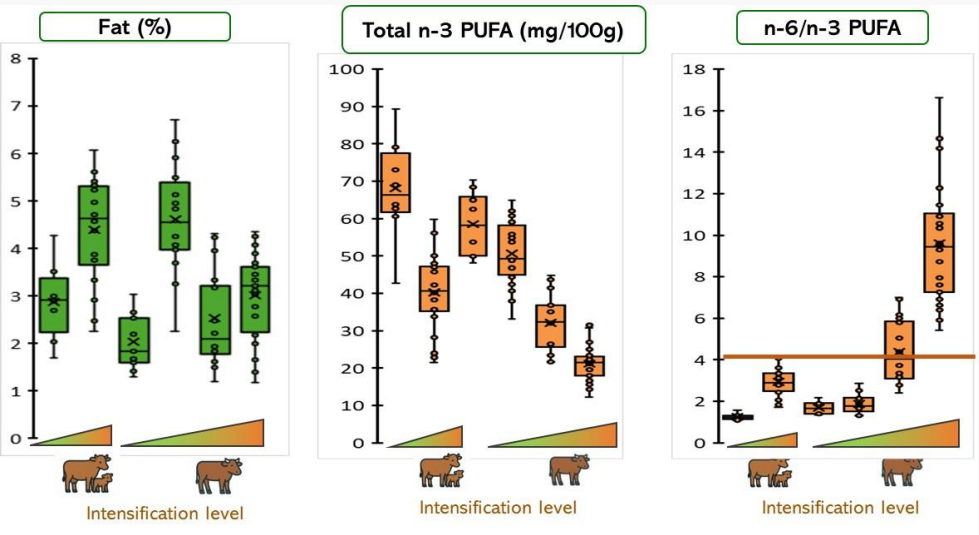


Fig 3. Nutritional traits related to intensification level for both suckler beef farms and fattening cattle farms.

We predicted an overall sensory quality score (cMQ4) combining tenderness, flavour, juiciness, and overall liking, using the 3G (Global Guaranteed Grading) model and data on animal, slaughter, and carcass characteristics. These results were validated through sensory evaluation tests conducted on some samples. Overall, the within-system variability was so substantial that it was not possible to identify any farming system as consistently producing better sensory quality than the others. All systems were capable of producing very high-quality beef (with scores above 60, green area of Fig. 4), although most of the beef produced fell into the medium or good quality categories.

No single system outperforms all others in terms of intrinsic beef quality. The benefits of grazing systems concern nutritional traits, particularly n-3 fatty acid content and the n-6/n-3 fatty acid ratio. However, grazing does not improve most beef quality traits in terms of consumer perception when consumers are not provided with information about farming practices.

Although heme iron, selenium, vitamin B12 and intramuscular fat contents varied within and between farming systems, no relationship with the level of intensification could be established.

In contrast, n-3 polyunsaturated fatty acid (PUFA) content clearly decreased with increasing intensification, whereas the n-6/n-3 fatty acid ratio increased, exceeding nutritional recommendations in the most intensive farming systems.

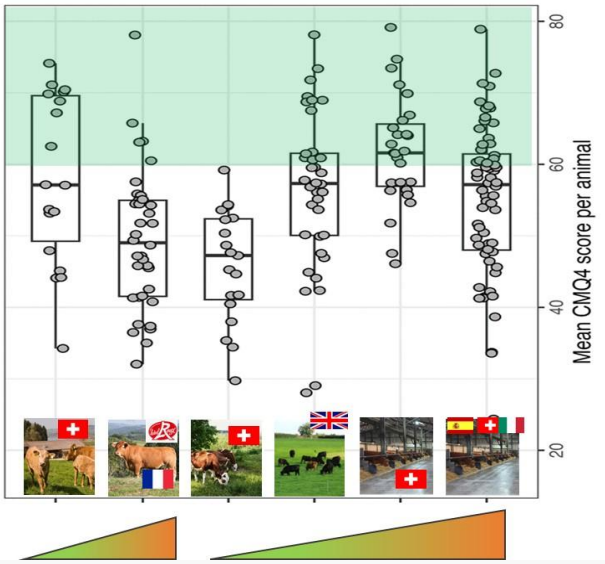


Fig 4. Eating quality related to intensification level for both suckler and fattening farms.

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These findings highlight that farming systems influence some specific beef quality traits, but not all. The clearest effects concern nutritionally relevant fatty acids (n-3 and n-6 families), largely driven by the proportion of grass in the diet. In contrast, the fat and protein contents and mineral concentrations of beef show no clear trend with increasing intensification. Instead, they reflect a combination of factors, including genetics, physiology, and feeding practices, that extend beyond farm typology.

Sensory differences between beef products are substantial within farming systems, including at the consumer level, but are much less pronounced between systems.

Food safety is maintained across all systems, with no contaminants exceeding regulatory thresholds.

These conclusions (i.e. the absence of clear gradients associated with intensification) are particularly true when intrinsic quality traits are combined to reflect the broader concept of One Quality.

Sensory quality	Meat Color
	Tenderness
	Juiciness
	Flavour
Technological quality	Depends on different factors such as ultimate pH
Nutritional quality	Lipids intakes
	Proteins intakes
	Minerals intakes
	Vitamins intakes
Safety	Benefits/risks of nutriments
	Microbiological risks
	Chemical risks
	Toxic risks

Fig. 5. Integrating intrinsic quality traits within the One Quality concept.

An important finding was the substantial variability observed in most beef quality traits, particularly sensory traits. The most significant differences were mainly associated with the proportion of grass in the diet, particularly grass consumed through grazing, with higher levels of fatty acids that are beneficial to human health. However, the concentrations of many nutritionally relevant compounds did not vary with the level of production inputs, and we did not identify any farming system that outperformed all the others across all quality traits. The considerable variability observed among farms operating under similar production conditions highlights the potential for significant improvements through better management practices, without necessarily changing the production system itself. Such improvements can enhance animal performance, product consistency, and consumer satisfaction while maintaining production efficiency.

Key references: Caumette et al. (2026), Agr. Syst.; Mouhanna et al. (2026), animal

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