Food Research Village

The impacts of dairy cow crossbreeding on the composition, yield, and ripening characteristics of full-fat Cheddar cheese

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Summary

- Milk derived from crossbred cows had significantly higher levels of protein and fat than pure Holstein-Friesian cows
- Cheese from crossbred cows is more yellow in colour than cheese from purebred Holstein-Friesian cows

The crossbreeding treatment did not significantly impact the composition, yield and maturation characteristics of full-fat Cheddar cheese.

Introduction

In Ireland, the national dairy herd is mainly comprised of Holstein-Friesian (HF) cows, a breed established through careful selective breeding of Holstein (HO) and Friesian (FR) cows. The HF breed is highly specialised, producing high volumes of milk with sufficient levels of protein and fat to maximise total-solids yields. In Ireland dairy farmers are paid based on the total protein and fat yielded with a penalty for milk volume, making milk-fat plus protein more important than milk volume.

European dairy systems have typically focused selective breeding efforts towards increased productivity and efficiency within the HF population. This approach has brought benefits, but a problematic consequence has been a reduction in genetic diversity. Breeding strategies such as crossbreeding can offer a solution to improving fertility and overall herd health.

In dairy herd management, a common strategy involves crossbreeding Jersey cows (JE) with HF, resulting in Jersey-Holstein-Friesian (JFX) cows. Previous studies at Teagasc Moorepark have shown that JFX cows outperform pure HF cows due to improved fertility and overall herd productivity. However, limited research has been conducted on how crossbreeding affects dairy products. To address this gap, researchers at Teagasc Moorepark investigated the effects of crossbreeding on the composition, yield, and maturation characteristics of full-fat Cheddar cheese. Cheese is a key dairy product in Ireland, with approximately one-third of the country's milk supply used for cheese production.

Milk composition

The raw milk and cheesemilk (i.e., milk standardised to a protein-to-fat ratio of 0.95) derived from JFX cows had significantly higher levels of protein and fat compared to milk derived from HF cows. However, no significant differences were found in the level of lactose, mineral composition and fatty acid profile between the two groups.

Cheese composition and yield

Crossbreeding had no significant effect on the moisture, protein, fat, salt, minerals and total fatty acid profile of the cheese. Cheddar cheese made with milk from JFX cows had, on average, a ~5-minute faster set-to-cut time (the time from adding the coagulant to cutting the curd) and a ~3% higher actual yield compared to HF cows. However, these differences were not statistically significant, but they could be worth further investigation.

Cheese colour

The JFX cheeses were significantly more yellow in colour compared to HF cheeses (Figure 1). This was confirmed through higher b* values. The b* value is a measure of colour from blue to yellow, and the significantly higher b* values indicate that JFX cheeses are more yellow than HF cheeses. The JFX cheeses also appeared more yellow than the HF cheeses to the eye.

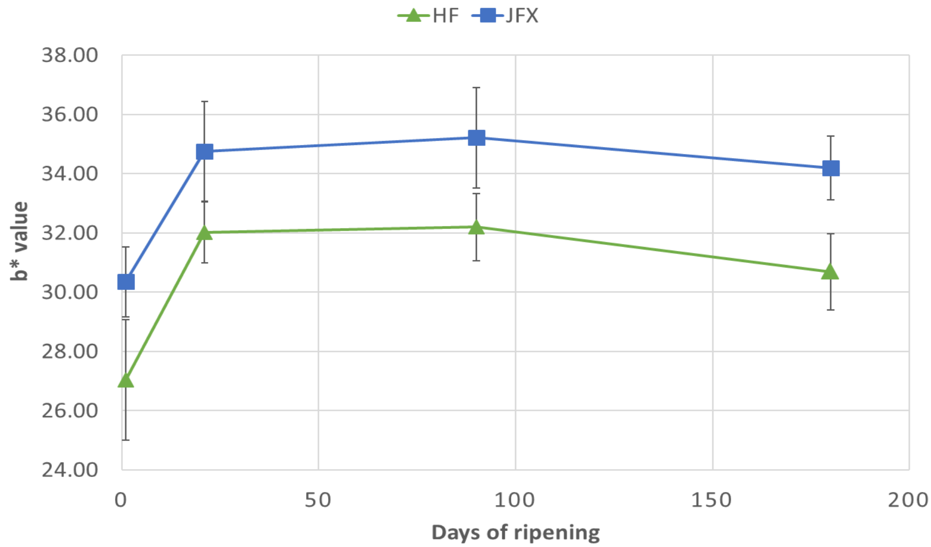

Figure 1. *The effect of Holstein-Friesian (▲, HF) and Jersey-Holstein-Friesian Crossbreeding (■, JFX) on the b* values of cheddar cheeses during ripening. Presented values are the means from three replicate cheese trials; error bars show standard deviations of the means*

Maturation characteristics

No significant differences were observed between HF and JFX Cheddar cheeses in terms of texture, proteolysis, pH, volatile-organic-compounds and free fatty acid profile.

Conclusion

This study suggests that crossbreeding Jersey with Holstein-Friesian cows does not negatively impact the cheesemaking properties of milk or final quality of full-fat Cheddar cheese.

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Genetic variation in bovine milk proteins: Implications for functional and nutritional properties

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Summary

- Genetic variation in milk proteins influences their nutritional and functional properties
- Certain variants improve heat stability, coagulation, and emulsification, key traits for dairy processing
- Understanding these differences supports selective breeding strategies to enhance milk quality and value

Introduction

Milk proteins play a vital role in the structure and functionality of a wide range of dairy products including cheese, yoghurt and dairy powders. They are influenced by the genetics of the cow, which has a significant effect on protein composition. Caseins form about 80% of total milk protein, existing predominantly in micellar form, while whey proteins make up the remaining 20% and are dissolved in the milk serum. Genetic polymorphisms occur in all six major proteins (αs1-, αs2-, β- & κ-casein, α-lactalbumin, and β-lactoglobulin), where variants arise from mutations that alter protein synthesis and expression leading to point substitutions of one or more amino acids within the individual proteins.

Genetic variants influence milk's heat stability, coagulation properties, and potentially human health and wellness. Most notably, β-casein variants A1 and A2 have been subject to controversy over the years relative to claimed implications surrounding health and wellness, with A1 being linked to the release of higher levels of a bioactive peptide during digestion. This difference in one amino acid in one protein in milk has created a whole portfolio of unique A2 milk products on the market. This highlights the potential of breeding cows with specific protein genotypes to tailor milk for improved functionality, processing characteristics and potentially health benefits.

The history of milk protein variants

The history of milk protein variants dates back to 1946 with the discovery of two discrete variants of the whey protein β-lactoglobulin. Variants of all six milk proteins have since been identified, with discoveries continuing into the early 2000s (Figure 1). Genetic mutations cause these variants, which are defined by point substitutions of specific amino acids. These mutations affect the protein's structure and function, sometimes altering phosphorylation patterns which influence protein behaviour. Genotype frequencies vary by breed. Holstein Friesians typically carry A1 and A2 β-casein variants, while Jerseys and Guernseys more commonly carry A2. κ-casein B variant is prevalent in Jerseys and reportedly improves coagulation properties a critical functionality necessary for cheese making. The lower frequency or "rare" variants are often breed-specific and regionally isolated.

Nutritionally, milk proteins contain bioactive peptides that are released during digestion and can have various physiological effects. Genetic variants affect the release and function of these peptides, with some variants, particularly related to the whey protein β-lactoglobulin, associated with allergenicity and antimicrobial activity.

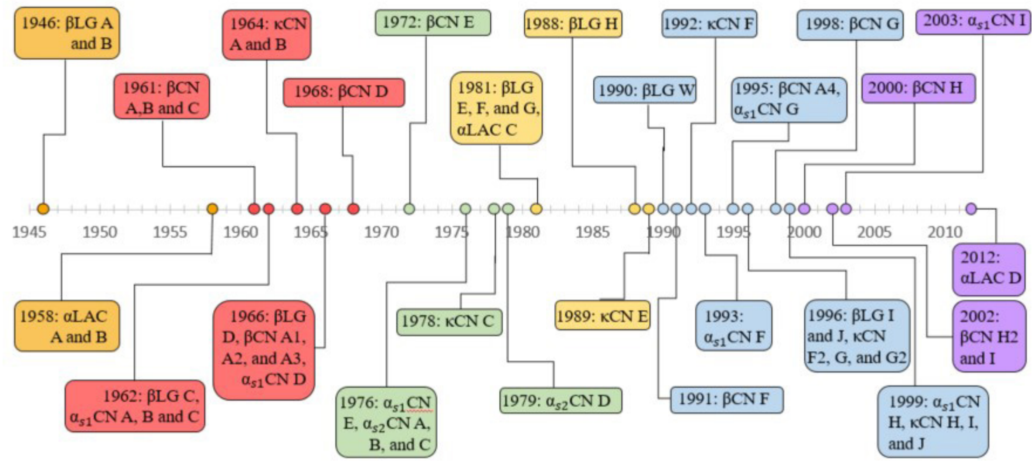

Figure 1. *Timeline of the discovery of milk protein genetic variants. ● < 1960, ● 1960 – 1969, ● 1970 – 1979, ● 1980 – 1989, ● 1990 – 1999, ● > 2000. The notations for the milk proteins are as follows; β-lactoglobulin (βLG), α-lactalbumin (αLAC), β-casein (βCN), α_{s1}-casein (α_{s1}CN), κ-casein (κCN) and α_{s2}-casein (α_{s2}CN). The letter proceeding with the milk protein indicates the genetic variant*

Functionally, genetic variants affect milk's performance in processing:

- **Heat Stability:** Influenced most strongly by β-lactoglobulin and κ-casein. B variants are more heat stable.
- **Coagulation:** Casein variants, particularly κ- and β-casein, impact rennet and acid coagulation properties. The BB genotype of κ-casein enhances gel strength and reduces coagulation time linked to higher levels of expression of the protein.
- **Emulsification:** Variants affect oil droplet size and stability. β-casein B and β-lactoglobulin A variants offer superior emulsifying properties.

Conclusion

Genetic variants in milk proteins can have a substantial impact on nutrition and processing. While much focus has been on β-casein variants A1 and A2, other proteins also significantly influence milk's behaviour and ongoing research is focused on identifying the distribution and evolution of these variants in the Irish herd. Whereby future breeding strategies could enhance milk's value by selecting for variants with favourable nutritional and functional traits. Additional research into minor proteins may unlock further applications and health benefits.

The A2 milk story: How cow genetics affect milk and cheddar cheese production

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Summary

- The genetic variant of β-casein in milk (A1 vs A2) can influence Cheddar cheese processing
- A2 milk coagulates slower than A1 milk
- Cheese made from A2 milk was firmer and more cohesive and digested differently under simulated digestion conditions
- As more A2-producing cows enter the national herd, cheese processors may need to adapt curd cutting times

Introduction

Bovine milk contains two major groups of milk proteins: casein and whey protein. These proteins are made up of individual amino acids linked together into a polypeptide chain. Within the casein group, β-casein exists in different genetic forms, the most common being A1 and A2. These differ by just one amino acid at position 67 in the polypeptide chain, with proline in A2 and histidine in A1. The national milk pool is currently comprised of a huge mixture of different genetic protein variants, with both A1 and A2 variants present.

However, over the last few years the number of cows in the national dairy herd producing only A2 milk has increased. This may be due to the prioritisation of breeding for higher levels of milk fat and protein, which appears to also be selecting for particular protein variants. As A2 milk becomes more common, it's important to understand how it affects dairy processing, especially for key products like Cheddar cheese.

Cheddar cheese processing and ripening

A study carried out at Teagasc Moorepark found that Cheddar cheese made from A2/A2 milk took longer to coagulate and required more time before curd cutting compared to A1/A1 and A1/A2 milk (Figure 1). While the onset of rennet coagulation was only slightly delayed, curd formation was noticeably slower.

Despite slower coagulation, ripening and proteolysis levels were similar across all cheese types. However, cheese made from A2/A2 and A1/A2 milk were firmer and more cohesive than those made from A1/A1 milk. Future work may need to be explored in order to speed up the rennet gelation process.

Gastric digestion

During simulated stomach digestion, A2/A2 cheeses showed lower levels of protein breakdown. This may be due to the structure of the A2 β-casein itself or the firmer cheese matrix. These differences could be important for understanding how A2 cheese is digested and absorbed in the body.

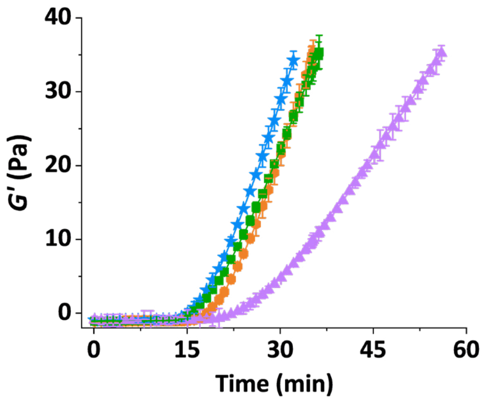

Figure 1. *Rennet gelation profiles for control (Orange), A1/A1 (Blue), A1/A2 (Green) and A2/A2 (Purple) milks. Control sample was taken from a bulk milk silo, containing a wide variety of milk protein variants*

Conclusion

As Ireland's national herd moves toward A2 milk production, adjustments in cheese manufacturing may be necessary. Cheesemakers should be aware that A2 milk behaves differently — particularly during rennet coagulation — and may require changes to standard curd-cutting protocols.

These findings have already been discussed with Irish milk processors. The dairy industry is advised to monitor and adapt to these changes to maintain consistent product quality.

Acknowledgements

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Exploring Kefir4All: Bringing science to life through citizen science

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Summary

- The Kefir4All project engaged 102 secondary school students from nine schools in hands-on microbiology, through milk and water kefir fermentation
- Students contributed to the largest artisanal kefir microbiology study to date in Ireland
- Kefir4All project highlights how citizen science can bridge education and cutting-edge research

Introduction

Citizen science encourages public participation in real-world scientific research. With recent updates to Ireland's Junior Cycle Science and upcoming changes to the Leaving Certificate curriculum, students are being encouraged to think and act like scientists, making projects like Kefir4All more timely than ever.

Between 2021 and 2023, students from Douglas Community School and eight other schools across Ireland participated in Kefir4All, a citizen science project coordinated by Teagasc researchers. Over a 21-week period, students became "citizen scientists," taking part in real scientific investigations, including at-home fermentations of milk and water kefir.

Citizen science in action

Kefir4All was launched as a collaboration between Teagasc researchers and science teachers who wanted to bring scientific investigation into the classroom. Students signed up through their schools and received specialised fermentation kits. Over the course of 21 weeks, students became "citizen scientists," regularly preparing milk and water kefir at home using the provided specialised equipment. They recorded their fermentation observations, explored different environmental conditions, and submitted their samples to Teagasc researchers, who then carried out an in-depth analysis of the microbial changes that occur during extended, artisanal-style fermentations.

Student engagement and scientific insight

Throughout the project, students and teachers stayed closely connected with the research team through emails, site visits, and dedicated feedback sessions. One highlight was the "Kefir4All Day" held in May 2022 at Teagasc Moorepark, where participants toured labs and learned about next-generation DNA sequencing and analysis of the microbial community in kefir samples.

This two-way collaboration gave students an opportunity to experience research in action, while also providing researchers with valuable long-term data from real-world fermentation settings.

At the end of the project, each student received a personalised report describing the fermentation results from their samples. In return, Teagasc gained a better understanding the public's perception of microbiology and fermentation, including culinary uses, flavour profiles, and approaches taken by different student groups.

Educational impact

Cian O'Mahony, lead teacher from Douglas Community School and an adult participant in the project, described Kefir4All as transformative. He noted that students not only explored microbiology, food science, and genetics, all relevant to the Leaving Certificate biology curriculum, but also gained confidence and curiosity through direct involvement in scientific research.

Students were given access to new equipment and learned practical skills that connected school science to real-world applications. Feedback from the students was overwhelmingly positive, and many expressed interest in pursuing science-related studies and careers as a result.

Conclusion

Kefir4All is a model for how citizen science can link students, teachers, and researchers. It showcased how young people can meaningfully contribute to scientific discovery while enhancing their own learning.

Building on this success, similar citizen science platforms are being developed at Teagasc research centres.

Visit www.vistamilk.ie/educational-resources for updates.

For a wider look at citizen science in Ireland, check out citizen-science.ie/projects.