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Editorial

Innovation in Dairy Processes and Products: Exploring Recent Advances, Analytical Applications, and Reimagining Traditional Systems

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1. Introduction

Milk and dairy science represent an extremely rich matter for scientific research. The complexity of milk as the raw ingredient and its components rules processing and affects the technological, nutritional, and quality traits of the final products [1]. Despite the traditionalist nature of production, the dairy industry is undergoing a transformation, fueled by technological advancements, growing consumer health awareness, environmental concerns, cultural preferences for traditional products, and a shift towards sustainable and circular practices.

In this evolving landscape, quality control and assurance procedures must adapt to the pace of innovation, incorporating new quality considerations. Traditional dairy quality control often involves wet chemistry, solvent extraction, and gravimetry, as well as instruments like chromatographs, electrophoresis machines, polarimeters, and rheometers. However, emerging technologies are driving the development of innovative dairy products and processes.

Therefore, both in dairy processing and quality control procedures, innovations are slowly but progressively introduced—which are implemented on-line and in-line–such as either those involving the exploitation of very fast and sensitive analytical methods such as NMR relaxometry [2], near infrared (NIR) spectroscopy [3], Internet of Things (IoT) devices [4], and those involving new dairy technologies, such as high-pressure processing to substitute thermal treatments and the encapsulation of biologically active ingredients into microparticles to generate functional dairy products, to cite just a couple of the more relevant examples.

The characterization of dairy products, given their complex nature, requires a multi-disciplinary analytical approach, and this is one of the key features of most of the papers published in the present Special Issue.

This Special Issue explores various aspects of dairy products, encompassing innovative cheese-making techniques with alternative renneting agents, non-thermal pasteurization methods, and the use of dairy by-products to enhance the textural properties of soft cheeses. Additionally, the nutritional composition of dairy products is explored, including the incorporation of non-conventional milk in infant formulae, the enrichment of goat milk with coffee nutrients together with the deep characterization of the final product using lipidomics, and the utilization of casein micelles-derived microparticles as carriers for bioactive compounds. Furthermore, this Special Issue highlights the combined application of advanced analytical techniques to uncover the intricate and unexplored characteristics of milk.

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The seven papers comprising this Special Issue can be broadly categorized into three groups: one focusing on the proposal of novel products or processes; a second group concerning papers that introduce innovative analytical methods for traditional systems; and a third group encompassing those papers that propose both a new process or product and a novel characterization method. It should be noted that this classification is just a first approximation, since the distinctions between these groups are often blurred. This blurring is largely due to the fact that all papers in the three groups share a common characteristic: they involve both a technological component of product or process innovation and a molecular characterization component of the result. It is worth noting that, in many cases, the proposal of new products or processes, and the subsequent in-depth evaluation of their quality, would not have been possible without the aid of new characterization methods. These methods provide access to unprecedented insights into the composition and structure of the proposed products.

New processes/products

- Exploring New Fruit- and Vegetable-Derived Rennet for Cheese Making;
- Evolution of Qualitative and Quantitative Lipid Profiles of High-Pressure-Processed Serra da Estrela Cheese throughout Storage.

New characterization methods

- Ion Mobility–Mass Spectrometry Approach for the Comparison of Sheep and Goat Milk Lipidomes.

New processes and new characterization methods

- Development and Chemico-Physical Characterization of Ovine Milk-Based Ingredients for Infant Formulae;
- Determining the Behavior of Water in Buttermilk Cheese with Polymerized Whey Protein Using Differential Scanning Calorimetry and Nuclear Magnetic Resonance Analysis;
- UHPLC-QTOF/MS Untargeted Lipidomics and Caffeine Carry-Over in Milk of Goats under Spent Coffee Ground Enriched Diet;
- Influence of Spray Drying on Encapsulation Efficiencies and Structure of Casein Micelles Loaded with Anthraquinones Extracted from Aloe vera Plant.

Finally, this Special Issue highlights a growing interest in sheep's and goat's milk compared to cow's milk. Of the seven published papers, four focus on products derived from sheep or goat, demonstrating the increased attention being given to these promising alternative dairy sources.

2. Overview

A brief overview of this Special Issue will guide the reader through the novelties presented in the published papers, highlighting the most relevant and innovative aspects introduced by each of the papers in the collection.

Among the papers belonging to the first group, i.e., those focused on the development of new dairy processes and products, the paper "Exploring New Fruit- and Vegetable-Derived Rennet for Cheese Making" considered plant-based alternatives to rennet in cheese making. The exploration of alternatives to calf rennet becomes important for those groups of consumers with peculiar ethical and/or nutritional needs. Moreover, it is important to address animal welfare and environmental sustainability issues and to promote the stability of the dairy supply chain. In another paper of the same group, titled "Evolution of Qualitative and Quantitative Lipid Profiles of High-Pressure-Processed Serra da Estrela Cheese throughout Storage", high-pressure processing (HPP) has been suggested as a promising technology in non-thermal microbiological stabilization treatment. HPP

can provide a uniform treatment in liquid and solid products, with minimal effects on taste, texture, appearance, or nutritional values [5], in contrast to the undesired effects of conventional high-temperature pasteurization treatment.

As mentioned above, other works published in this Special Issue dealt with innovation in the dairy sector suggesting both new products and new characterization methods. Among the contributions within this group of studies, the effect of whey protein in buttermilk cheese as an ingredient with which to increase the nutritional value and improve the cheese making process was discussed in the paper "Determining the Behavior of Water in Buttermilk Cheese with Polymerized Whey Protein Using Differential Scanning Calorimetry and Nuclear Magnetic Resonance Analysis". On one hand, this paper highlights the potential of dairy by-products in the development of secondary products with nutritional and technological value in consideration of food waste reduction. Furthermore, this work represents an additional contribution that clearly suggests, with data support, that NMR relaxometry is gaining ground as a complementary and informative technique for assessing the state of biopolymers in complex dairy materials. It introduces new analytical parameters that appear to be highly sensitive to the process, microstructure, molecular mobility, and sensory quality of dairy products. The introduction of this technique into the industrial environment is becoming increasingly feasible and reasonable. In the same group, the paper "Development and Chemico-Physical Characterization of Ovine Milk-Based Ingredients for Infant Formulae" presented a detailed study of infant milk formulas based on ovine milk. Alternatives to cow milk for infant nutrition have been considered especially in light of the spreading of cow milk's allergies. In this sense, ovine milk can be considered as a valuable ingredient for infants nutrition, since it contains a variety of essential nutrients for infants which are a peculiar characteristic of sheep's milk. An interesting application of NMR-based metabolic profiling of the new formulations has been suggested and was able to cast a new light on the nutritional quality of infant formulations. The effect of supplementing the diet of lactating goats with spent coffee grounds in terms of changes of the lipid profiles of milk has been investigated in the paper "UHPLC-QTOF/MS Untargeted Lipidomics and Caffeine Carry-Over in Milk of Goats under Spent Coffee Ground Enriched Diet" analyzed the reuse of food byproducts, namely, spent coffee grounds, to supplement the diet of lactating goats. The reuse of bioresources is envisaged in the food industry as an environment safeguard in the interest of sustainability and as a suitable means by which to promote circular economic practices. Although the technique used, UHPLC-QTOF/MS, is technologically advanced and highly informative per se, targeted quantitative approaches are highly required to better understand metabolic changes induced by such dietary interventions.

The paper "Influence of Spray Drying on Encapsulation Efficiencies and Structure of Casein Micelles Loaded with Anthraquinones Extracted from Aloe vera Plant" proposed the synthesis and characterization of spray dried casein micelles microcapsules to deliver anthraquinones extracted from Aloe Vera. Casein micelles are among the most used carriers for their low cost and flexible performance, making their wider exploitation at industrial scale very promising. Anthraquinones have excellent biological activities (anticancer, anti-inflammatory, diuretic, antiarthritic, antifungal, antibacterial). Anthraquinones powder, aloe vera freeze-dried powder, and whole aloe vera gel were encapsulated into casein micelles. Encapsulation efficiency and stability was regulated by the type of anthraquinone, the pH of the solution, and the nanostructure of casein micelles during spray drying.

The only paper discussing just the application of new characterization methods, titled "Ion Mobility–Mass Spectrometry Approach for the Comparison of Sheep and Goat Milk Lipidomes", presented a new analytical technique based on ion mobility–mass spectrometry and discussed its use to deeply investigate and compare lipid species in goat and sheep

milk. These differences and others identified by the authors could have an impact on the nutritional and functional qualities of the two milks, including digestibility and potential health advantages. The combined use of ion mobility and mass spectroscopy allowed for the unraveling of new features of these milks, including compounds with biological significance. The beneficial health effect of some of these compounds is well known [6]. Most importantly, analysis can be carried out in a very fast way, paving the way for further studies and application in routine quality control.

This Special Issue, "Advance in Processing and Quality Control of Dairy Products", considers very diverse topics representing the fascinating complexity of innovation in the dairy sector, bringing to light new challenges in the improvement and characterization of dairy products, without neglecting the historical and traditional traits of milk and cheese. Innovative approaches in dairy products science have been discussed, covering the technological, nutritional, analytical, and quality aspects of milk and cheese products.

The editors of this Special Issue would like to thank all the authors involved in its production, and we invite further scientific activity in this promising area.

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