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From Tank to Table: Seasonal Trends in Density and Dry Matter and Their Impact on Dairy Processing

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Abstract: Milk composition varies significantly with environmental conditions and farm management practices, influencing its suitability for dairy processing. This study investigates seasonal variations in milk density and dry matter content based on weekly bulk tank samples collected from a dairy cattle farm. Higher temperatures in summer months often lead to a reduction in dry matter due to heat stress and changes in feed intake, while cooler seasons typically promote higher concentrations of solids. Understanding and predicting these variations is essential not only for maintaining consistent product quality but also for improving yield forecasts and optimizing processing strategies throughout the year. Through statistical analysis, we identify clear seasonal patterns in milk quality parameters and explore their implications for the theoretical yield of dairy products such as cheese and yogurt. Using established yield estimation models, we assess how fluctuations in milk composition across seasons can affect product yield and processing efficiency. This approach demonstrates that compositional monitoring at the farm level can provide valuable insight into potential processing outcomes. Our findings offer practical recommendations for both dairy producers and processors seeking to optimize production based on seasonal quality trends.

Keywords: seasonal variation; cheese yield; yogurt yield; dairy processing; bulk tank milk; milk quality monitoring

Introduction:

Milk, a vital biological fluid, supports the global dairy industry. Its fat, protein, lactose, minerals, and water contents determine the nutritional value of products like cheese and yogurt. Fluctuations in composition throughout the year pose challenges for processors striving for consistency. Adaptive processing strategies are essential to achieve product uniformity and manufacturing efficiency. This paper critically examines seasonal variations in two key parameters of bulk tank milk: density and dry matter content. A core objective is to assess the implications of these fluctuations on cheese and yogurt yield and quality, using established predictive models. The economic effects on milk producers and processors highlight the importance of this analysis. Bulk tank milk analysis is a cost-effective way to monitor herd-level milk quality trends in modern dairy farm management. While protein and fat content are often examined, dry matter and density data are less frequently analysed for predicting processing outcomes over time. Connecting these variations to cheese and yogurt yield estimates through established models is an underutilized method in dairy science. This study analyses weekly bulk tank milk samples from a dairy farm over a year (2024), focusing on density and dry matter content. It evaluates seasonal trends and yield estimation formulas to demonstrate the predictive value of milk composition monitoring, providing insights for producers and processors to enhance production planning and processing efficiency.

Material and method:

The study took place at the Research and Development Station for Cattle Breeding Dancu in northeastern Romania, focusing on a closed herd of Holstein-Friesian dairy cows with consistent feeding, housing, and milking protocols. Cows were given a Total Mixed Ration (TMR) adapted seasonally based on forage availability and nutritional needs. Weekly bulk tank milk samples were collected from January to December 2024 after morning milking to ensure uniformity from all lactating cows. Two primary milk quality parameters assessed were Milk Density (g/cm^3) and Dry Matter (%), measured at 20°C with a calibrated electronic analyser following ISO standards. Data was categorized by season: Winter (Dec-Feb), Spring (Mar-May), Summer (Jun-Aug), and Autumn (Sep-Nov) to evaluate intra- and inter-annual trends. Theoretical cheese yield (CY) was calculated using the Van Slyke formula: $CY=(0.93\times Fat)+(0.10\times Casein)-0.1$, while descriptive statistics were employed for detailed analysis of the parameters, including mean, standard deviation, minimum, and maximum values.

Results and discussions:

Seasonal Fluctuations in Bulk Tank ***Milk Density and Dry Matter Content***

1. Milk Density Variations
2. Dry Matter (Total Solids and Solids-Not-Fat) Variations

Impact of Seasonal Milk Variations on Theoretical Dairy Product Yield and Quality

1. Milk Density: Processing Significance and Relationship with Solids
2. Theoretical Cheese Yield

2.1. Overview of Cheese Yield Prediction Formulae
2.2. Estimation of Theoretical Cheese Yield Variations
2.3. Consequential Effects on Cheese Moisture, Texture, and Processability

- ✓ Rennet Coagulation Properties / Syneresis / Cheese Moisture and Texture / Fat and Protein Recovery

Theoretical Yogurt Yield and Quality

3.1. Principles of Yogurt Production: Importance of Solids and Protein

Milk proteins are central to yogurt structure:

- ✓ Caseins form the primary three-dimensional gel network.
- ✓ Whey proteins

3.2. Estimation of Impacts on Yogurt Manufacturing

Fortification Needs / Impact on Texture and Syneresis

Mitigation Strategies, Economic Considerations, and Future Research Perspectives

4.1. On-Farm Management Practices
4.2. Dairy Processing Adjustments and Technological Innovations

- ✓ Milk Standardization:
- ✓ Membrane Filtration Technologies (Ultrafiltration - UF / Microfiltration - MF
- ✓ Process Analytical Technology (PAT):
- ✓ Predictive Modelling and Data Analytics:
- ✓ Adjustment of Process Parameters:

4.3. Economic Implications

For Dairy Farmers / For Dairy Processors / Variable Product Yields / Increased Standardization Costs / Processing Inefficiencies / Inconsistent Product Quality

4.4. Future Research Perspectives

Advanced Predictive Models / Novel Nutritional and Management Strategies / Impact of Minor Components and Protein Functionality / Refinement of Process Analytical Technologies / Economic Modelling and Decision Support / Climate Change Impacts / Genetic Markers for Stability

Conclusions:

This study compellingly demonstrates that the density of bulk tank milk and the levels of dry matter concentration experience notable variations throughout different seasons. These variations stem from a complex interplay of environmental factors—mainly climate conditions like temperature, humidity, and photoperiod influencing feed availability and animal stress—along with farm management practices such as nutrition strategies, lactation dynamics, calving patterns, genetic selection, and animal health. Seasonal shifts in milk composition significantly affect the dairy processing sector. For cheesemaking, variations in fat and casein levels impact theoretical cheese yields, as highlighted by models like the Van Slyke formula. Additionally, changes in milk protein functionality and mineral balance can influence key parameters such as rennet coagulation and curd development, thereby affecting cheese moisture, texture, and overall quality. In yogurt production, while yield is volumetric, the initial solids and protein content dictate the required fortification to achieve desired textural properties and prevent defects such as syneresis. Lower native solids in particular seasons lead to increased fortification needs and costs. Milk density, reflecting fat and solids-not-fat content, also varies seasonally, affecting volumetric measurements and processing efficiency. Ongoing research and technological advancements in predictive analytics, dietary solutions, and real-time monitoring will offer tools for understanding seasonal milk composition. Climate change pressures will further heighten these seasonal challenges, making innovations and adaptive strategies crucial for a resilient dairy sector.