CDR Paper 2601

Oat Milk and Oat-Based Beverages: Composition, Production Process and the Role of Chemical Analysis in Quality Control

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1. Introduction to Oat Drink Processing and Analytical Challenges

Over the past decade, oat-based beverages have become the fastest-growing segment among plant-based milk alternatives, driven by advances in processing technologies that enable the conversion of cereal raw materials into stable and safe beverages. Compared to standard dairy milk processing, oat drinks typically require tighter control of **enzymatic hydrolysis** and **fortification**, while **thermal treatment and homogenization** must be optimized in relation to recipe-dependent interactions between carbohydrates, proteins, lipids and minerals to ensure physical stability and consistent functionality.

As oat drinks have reached large-scale industrial production, the need for **robust chemical analysis** has increased to ensure process reproducibility, product stability and regulatory compliance. Variability in raw materials and processing conditions can significantly affect key chemical parameters, making analytical control a critical element in modern oat drink manufacturing.

2. Composition, Nutritional Profile and Production Process of Oat Drinks

Nutritional Composition and Comparison with Cow's Milk

Oat-based beverages differ intrinsically from cow's milk due to their botanical origin. Their composition reflects the nutritional properties of oats, combined with targeted fortification to achieve a balanced profile.

Compared to semi-skimmed cow's milk, fortified oat drinks typically contain:

- **Higher levels of dietary fibre**, primarily beta-glucans.
- **Higher proportions of unsaturated fats (oleic, linoleic, and linolenic acids)**, with lower saturated fat content.
- **Comparable energy and calcium levels**, depending on fortification strategy.
- **Lower protein content**, although oat proteins are of high biological quality.
- **No cholesterol, lactose or milk proteins**.

Oats are recognized for their content of beta-glucans, soluble fibres that contribute to cholesterol reduction by limiting intestinal absorption. Fortification is a critical step in oat drink formulation. Vitamins and minerals such as **calcium, iodine, riboflavin (B2), vitamin D and vitamin B12** are commonly added to compensate for nutrients naturally present in dairy milk. From a regulatory and quality standpoint, fortification requires precise dosing and analytical verification.

Raw Materials and Formulation

Typical oat drinks consist of approximately **85–88% water**, **6–11% oats**, vegetable oil, salt and micronutrients. Rapeseed oil is frequently used to enhance mouthfeel and foam stability, particularly in barista formulations, due to its favorable fatty acid profile.

In some formulations, alternative protein sources such as peas or by-products like brewery spent grain and oilseed press cakes are explored to increase protein content while improving sustainability through by-product valorization.

Production Process and Critical Control Points

Oat drink production involves several interconnected technological steps:

1. **Oat milling or slurry preparation**.
2. **Enzymatic hydrolysis** of starches and polysaccharides to improve sweetness, stability and mouthfeel.
3. **Heat treatment**, often via direct UHT processing at **138–144°C**, to ensure microbiological safety and enzyme inactivation.
4. **Homogenization**, to stabilize the emulsion and prevent phase separation.
5. **Fortification and formulation adjustments**.
6. **Aseptic filling**.

Each phase introduces potential variability affecting **sugar profile, protein integrity, mineral balance and pH stability**, making analytical control essential throughout the process.

3. Chemical Analysis Challenges in Oat Drink Production and the Role of CDR DrinkLab

Quality control of oat-based beverages requires the monitoring of multiple chemical parameters across raw materials, intermediate products and final formulations. Conventional laboratory methods often involve complex sample preparation, enzymatic assays and dedicated laboratory infrastructure, which may limit their use for routine or in-process controls.

CDR DrinkLab addresses these challenges by enabling **rapid, reliable chemical analysis directly in production environments or quality control laboratories**, without extensive sample preparation.

Key Parameters Analyzable with CDR DrinkLab
CDR DrinkLab allows the determination of several critical parameters, including:

- **Fermentable sugars**, essential for controlling enzymatic hydrolysis and sweetness.
- **Total sugars**, relevant for nutritional labeling and regulatory compliance.
- **Organic acids (acetic acid e total lactic acid D+L)**, influencing pH stability and sensory profile.
- **Alcohol**, particularly relevant for fermented or hybrid beverages. *[in development]*
- **Ammonia**, a key indicator of protein degradation and microbial activity.
- **Free Amino Nitrogen (FAN),** reflecting the availability of soluble organic nitrogen resulting from protein hydrolysis. *[in development]*

The use of **pre-calibrated reagents and minimal sample volumes** ensures analytical consistency while reducing operator dependency. This approach is particularly advantageous for producers lacking fully equipped analytical laboratories or seeking faster decision-making during production.

Analytical Parameter	Significance in Production	Indicator Type	Impact on Final Product
Ammonia	Indicator of protein degradation and microbial activity	Degradation / Early warning indicator	Impacts biochemical stability, safety, and sensory quality
Fermentable sugars	Controlling enzymatic hydrolysis and sweetness	Process efficiency	Influences sweetness and sensory profile
Total sugars	Nutritional labeling and regulatory compliance	Process efficiency	Influences nutritional profile and regulatory status
Free Amino Nitrogen (FAN)	Reflecting availability of soluble organic nitrogen from protein hydrolysis	Process efficiency	Optimizes protein solubilization and functional properties
Organic acids	Influencing pH stability	Degradation / Stability	Influences sensory profile and chemical stability
Alcohol	Relevant for fermented or hybrid beverages	Process efficiency	Defines beverage category and sensory properties

4. Focus on Ammonia Analysis in Plant-Based Beverages

Ammonia concentration in plant-based beverages, including oat, soy, rice and other vegetable drinks, is a **critical quality parameter** for process and product control. Elevated ammonia levels may indicate:

- **Protein degradation during processing**, resulting from excessive thermal stress or uncontrolled biochemical reactions.
- **Microbial activity**, associated with deamination of amino acids and nitrogen metabolism.
- **Inadequate heat treatment or sanitation**, leading to residual enzymatic or microbial activity during storage.

In the context of oat drink production, ammonia analysis provides information that is **complementary to Free Amino Nitrogen (FAN)** determination. While **FAN reflects the concentration of soluble organic nitrogen compounds**, such as amino acids and short peptides generated during controlled protein hydrolysis, **ammonia represents inorganic nitrogen** and is primarily associated with **undesired degradation phenomena**.

From a process control perspective, **FAN is linked to formulation and enzymatic treatment efficiency**, supporting the optimization of protein solubilization and functional properties. In contrast, **ammonia serves as an early warning indicator**, signaling potential deviations related to protein breakdown, microbial contamination or insufficient process control.

Routine monitoring of ammonia, in combination with FAN determination, therefore enables a more comprehensive assessment of **biochemical stability, process robustness and product safety** in oat-based beverages, supporting timely corrective actions and consistent product quality.

Routine monitoring of ammonia is therefore essential to ensure **product stability, safety and sensory quality**.

5. Method Correlation: CDR DrinkLab vs Reference Assays

The determination of **ammonium concentration** is a well-established analytical approach for monitoring the **quality and biochemical evolution of milk and dairy products during technological processing**, and the same principle applies to **plant-based beverages**, including oat drinks. Ammonia can originate from protein degradation, enzymatic activity or microbial metabolism, making it a sensitive indicator of process control and product stability.

Traditionally, ammonia is quantified using **enzymatic reference methods**, such as the **Megazyme Ammonia Assay Kits**, which are widely adopted in industrial and research laboratories due to their specificity and standardized protocols. These enzymatic assays are commonly used as benchmark techniques for routine quality control and method validation.

In addition to enzymatic methods, **chromatographic techniques** are described in the scientific literature as reference approaches for ammonium determination. In particular, methods based on **cation-exchange chromatography coupled with suppressed conductivity detection** allow the separation and quantification of ammonium ions with high analytical sensitivity. These techniques, however, require **appropriate sample preparation**, dedicated instrumentation and skilled personnel, which often limits their applicability to centralized or highly equipped laboratories.

Other official or standardized analytical approaches for ammonia determination include:

- **Ion chromatography**, as described in international standard methods for water and food analysis.
- **Spectrophotometric methods** based on the Berthelot reaction or related colorimetric principles, referenced in several official compendia.
- **Enzymatic UV methods**, recognized in food and beverage analysis as reliable reference techniques.

Comparative studies performed on various oat beverages demonstrate a **strong correlation between ammonia values obtained using CDR DrinkLab and those measured with enzymatic reference assays**, such as Megazyme kits.

CDR (ppm)	Official method (ppm)
6.28	4.13
43.3	32.1
45.1	38.4
42.5	36.8
37.6	34.1
37.0	33.1
37.6	34.5
41.0	35.8
37.8	32.9

Table 1: Correlation study on Ammonia between CDR DrinkLab and the Megazyme Method

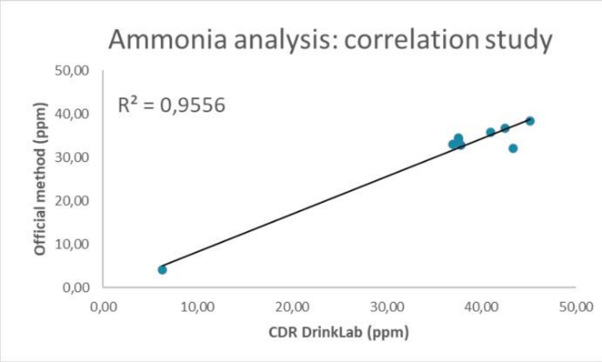


Figure 1: Correlation study on Ammonia between CDR DrinkLab and the Megazyme Method

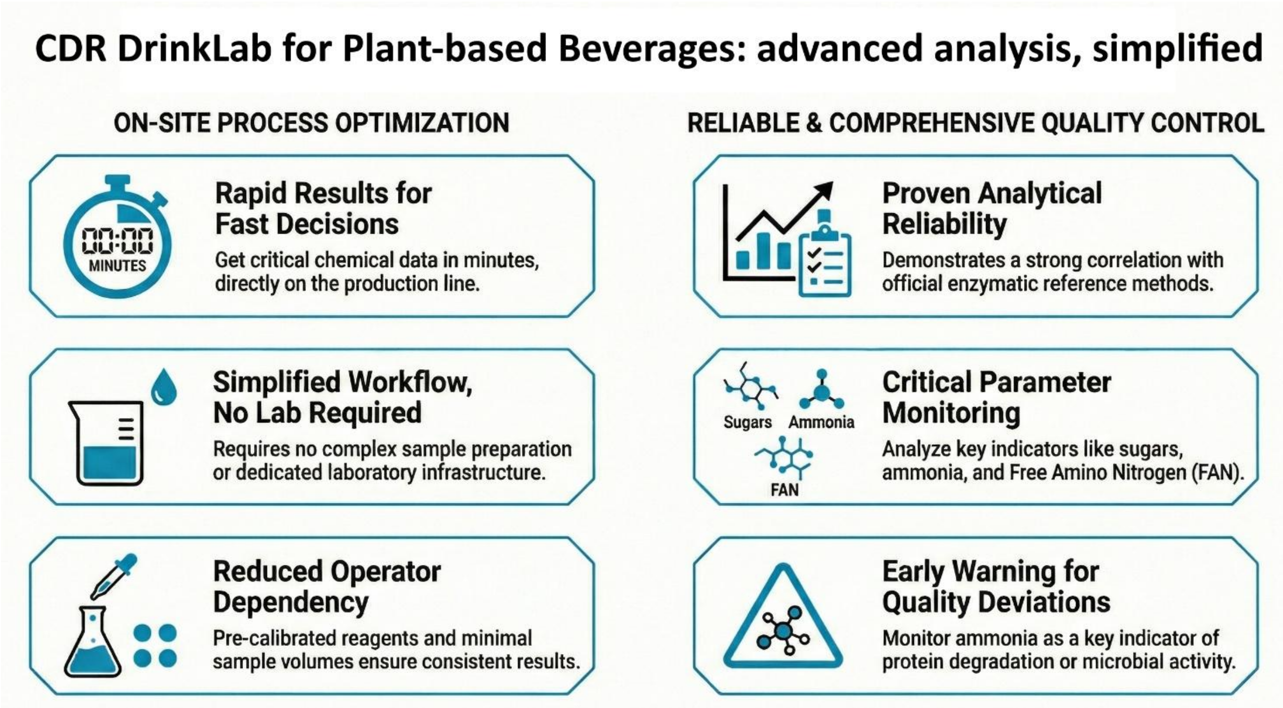
The observed correlation (Table 1, Graph 1) shows a **high coefficient of determination (R^2)**, confirming the analytical reliability of CDR DrinkLab for ammonia determination in complex plant-based matrices. By eliminating complex sample preparation and reducing analysis time, CDR DrinkLab enables rapid, on-site ammonia monitoring in oat drink production.

6. Conclusions

The rapid expansion of oat-based beverages reflects a convergence of sustainability, nutritional awareness and technological innovation. However, the complexity of oat drink formulation and processing requires **robust chemical control at every production stage**.

Analytical challenges associated with traditional laboratory methods can limit process responsiveness and increase operational costs. In this context, **CDR DrinkLab provides an effective solution**, combining speed, ease of use and analytical reliability for the monitoring of key quality parameters.

The demonstrated correlation with established reference methods, particularly for ammonia analysis, further supports the suitability of CDR DrinkLab as a practical tool for quality control in modern plant-based beverage production.



Bibliography

1. Tetra Pak. *Oat beverages are booming. Here's why.* Tetra Pak Global, 2023. Tetra Pak
2. GFI Europe. *Market insights on European plant based sales 2020 to 2022 (NielsenIQ based analysis).* The Good Food Institute Europe, 2023. GFI Europe
3. Oatly. *Our process (patented technology and production approach).* Oatly, web page. oatly.com
4. *UHT processing in the context of plant based beverages: A scientific review. Current Research in Food Science*, 2024. ScienceDirect
5. *Innovative technologies for manufacturing plant based non dairy milk substitutes and their impact on nutritional, sensory, and safety aspects: A review. Current Research in Food Science*, 2021. ScienceDirect
6. Novozymes. *Oat based beverage, technical document (enzyme selection, hydrolysis outcomes, process considerations).* Novozymes, PDF. biosolutions.novozymes.com
7. *Can plant based milk alternatives fully replicate UHT cow milk? A review focusing on sensory and physicochemical properties. Beverages* (MDPI), 2025. MDPI
8. Megazyme. *Ammonia Assay Kit (Rapid) K-AMIAR, product page and method overview.* Megazyme. megazyme.com