Advanced Stability Analysis of Plant-Based Beverages: Oat Milk

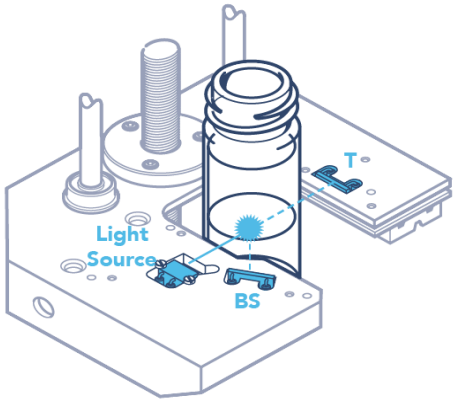
CONTEXT

Commercial **oat beverages** vary widely in formulation, from clean-label products containing only water and oats to more engineered systems incorporating vegetable oils and stabilizing salts. As complex multiphase systems composed of insoluble particles, soluble fibers, and lipids, these beverages are susceptible to destabilization phenomena such as sedimentation and creaming during storage.

The objective of this study was to compare the **destabilization pathways** and **overall physical stability** of three commercial oat beverages during refrigerated storage using TURBISCAN technology, and to evaluate the impact of formulation strategy on stability behavior.

TURBISCAN: How does it work?

TURBISCAN technology, based on Static Multiple Light Scattering (SMLS), consists of sending light pulses (880 nm) into a sample along its height. The reading head scans the sample by moving vertically along the analysis cell and acquires data every 20 µm. Measurements are made over time, and variations in the backscattering and transmission levels due to sample instability are recorded. The signal is directly linked to the evolution of particle concentration (φ) and size (d) by the Mie theory. Samples with a particle concentration from **10^{-4} to 95% (v/v)** and from **10nm to 1mm** in particle size can be measured as is.



$$BS = f\ (\varphi, d, np, nf)$$

Figure 1: *TURBISCAN measurement head*

The instrument enables monitoring of changes in physical stability (coalescence, creaming, sedimentation, phase separation, etc.) without dilution or stress, and thus follows **ISO TR 13097 guidelines**.

ISO TR13097 defines scanning and spatially resolving techniques as perfectly suitable for stability analysis and suggests that the

acceleration procedures applied to shorten test duration must not denature the initial product.

EXPERIMENTAL RESULTS

Three commercial oat milk samples were analyzed using TURBISCAN technology. Each sample was poured into a 20 mL glass vial without any additional preparation or dilution. The vials were sealed with caps and placed in the TURBISCAN device for seven days at a controlled temperature of **5°C**, with continuous scanning throughout the analysis. This seven-day duration was used for initial screening; however, TURBISCAN technology can distinguish destabilization phenomena within just a couple of hours.

The following figures present the ΔBS profiles as a function of sample height for the three oat milk samples over the seven days of analysis. The first scan is shown in blue and the final scan in red, enabling visualization of the destabilization phenomena occurring over time.

Sample A

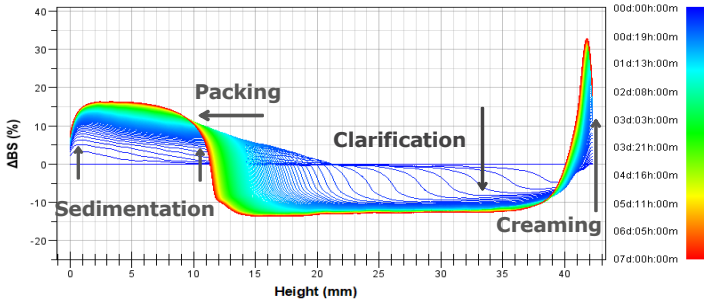


Figure 2: *Destabilization profile for Sample A Oat milk*

Sample B

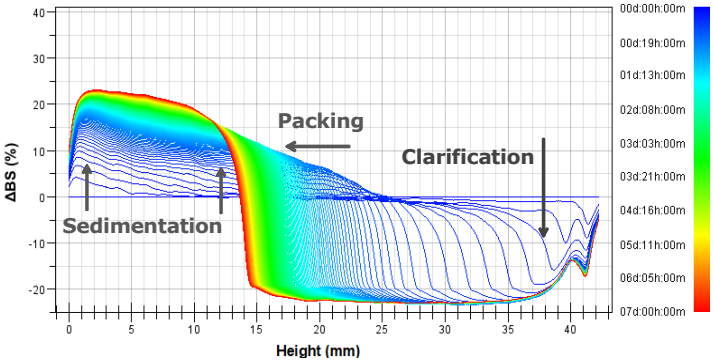


Figure 3: *Destabilization profile for Sample B Oat milk*

Sample C

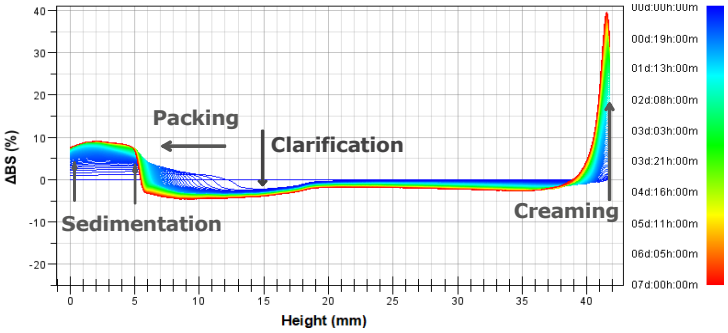


Figure 4: *Destabilization profile for Sample C Oat milk*

With TURBISCAN, it is possible to distinguish different phenomena of destabilization in 3 different zones of the samples (top, middle, and bottom), as summarized in Table 1.

Sample	Bottom	Middle	Top
A	Sedimentation of particles	Clarification	Creaming
B	Sedimentation of particles	Clarification	/
C	Sedimentation of particles	Clarification	Creaming

Table 1: *Phenomena observed in three different zones of each oat milk sample: A, B, and C*

Sample B does not exhibit a pronounced creaming layer at the top of the sample, suggesting that the oil droplets remain well dispersed within the continuous phase. However, significant sedimentation is observed at the bottom, likely to originate from insoluble oat components such as residual particles or insoluble fibers.

THE GLOBAL STABILITY

The global stability of samples can be assessed by TURBISCAN thanks to the **TURBISCAN Stability Index** (**TSI**). It integrates all signal variations detected along the sample height due to destabilization phenomena (sedimentation, clarification, creaming, size variation, etc.). At a given ageing time, the higher the TSI, the less stable the sample.

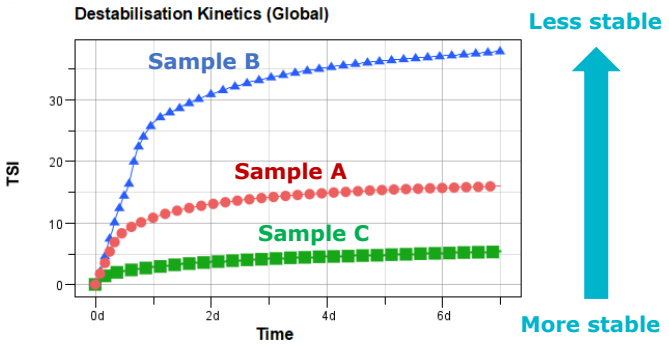


Figure 5: *TURBISCAN Stability Index versus time for each oat milk sample A, B, and C*

Figure 5 shows the TSI values for each oat milk sample. Among the three samples, Sample C exhibited the lowest TSI throughout the analysis period, indicating the highest global stability. Although this sample displayed a pronounced creaming layer, the total signal variation remained limited compared to Samples A and B.

In contrast, Sample B showed the highest TSI values, consistent with progressive multi-zone destabilization and continuous structural evolution, while Sample A demonstrated intermediate behavior.

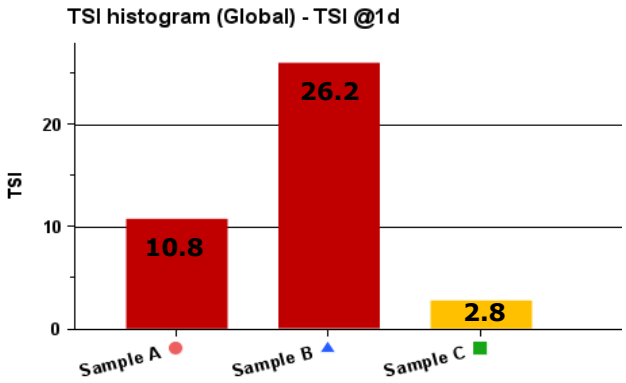


Figure 6*: TURBISCAN Stability Index for each oat milk sample A, B, and C at one day*

Importantly, Figure 6 shows that the stability ranking was already observable after **one day of analysis**, showing that reliable comparative stability information can be obtained much faster than with traditional shelf-life testing or visual observation.

SEDIMENTATION MIGRATION RATE

More detailed analysis can be carried out on the data. Figure 7 shows the sedimentation kinetics. It shows the peak thickness, so the thickness of the sediment layer, as a function of time. The migration rate of dispersed insoluble oat materials is obtained from the slope of the left part of each curve by automatic data computation.

Additionally, this graph can show how much the sedimentation layer packs over the course of the analysis. The packing kinetic can be found from the slope of the right part of each curve, again by automatic computation.

The sedimentation kinetics revealed differences in the migration rate of dispersed insoluble oat materials among the samples. Sample B exhibited the fastest sediment growth, consistent with a higher TSI and greater overall instability. Sample A showed intermediate sedimentation formation, while Sample C demonstrated slower sediment development, indicating reduced cumulative structural evolution.

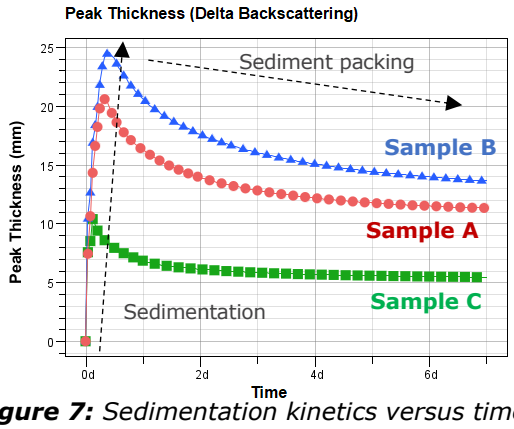


Figure 7: *Sedimentation kinetics versus time for oat milk samples A, B, and C.*

Sample	Sedimentation Kinetic	Packing Kinetic	Final Sedimentation layer
A	2.38mm/hr	-1.76mm/d	11.32mm
B	2.09mm/hr	-2.27mm/d	13.62mm
C	3.21mm/hr	-0.73mm/d	5.44mm

CONCLUSION

TURBISCAN analysis successfully distinguished the destabilization behaviors of the three oat beverages by identifying creaming of oil droplets, sedimentation of insoluble particles (fibers, protein…), and clarification.
While Samples A and C exhibited both sedimentation and creaming, Sample B does not display any creaming of oil droplets, yet with greater overall structural evolution.

Sample C presented the lowest **TSI**, indicating the **highest global overall stability**:

Visual observation after 7 days (Figure 8) confirms the same sedimentation ranking already identified by **TURBISCAN after just 1 day**, with Sample C showing the highest stability, followed by A and B. However, while sedimentation becomes visible over time, creaming remains undetectable by eye even after prolonged storage. TURBISCAN, on the other hand, reveals both phenomena within only a few hours, providing rapid, sensitive, and comprehensive insight into destabilization processes long before they become visible.

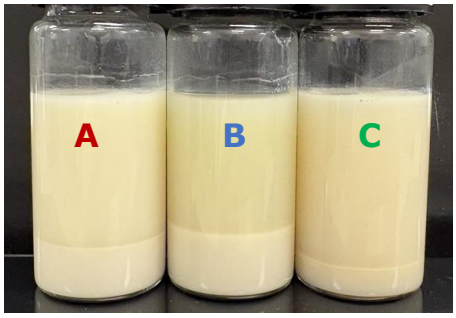


Figure 8: *Picture of samples A, B, and C after 7 days of analysis at 5 °C*

TURBISCAN enables **rapid comparative stability assessment** without applying **stress** or altering the product. Visual appearance alone may not reveal clear differences between samples during the early stages of storage, highlighting the advantage of TURBISCAN measurements in **detecting and quantifying all destabilization phenomena long before they become visible to the naked eye**. Such early insights can significantly accelerate formulation screening and product development for plant-based beverages.