APPLICATION NOTE

# Beyond passive cooling: how the Omni Bead Ruptor Elite Cryo Cooling Unit outperforms conventional bead mill refrigeration systems.


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**Omni Bead Ruptor Cryo Cooling Unit**




## Summary

Bead mill homogenization is a reliable and efficient sample disruption process utilized across diverse laboratory applications from tissue processing to microbial lysis. However, laboratories working with heat-sensitive analytes, particularly RNA and proteins, require additional consideration to their sample preparation in all steps where heat can influence the results for the extracted analyte. High-speed homogenization produces significant heat that can degrade targeted molecules, compromise data quality, and affect downstream analysis such as RT-PCR, RNA sequencing, and protein analysis.

Traditional homogenization systems rely on passive cooling methods to manage temperature rise, including pre-cooling of sample tubes, the use of cold buffers, or intermittent processing cycles with extended dwell periods. While these approaches offer some degree of thermal management, they add complexity to workflows, extend total processing time, and cannot guarantee consistent temperature control across samples throughout homogenization, ultimately limiting throughput and reproducibility.

With this limitation in mind, the Omni Bead Ruptor™ Cryo Cooling Unit is an active cooling solution that continuously circulates chilled air through the chamber of the Bead Ruptor Elite™ during homogenization and immerses tubes in continuous cold air flow. In response to concerns about thermal degradation when using ambient-temperature buffers, the Cryo Cooling Unit can be paired with pre-chilled buffers to provide an additional layer of thermal protection. This combined approach would allow laboratories to maintain sample integrity while processing at maximum speed and allowing a more effective and efficient method of preserving analytes for downstream analysis.

Not all cooling solutions are created equal. Some manufacturers rely on repurposed cooling solutions designed for cooling samples in a state of stable thermal conditions. However, bead beating creates complexity that requires optimization because of the nature of homogenization and friction generated by the bead media, sample, and homogenization buffer colliding with each other inside the processing tube.

Competitor B's bead mill system features an integrated refrigeration unit designed to actively cool and maintain internal chamber temperature. However, this approach has demonstrated limited thermal efficiency and struggles to maintain adequate temperature control as processing speeds increase, compared to direct air circulation. Beyond the cooling limitations, Competitor B's advertised speed of 6 m/s is equivalent to only 3.1 m/s in true linear speed on the Bead Ruptor Elite. This disparity in processing speed has direct implications on the quality and consistency of sample preparation; laboratories that rely on Competitor B's system may experience incomplete homogenization when processing mechanically demanding sample types such as hard tissues, seeds, or robust microbial cells, where higher linear speeds are essential for achieving complete and consistent lysis[4]. The Omni Bead Ruptor Elite bead mill homogenizer reaches a maximum linear speed of 8.0 m/s, with majority of applications requiring 4-6 m/s, providing laboratories with the processing speeds necessary to fully homogenize challenging sample matrices.

In this application note, the Omni Bead Ruptor Elite paired with the Cryo Cooling Unit were directly compared to Competitor B's system to evaluate temperature control performance and processing speed. Based on the presented data, we can extrapolate the impact of thermal management on the integrity of thermally labile analytes and reveal which system is superior for laboratories requiring homogenization with active cooling for sensitive downstream applications.

## Materials and methods

## Equipment

- Omni Bead Ruptor Elite bead mill homogenizer (part number 19-042E)
- Omni Bead Ruptor Cryo Cooling Unit (part number 19-8005)
- Hard tissue homogenizing mix (part number 19-628)

## Procedure

**Bead mill speed theory**

**Omni Bead Ruptor Elite with Cryo Cooling attachment:**

The Omni Bead Ruptor Elite can process at speeds ranging from 0.8-8.0 m/s. When using liquid nitrogen, the Cryo Cooling Unit can produce an internal chamber temperature of -20 °C as described in the user manual. A matrix of speeds and times were examined as described in Table 1 below. The lowest speed tested was 3.1 m/s and the highest speed tested was 8 m/s. This range of speeds begins with an equivalent max linear speed to 6 m/s on the Competitor B instrument and finishes with the max speed capable on the Omni Bead Ruptor Elite. Additionally, the effects of prechilled buffers were examined on the Omni Bead Ruptor Elite while using the Cryo Cooling Unit.

As a control to display the rise in temperature, tubes were also processed on the Omni Bead Ruptor Elite at ambient temperatures (without active cooling).

**Competitor B:**

Competitor B's bead mill has wide programmable processing speed range up to 7 m/s. It was determined via calculation that 6 m/s on the Competitor B bead mill is the equivalent of 3.1 m/s on the Omni Bead Ruptor Elite. To determine linear velocity, motor speed and width of the carriage measurements were obtained and used as variables in the linear velocity equation below. The instrument's temperature control function was set to the lowest possible temperature set point. The resulting lowest maximum temperature was recorded in Table 1. The velocity used with this instrument was chosen as a comparison point due to common protocols described by both users of the instrument and published methods.

$$\text{Maximum linear velocity} = \omega^{*}A$$

**Tube and processing conditions:**

Seventy-five 2 mL tubes pre-filled with 2.8 mm ceramic bead media (part number 19-628) were filled with 1 mL of DI water, 56 of those 2 mL tubes, containing 1 mL water, were left to sit at room temperature with ample time to reach ambient temperature. The other 19 tubes were refrigerated overnight in a 4-8 °C refrigerator to evaluate the effects of cold buffers with the Cryo Cooling Unit. A calibrated digital thermometer was utilized to record internal tube temperatures, ambient room air, and internal chamber temperatures on the Omni Bead Ruptor Elite and Competitor B's homogenizer. All data was recorded in a spreadsheet and visualized in the figures below.

Table 1: Sample homogenization summary

| Condition name | Temperature | Speed (m/s) | Time (sec) |
|---|---|---|---|
| Cryo Bead Ruptor Elite + Ambient Buffer + cold processing utilizing liquid nitrogen and medical air | -20 °C | 3.1 | 0, 10, 20, 30, 40, 50, 60 |
| | | 4.0 | 0, 30, 40, 60 |
| | | 5.0 | 0, 30, 60 |
| | | 6.0 | 0, 30, 60 |
| | | 7.1 | 0, 30, 60 |
| | | 8.0 | 0, 30, 60 |
| Cryo Bead Ruptor Elite + Cold Buffer + cold processing utilizing liquid nitrogen and medical air | -20 °C | 3.1 | 0, 30, 40, 60 |
| | | 4.0 | 0, 30, 40, 60 |
| | | 5.0 | 0, 30, 40, 60 |
| | | 6.0 | 0, 30, 40, 60 |
| | | 7.1 | 0, 30, 40, 60 |
| | | 8.0 | 0, 30, 40, 60 |
| Omni Bead Ruptor Elite + RT processing | Ambient | 3.1 | 0, 10, 20, 30, 40, 50, 60 |
| Competitor Bead mill + cold processing | -10 °C | 3.1 | 0, 40, 50, 60 |
| Competitor Bead mill + room temperature processing | Ambient | 3.1 | 0, 10, 20, 30, 40, 50, 60 |

## Results

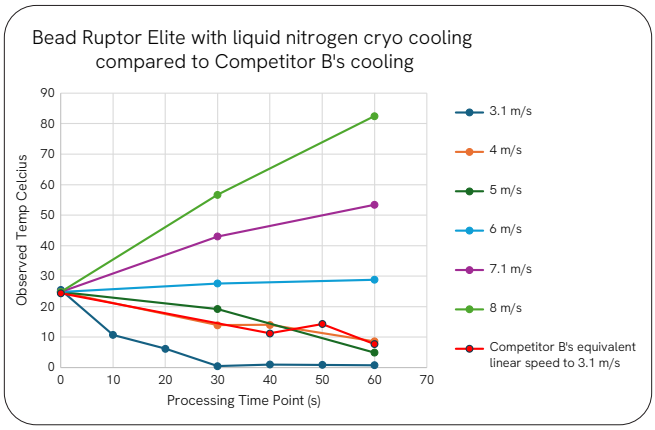



Figure 1: Internal tube temperatures observed during homogenization with the Omni Bead Ruptor Elite utilizing liquid nitrogen in the Cryo Cooling Unit featuring multiple speed settings compared to Competitor B's cooling unit with speed set to equivalent linear speed of 3.1 m/s on the Omni Bead Ruptor Elite.

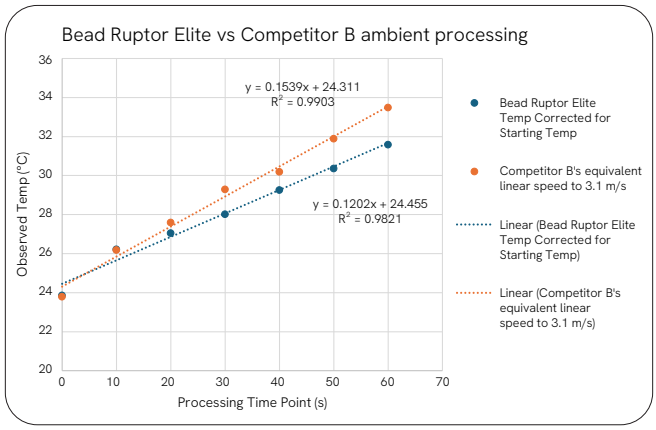



Figure 2: Internal tube temperatures of Competitor B's unit compared to the Omni Bead Ruptor Elite utilizing ambient processing conditions across time.

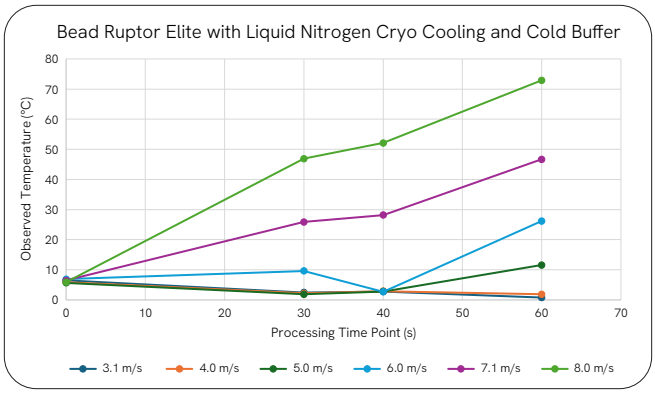



Figure 3: Internal tube temperatures utilizing the Omni Bead Ruptor Elite, liquid nitrogen cryo cooling, and cold buffers across time points with multiple speed settings.

During ambient processing, we corrected the temperatures of the Omni Bead Ruptor Elite to have an equivalent starting temperature as Competitor B, making comparison of sample temperature increase easier. Both systems were processed at equivalent linear speeds of 3.1 m/s. Competitor B's system operating at room temperature showed a steady temperature increase of 9.7 °C over 60 seconds, while the Omni Bead Ruptor Elite under the same conditions rose by 7.7 °C.

When Competitor B was used with cooling activated and set to the lowest possible temperature (unit cooled to -10 °C), temperatures decreased overall during homogenization reaching a minimum temperature of 7.7 °C after 60 seconds.

Using 3.1 m/s as an initial starting point, 2 mL tubes with ambient buffer processed on the Bead Ruptor Elite equipped with the Cryo Cooling Unit resulted in temperatures dropping to 10.7 °C in 10 seconds and continued to decrease in temperature to 0.8 °C in 60 seconds. End point temperatures of each processing run generally rose as the velocity of the tube carriage increased. Homogenization using 3.1, 4, and 5 m/s on the Omni Bead Ruptor Elite equipped with the Cryo Cooling Unit all resulted in a reduction in internal tube temperatures, each with terminal temperatures of 10 °C or less at the 60 second timepoint. For all speeds exceeding 5 m/s, temperatures rose over the homogenization run. For 6, 7, and 8 m/s, terminal end point temperatures were 28.4, 53.4, and 82.5 °C respectively.

When evaluating the effects of prechilled homogenization buffers, a similar effect is seen. Homogenization runs at 3.1 and 4 m/s each create internal tube temps at any time point lower than the starting temperature of the homogenization run. Both 5 and 6 m/s display temperatures of 10 °C or less at the 30 second time point but eventually rise to higher temperatures with prolonged processing runs. 7 and 8 m/s show rapid increases in temperature with each of their end point temperatures being 46.7 and 72.9 °C respectively.

## Conclusions

The Omni Bead Ruptor Elite with the Cryo Cooling Unit directly addresses one of the most persistent challenges of bead mill homogenization by rapidly reducing the internal tube temperatures during homogenization. This is facilitated directly by providing liquid nitrogen-cooled air continuously circulating through the homogenization chamber. This allows for a user to utilize the Cryo Cooling Unit to homogenize samples at elevated speeds with the benefit of a cold environment that is ideal for heat sensitive or unstable analytes. This cooling approach provides more consistent and efficient temperature control across a wider range of processing speeds compared to Competitor B's refrigeration system, which at comparable linear speeds, is slower to cool the internal temperatures of the homogenization tube.

Some homogenization devices, like Competitor B, may utilize inaccurate speeds or reported RPM measurements for their homogenization parameters. This could lead to protocols that are incompatible between units as well as inaccurate information when customers are trying to homogenize samples that require higher speeds.

Tough, dense, or elastic samples require high speed settings to fully homogenize and lyse cellular matrices. Often 5 m/s will support this requirement with tissue samples that are less than 100 mg. While using the Cryo Cooling Unit on the Omni Bead Ruptor Elite, it is possible to create an environment that can result in those tough tissues being effectively homogenized while also keeping the sample within refrigerated temperatures.

This study's thermal performance assessment shows the limitations of Competitor B's approach to cooling. At equivalent linear speeds of 3.1 m/s, the Omni Bead Ruptor Elite demonstrated lower heat generation than Competitor B, a 7 °C difference that could translate to preservation of heat-sensitive analytes. The thermal advantage of the Cryo Cooling Unit's system persists across a wider range of processing speeds, maintaining sub-10 °C temperatures up to 5 m/s with ambient buffers and extending to 6 m/s using pre-chilled buffers. Competitor B's system cannot match the performance shown in this study, as its cooling capacity is insufficient in managing heat generation produced during high-speed bead beating.

For laboratories where both sample integrity and processing efficiency are critical, the Bead Ruptor Elite with Cryo Cooling Unit supports a comprehensive solution. The combination of active cooling, accurate speed reporting, and a broad range of processing speeds help laboratories process difficult sample matrices while maintaining a cooled environment needed to preserve heat-sensitive analytes. The Omni Bead Ruptor Elite combined with the Cryo Cooling Unit is an effective platform for reliable homogenization of heat sensitive samples that are intended for downstream applications like RT-PCR, RNA sequencing, and protein analysis.

## References


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