

DEVELOPING STATISTICAL MODELS TO PREDICT THE POTENCY OF STRESSED INSULINS

Background

Insulin is an essential medication for diabetes management, yet its stability and biological activity can be compromised by real-world conditions such as elevated temperatures or physical stress (e.g., shaking). This study quantifies insulin aspart stability and biological activity under recommended and non-recommended storage conditions using in-cell Western (ICW) assays and three Bayesian models of increasing complexity.

Methods

Baseline model

Observed insulin receptor activation was modeled as a function of background signal, insulin potency and cell count:

$$\log X_i \sim \mathcal{N}(\log(\varepsilon + \rho_{c(i)} N_i), \sigma^2),$$

where $\rho_{c(i)}$ captures the relative insulin potency for each temperature-duration condition.

- ✓ Fully flexible, serves as a reference model.
- ✗ Cannot predict unobserved temperatures or durations.

Degradation model

Insulin degradation is assumed to follow exponential decay:

$$\rho_c = e^{-\kappa_{t(c)} d(c)},$$

where ρ_c is the potency after exposure to temperature t for d days,

and κ_t is the temperature-specific degradation rate.

- ✓ Enables prediction to unobserved durations.
- ✗ Cannot extrapolate to new temperatures.

Full model

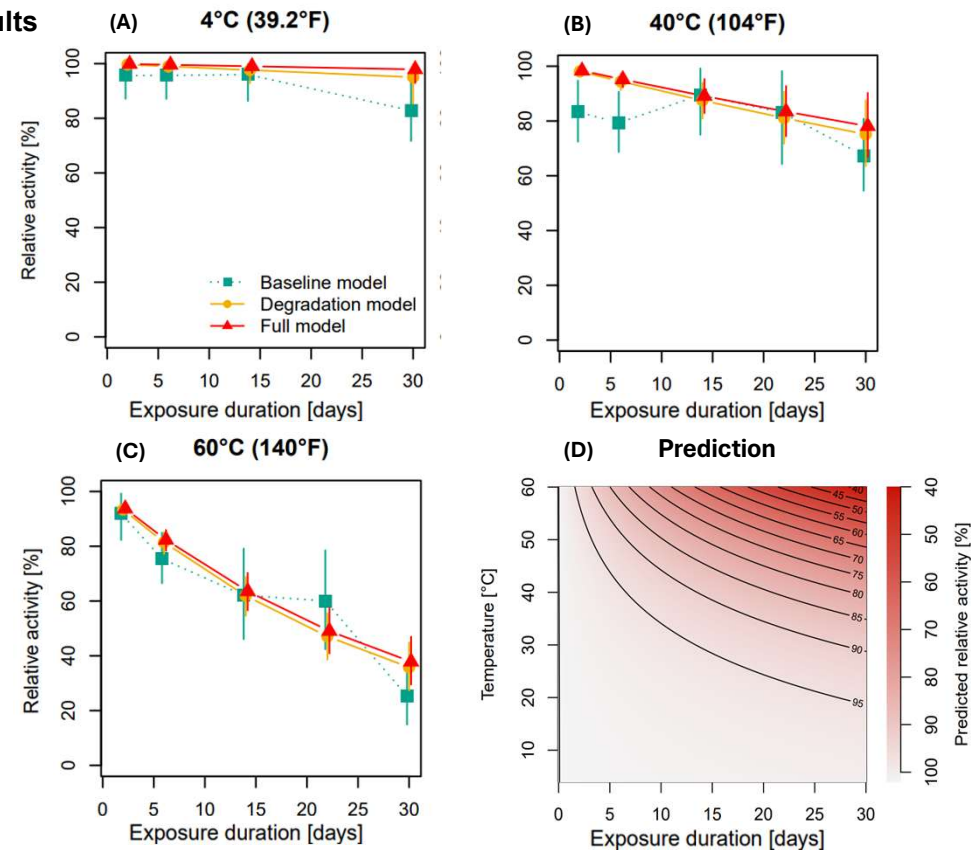
Degradation rates are modeled using a log-linear (Arrhenius-like²) model

$$\log \kappa_t = \alpha + \beta T_t,$$

with intercept α and slope β .

- ✓ Enables prediction to unobserved durations and temperatures (within experimental range).

Results



(A-C) Insulin aspart's relative activity at 4°C (39.2°F), 40°C (104°F), and 60°C (140°F) across different exposure durations.

Shown are median estimates and 95% posterior intervals for the baseline, degradation, and full model.

(D) Predicted mean insulin potency across the full grid of temperatures and durations based on the inferred full model.

Conclusion and Outlook

Functional ICW assays provide a quantitative & biologically meaningful measure to determine the biological activity of insulin under thermal stress. Combining these data within a hierarchical modeling framework enables prediction of insulin activity under real-world scenarios. This approach supports improved insulin stability assessment and contributes to safer, more reliable diabetes therapy. In the future, additional insulins will be evaluated to refine our model.