Comparing the metabolic effects of a moderate heat load to feed restriction in *Bos taurus*

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Background

- An ongoing issue in the agriculture industry, **heat stress** occurs when an organism's total heat load exceeds its capacity for heat dissipation [1] and leads to **reduced feed intake** [2]
- Maintaining optimum livestock health is critical in maximizing agricultural profitability and efficiency
  - It is important to understand metabolic pathways affected by heat stress to counteract its negative effects and thus help maintain cattle weight and growth
- We analysed a case of acute heat stress in Black Angus steers (*Bos taurus*) conducted in three stages (pre-challenge, challenge, recovery) in temperature-controlled climate chambers (Qld Animal Science Precinct, Gatton)
- Two groups: **moderate heat stress** (T_a max 35°C) and **feed restriction** (T_a max 20°C)
  - Feed-restricted group (FR) mimicked feed patterns of the heat stress group (HS) during challenge
- We used data from [1]H NMR spectroscopy to run comparative multivariate OPLS analyses which we used to identify metabolites and, when combined with clinical biochemistry data, infer metabolic pathways affected by both moderate heat stress and feed restriction.

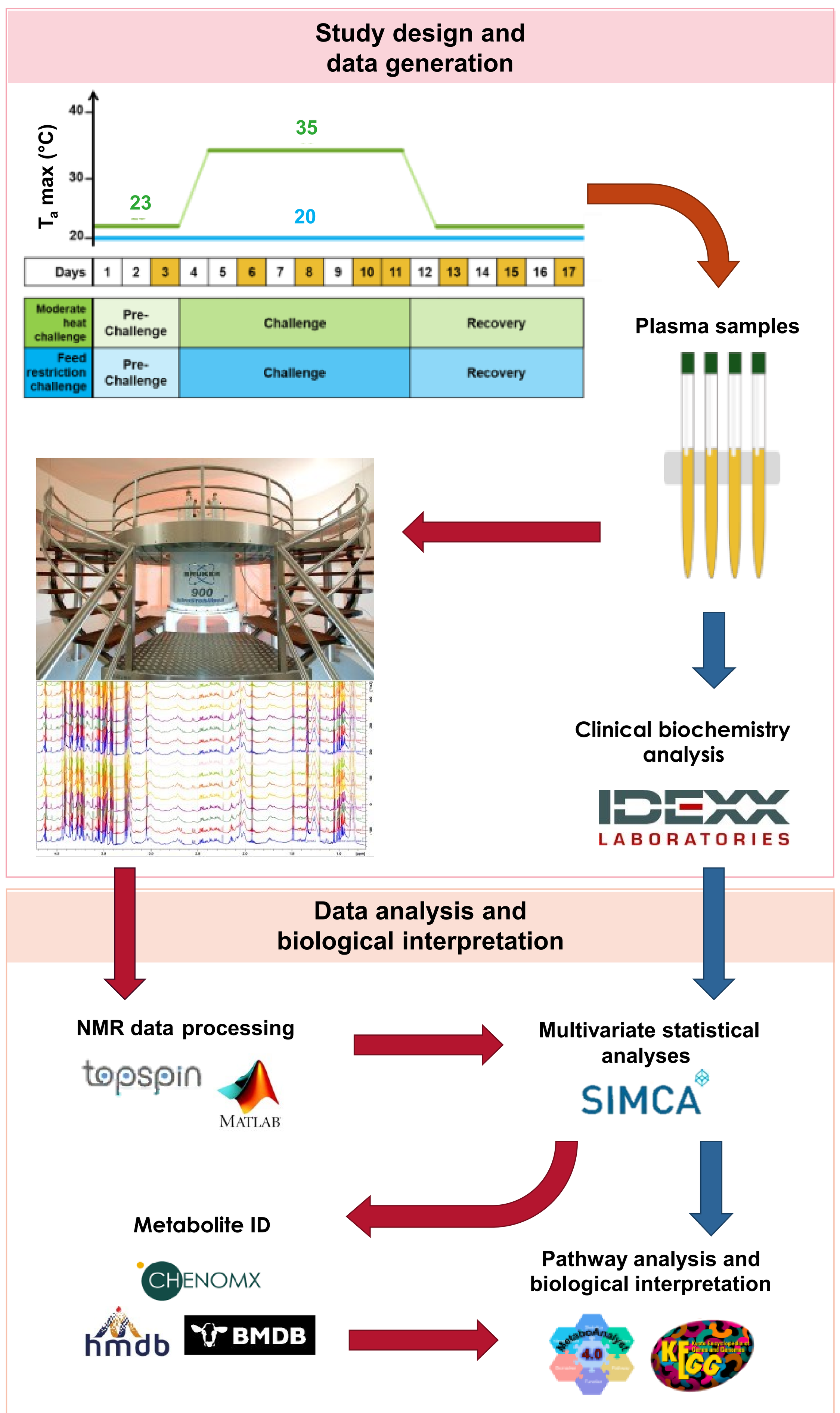

Figure 1: Study pipeline. Plasma samples were collected and analysed by clinical biochemistry (blue arrows) and NMR (red arrows). NMR spectra were acquired on a 900 MHz [1]H-NMR spectrometer, processed in TopSpin, and aligned with the MATLAB program *icoshift* [3]. Processed spectra were data-reduced to consecutive integral regions of equal width (0.001 ppm) prior to multivariate statistical analysis in SIMCA-P+ 12.0 (Umetrics AB, Sweden). Metabolites were identified using a combination of Chenomx NMR Suite (v 8.3), Human Metabolome and Bovine Metabolome databases. This was used in combination with multivariate statistics data from the clinical biochemistry analyses to characterise metabolic pathways with MetaboAnalyst 2.0 [4] and KEGG.

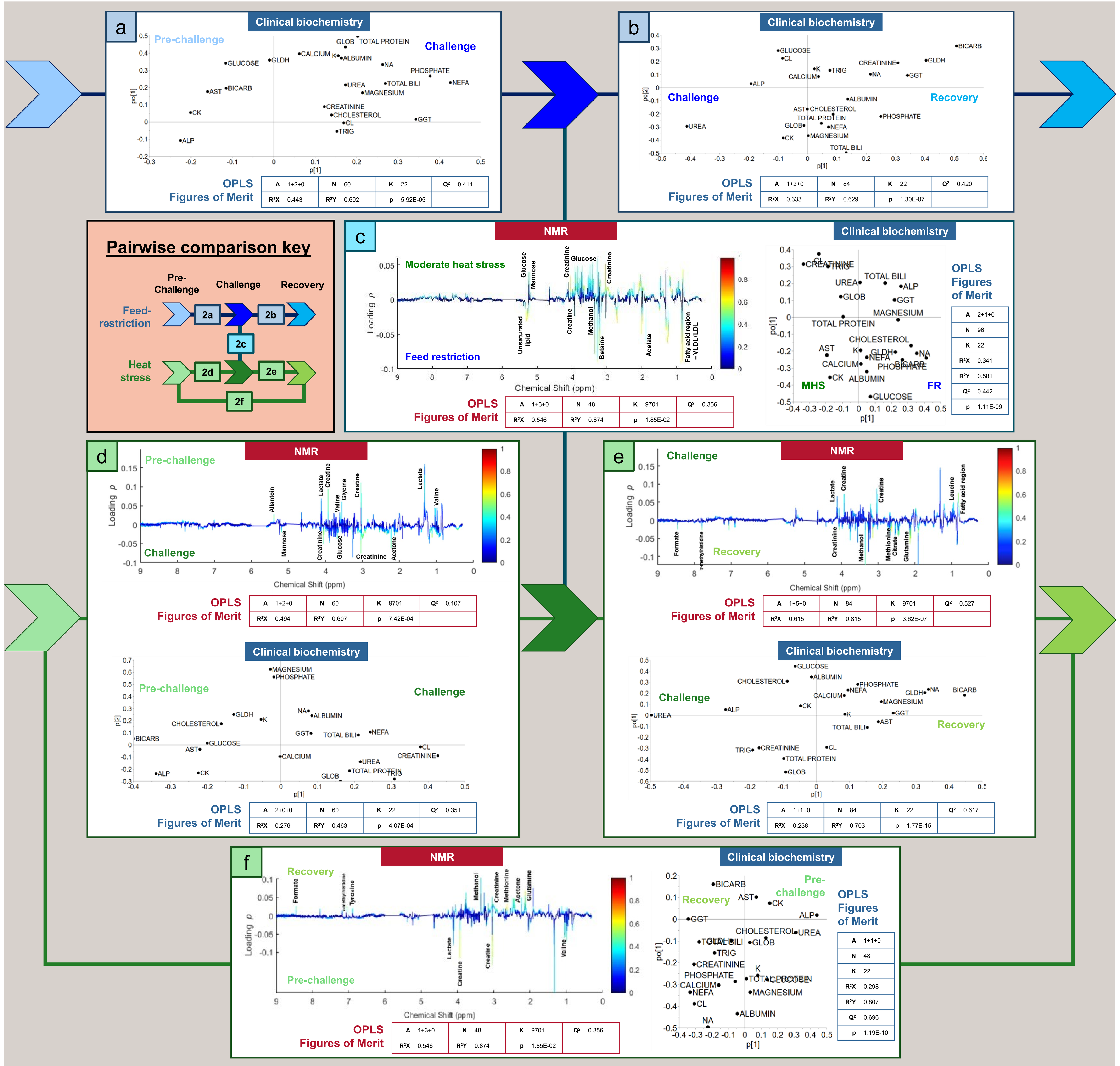

Figure 2: Loadings plots of multivariate OPLS analyses of pairwise comparisons between treatments and stages, per Key (orange box). Coloured 1D plots correspond to NMR data (red) and 2D plots correspond to the clinical biochemistry data (blue). Both plots are also annotated with the figures of merit of the respective OPLS models. The loadings plots show levels of metabolites and clinical biochemistry parameters increasing or decreasing depending on the treatment. (a) OPLS loadings between the pre-challenge and challenge stages of the feed-restricted group, clinical data only; (b) OPLS loadings between the challenge and recovery stages of the feed-restricted group, clinical data only; (c) OPLS loadings between the feed restricted and heat stress groups during challenge; (d) OPLS loadings between the pre-challenge and challenge stages of the heat stress group; (e) OPLS loadings between the challenge and recovery stages of the heat stress group; (f) OPLS loadings between the pre-challenge and recovery stages of the heat stress group.

Results and discussion

- Feed-restricted cattle tend towards negative energy balance (NEBAL), indicated by alterations in carbohydrate and lipid metabolism
- Elevated triglycerides during feed restriction suggests mobilisation from adipose stores to compensate for lower dietary glucose (fig 2a) [5]
- Microbial populations affected by reduced feed intake are stabilised, as indicated by reduced urea during feed restriction recovery (fig 2b) [6]
- Similar responses are seen during heat stress (fig 2d-e) – i.e., cattle in NEBAL
  - When comparing both groups during challenge (fig 2c), fatty acid mobilisation is shown to be unique to feed restriction
  - Differences in glucose sparing mechanisms during both challenges as indicated by increased glucose in heat stress but decreased in feed restriction (NMR), while the animal attempts to reduce endogenous heat
- Cattle recovering from heat stress did not fully return to the pre-challenge state (fig 2f), indicating homeorhetic mechanisms are still occurring; muscle rebuild (creatinine) and rumen function are still returning to pre-challenge levels.

Conclusions and future work

- Cattle experiencing a moderate heat load are in negative energy balance, similar to those experiencing feed restriction
- Glucose-sparing mechanisms differ between both groups as the heat stressed animal attempts to reduce endogenous heat
- Homeorhesis is still occurring during recovery as the heat stressed animal attempts to return to its pre-challenge state
- Though metabolic perturbations occur in cattle experiencing a moderate heat load, the subtleties of change suggest that cattle can be resilient to this level of stress. A higher heat load challenge (i.e., severe heat stress) may produce a more pronounced metabolic response.

References

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