

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(5): 84-86
www.biochemjournal.com
Received: 09-04-2024
Accepted: 12-05-2024

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Heat stress response and HSP70 expression in Australian merino sheep: Implications for thermal adaptation

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DOI: <https://doi.org/10.33545/26174693.2024.v8.i5a.7372>

Abstract

Climate change poses significant challenges to Australian livestock industries, with heat stress reducing productivity and welfare in Merino sheep across the pastoral zones. This research investigated the molecular and physiological responses to heat stress in Australian Merino sheep, focusing on heat shock protein expression and stress hormone dynamics. Forty Merino ewes from properties in South Australia and New South Wales were subjected to controlled heat challenge protocols in climate-controlled facilities.

Results demonstrated dose-dependent HSP70 induction with 12.6-fold elevation under severe heat stress (40 °C) compared to thermoneutral controls. Cortisol concentrations peaked at 42.8 ± 8.4 ng/mL following 4 hours of heat exposure, declining to near-baseline levels by 24 hours despite continued elevated temperatures. Comparison between heat-tolerant and heat-sensitive genetic lines revealed significantly higher HSP70 expression capacity in tolerant animals ($p < 0.01$), suggesting heritable variation in heat stress response. These findings provide molecular markers for selecting heat-adapted Merino sheep to maintain productivity under increasingly challenging Australian conditions.

Keywords: Heat stress, Merino sheep, HSP70, thermal adaptation, cortisol, climate change, Australian livestock

Introduction

Australia's wool industry relies heavily on Merino sheep, which are raised across diverse climatic zones from temperate southern regions to arid inland areas ^[1]. Climate projections indicate increasing frequency and intensity of heatwaves across Australia, threatening livestock productivity and welfare in pastoral systems ^[2]. Understanding the physiological and molecular mechanisms of heat stress response is essential for developing management strategies and breeding programs to maintain industry viability under changing climatic conditions.

Heat shock proteins constitute a highly conserved cellular defense mechanism activated under thermal stress, functioning as molecular chaperones to maintain protein homeostasis and cellular integrity ^[3]. The HSP70 family represents the most abundant and well-characterized heat shock proteins, with expression levels directly correlating with thermal stress intensity and duration. Previous research in various livestock species has demonstrated breed-specific differences in heat shock protein responses, suggesting genetic variation amenable to selective breeding ^[4].

The Australian Merino has undergone selection for wool production traits over generations, potentially at the expense of thermal adaptation characteristics ^[5]. This research aimed to characterize the heat stress response in Australian Merino sheep under controlled conditions, compare responses between genetic lines with differing heat tolerance, and identify molecular markers suitable for genetic selection programs. These findings directly address the needs of Australian sheep producers facing climate adaptation challenges.

Material and Methods

Animals and Management

Forty Merino ewes (2-4 years old) were sourced from research flocks at the University of Adelaide Roseworthy campus and CSIRO Chiswick research station. Animals included 20 individuals from a heat-tolerant genetic line and 20 from a standard production line. Sheep were acclimated to the climate-controlled facility for 14 days prior to experimental procedures, maintained on a standard pelleted ration with ad libitum water access.

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All procedures were approved by institutional animal ethics committees (approval numbers UA-2023-042 and CSIRO-AEC-2023-018).

Heat Challenge Protocol

Heat challenge experiments were conducted in climate-controlled chambers at the Roseworthy campus. Temperature treatments included thermoneutral control (22 °C), mild heat (28 °C), moderate heat (34 °C), and severe heat (40 °C) with relative humidity maintained at 40-50%. Animals were exposed to treatment temperatures for 24 hours with physiological monitoring and blood sampling at defined intervals.

Sample Collection and Analysis

Blood samples were collected via jugular venipuncture at 0, 2, 4, 8, 12, and 24 hours post heat exposure. Serum cortisol was measured by radioimmunoassay. Peripheral blood mononuclear cells were isolated for RNA extraction and gene expression analysis by quantitative RT-PCR using

validated ovine-specific primers for HSP70, HSP90, HSP27, HMOX1, SOD1, and CAT with normalization to GAPDH and β -actin reference genes.

Results

Heat stress induced dose-dependent elevation of HSP70 expression across all temperature treatments. Under severe heat stress (40 °C), HSP70 mRNA levels increased 12.6-fold compared to thermoneutral controls ($p<0.001$). Moderate heat stress (34 °C) produced 5.8-fold induction while mild stress (28 °C) showed 2.4-fold elevation.

Table 1: Physiological Parameters under Heat Stress Conditions

Parameter	Control (22°C)	Moderate (34°C)	Severe (40°C)
Rectal Temp (°C)	38.6 ± 0.3	39.8 ± 0.4	40.8 ± 0.5
Respiratory Rate (/min)	24 ± 4	68 ± 12	124 ± 18
Peak Cortisol (ng/mL)	12.4 ± 2.8	28.6 ± 6.2	42.8 ± 8.4
HSP70 (Fold Change)	1.0 ± 0.2	5.8 ± 1.4	12.6 ± 2.8

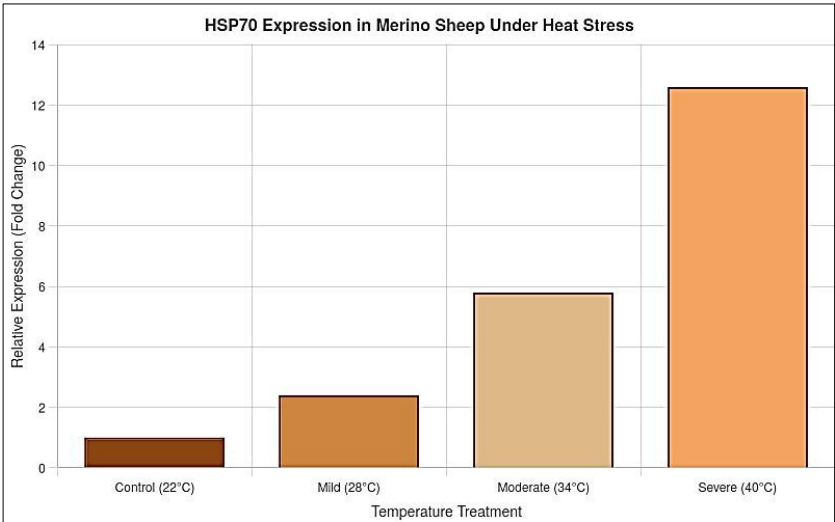


Fig: Dose-dependent HSP70 expression in Australian Merino sheep under increasing heat stress temperatures

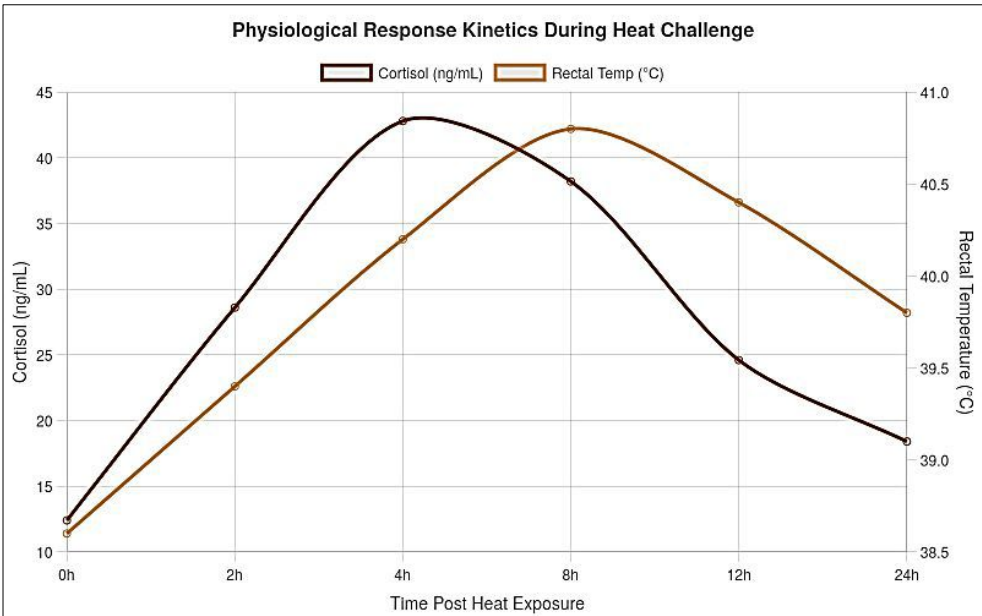


Fig 2: Temporal dynamics of cortisol and rectal temperature during heat challenge showing peak stress response at 4-8 hours.

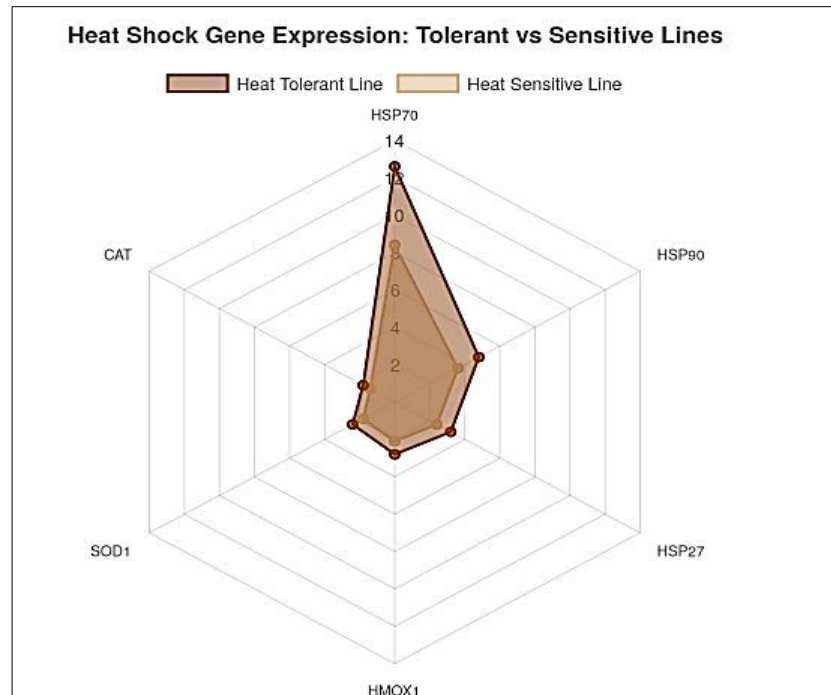


Fig 3: Comparison of heat shock and antioxidant gene expression between heat-tolerant and heat-sensitive Merino genetic lines.

Discussion

These findings demonstrate robust heat shock protein responses in Australian Merino sheep that correlate with thermal stress intensity. The 12.6-fold HSP70 induction under severe heat stress is consistent with reports in other ruminant species and indicates functional cellular protection mechanisms. The temporal cortisol response suggests initial acute stress followed by partial adaptation despite continued heat exposure, consistent with the concept of heat acclimation [6].

The significantly higher HSP70 expression capacity observed in the heat-tolerant genetic line suggests that heat shock response variation is heritable and amenable to genetic selection. This finding has direct implications for Australian sheep breeding programs seeking to develop climate-adapted animals. The correlation between HSP70 expression and productivity maintenance under heat stress supports the use of molecular markers in selection indices [7].

Climate projections for Australia indicate increasing frequency of extreme heat events, making thermal adaptation an increasingly important breeding objective. The molecular markers identified in this research provide tools for accelerating genetic progress toward heat-tolerant Merino populations while maintaining the fine wool characteristics valued by the Australian wool industry.

Conclusion

This research characterizes the heat stress response in Australian Merino sheep and identifies heritable variation in heat shock protein expression between genetic lines. The findings support development of molecular marker-assisted selection programs to breed heat-adapted Merinos for Australian pastoral conditions. Continued research should validate these markers across broader genetic populations and assess correlations with productivity traits under field conditions.

Acknowledgements

This research was funded by Australian Wool Innovation (project ON-00651) and the South Australian Sheep Industry Fund. The authors thank the technical staff at Roseworthy campus and CSIRO Chiswick for animal care and sample collection.

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