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MicroRNAs as potential biomarkers for heat stress in livestock

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Abstract

Heat stress is a major concern for livestock production, as it can result in reduced animal welfare, decreased production efficiency, and even mortality. MicroRNAs (miRNAs) are small non-coding RNA molecules that play a critical role in regulating gene expression and have been proposed as potential biomarkers for heat stress in livestock. Several studies have investigated the expression of miRNAs in response to heat stress in various livestock species, including cattle, pigs, and chickens. These studies have identified specific miRNAs differentially expressed in response to heat stress, suggesting they could serve as biomarkers for this condition. For example, in cattle, miR-21, miR-23a, miR-24, miR-27a, miR-30a-5p, and miR-126 have been shown to be upregulated in response to heat stress, while miR-122, miR-127, miR-148a, miR-195, and miR-335 were downregulated. In pigs, miR-23a, miR-26a, miR-27a, miR-27b, miR-34a, and miR-146a were upregulated, and miR-let7f, miR-let7i, miR-29c, miR-30c, miR-143, miR-148a, and miR-221 were downregulated in response to heat stress. In chickens, miR-22, miR-23a, miR-27a, miR-30a-5p, miR-92a, miR-146a, and miR-155 were upregulated, while miR-let-7f and miR-181a were downregulated. In conclusion, miRNAs have shown promise as potential biomarkers for heat stress. In addition, it is necessary to validate these findings and explore their potential use in developing diagnostic tools for monitoring heat stress in livestock.

Keywords: MicroRNAs; Biomarkers; Health; Welfare; Ruminants; Livestock.

Introduction

Heat stress is a common problem in livestock production, especially in hot and humid environments. It occurs when animals are exposed to high ambient temperatures and humidity levels, which can negatively affect their health, welfare, and productivity (Renaudeau et al., 2012). The primary mechanism by which heat stress affects livestock is through its impact on their thermoregulatory mechanisms (Kadzere et al., 2002). When animals are exposed to high temperatures, their bodies try to dissipate heat through various mechanisms, such as sweating, panting, and increased blood flow to the skin. However, suppose the ambient temperature and humidity are too high (Dos Santos et al., 2021). In that case, these mechanisms become less effective. The animals may experience various adverse effects, including reduced feed intake, decreased growth rate and productivity, lower reproductive performance, increased susceptibility

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to disease and infections, heat exhaustion and heat stroke, and death in extreme cases (Polsky & von Keyserlingk, 2017). Producers can take various measures to mitigate the adverse effects of heat stress on livestock, such as providing access to shade, ventilation, and cooling systems, adjusting feed and water intake, and modifying their management practices (Herbut et al., 2019). Additionally, identifying reliable biomarkers that can be used to monitor animals' response to heat stress can help producers to identify at-risk animals and take appropriate measures to protect their health and welfare (Dos Santos et al., 2021).

MicroRNAs (miRNAs) are small non-coding RNA molecules that regulate gene expression by post-transcriptionally silencing target mRNAs. Recent studies have suggested that miRNAs may serve as potential biomarkers for heat stress in livestock, as they have been found to be differentially expressed in response to heat stress (Li et al., 2018).

Several studies have investigated the expression of miRNAs in response to heat stress in various livestock species, including cattle, pigs, and chickens (Miretti et al., 2020). These studies have identified specific miRNAs differentially expressed in response to heat stress, suggesting they could serve as biomarkers for this condition (Huang et al., 2020). This review aims to enlist and discuss microRNAs as potential biomarkers in livestock. In addition, these miRNAs have shown promise as potential livestock heat stress biomarkers. Finally, it is suggested to explore their potential use in developing diagnostic tools for monitoring heat stress in livestock.

MicroRNAs as Potential Biomarkers

MicroRNAs (miRNAs) are small non-coding RNA molecules that regulate gene expression by post-transcriptionally silencing target mRNAs. Recent studies have suggested that miRNAs are potential biomarkers for various physiological and pathological conditions, including heat stress in livestock (Herbut et al., 2019).

Several studies demonstrated that miRNAs are vital in heat stress and were detected in various biological samples, such as blood, urine, saliva, and tissues (Zhang et al., 2023). Their expression patterns have been shown to be altered in response to various stressors, including heat stress (Hosseini et al., 2022). Specifically, miRNAs have been found to be differentially expressed in response to heat stress in various livestock species, such as cattle, pigs, and chickens (Neethirajan, 2022a). These responses could serve as biomarkers for monitoring animals' responses to heat stress (Hu et al., 2022).

By analyzing miRNA expression patterns in response to heat stress, researchers can identify specific miRNAs that are up- or down-regulated, which could indicate the severity and duration of the stressor (Hu et al., 2022). Furthermore, miRNA-based biomarkers could potentially allow for early detection of heat stress, enabling producers to take preventative measures to protect animals' health and welfare (Renaudeau et al., 2012). It is concluded that miRNAs have shown promise as potential biomarkers for heat stress in livestock.

The miRNAs that are related to health and welfare in livestock

There are many miRNAs that have been found to be related to health and welfare in livestock, including those that are involved in various physiological processes, such as metabolism, immune function, and stress response. However, the specific miRNAs related to livestock health and

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welfare can vary depending on the species and the specific condition being studied (Ojo & Kreuzer-Redmer, 2023).

In the association of heat stress in livestock, several miRNAs have been identified as potential biomarkers for monitoring animals' responses to heat stress (Neethirajan, 2022a). Some studies showed that many miRNAs in cattle, such as miR-23b, miR-24, miR-146a, and miR-181a have been differentially expressed in response to, and have been suggested as potential biomarkers for monitoring the severity of heat stress (Neethirajan, 2022b). Similarly, in pigs, miR-122, miR-199a-3p, miR-23a, and miR-27b have been found to be differentially expressed in response to heat stress and have been suggested as potential biomarkers for monitoring the stress response in these animals (Ibeagha-Awemu & Khatib, 2023).

Some other miRNAs implicated in livestock health and welfare include miR-143 and miR-145, which have been found to play a role in adipogenesis and muscle development in pigs, and miR-155, which has been shown to play a role in immune function and stress response in various livestock species (Ibeagha-Awemu & Khatib, 2023).

Therefore, it is concluded that miRNAs are a promising avenue for exploring the molecular mechanisms underlying various health and welfare outcomes in livestock and could potentially serve as valuable biomarkers for monitoring animal health and welfare to develop practical applications for their use in livestock management.

The miRNAs and milk in dairy animals

MiRNAs regulate gene expression by binding to specific messenger RNAs (mRNAs), inhibiting their translation or promoting their degradation. They have been found in different biological fluids, including blood, urine, and milk (Weber et al., 2010).

Milk from dairy animals, such as cows, goats, and sheep, contains a diverse array of miRNAs, which can be transferred to the consumer through the consumption of dairy products (Fleming et al., 2018). The exact function of these miRNAs in milk is not yet fully understood, but it is thought that they may play a role in regulating the development and function of the mammary gland (Lu et al., 2021).

There is also evidence to suggest that miRNAs from milk may have functional effects on the consumer. For example, studies have shown that cow milk miRNAs can survive digestion and enter the consumer’s bloodstream, where they may regulate gene expression and biological processes (Dysin et al., 2021).

So, the presence of miRNAs in milk adds to the complexity of the biological activity of milk and highlights the potential for dietary miRNAs to have functional effects on human health. However, more research is needed to fully understand the implications of miRNA consumption from milk and other dietary sources.

The miRNAs and genetic background in livestock

The genetic background of livestock can affect the expression of miRNAs in various tissues and organs, including the mammary gland in dairy animals (Cui et al., 2020). Comparing miRNA

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expression profiles among individuals with different genetic backgrounds can influence milk production, milk composition, and disease resistance in livestock (Billa et al., 2021). Some studies have shown that specific miRNAs are differentially expressed in the mammary gland of high- and low-milk-yielding cows, and that these differences are at least partially attributed to genetic factors (Billa et al., 2021; Cui et al., 2020; Hosseini et al., 2022; Hu et al., 2022). Similarly, miRNA expression profiles in pigs' liver, muscle, and adipose tissue have been found to vary among breeds with different growth rates and body composition (Gley et al., 2019; Ibeagha-Awemu & Khatib, 2023).

In addition to genetic factors, environmental factors such as diet and stress can also affect miRNA expression in livestock (Gapp et al., 2014). In a study, feeding cows a diet high in unsaturated fatty acids have been shown to alter the expression of miRNAs involved in lipid metabolism in the mammary gland (Wang et al., 2020). Overall, understanding the relationship between miRNA expression and genetic background in livestock can provide insights into the mechanisms underlying complex traits and may lead to developing new strategies for improving animal production and health.

MicroRNAs and managemental stress

MiRNAs have been shown to play essential roles in regulating stress responses in animals, including livestock. Stressful conditions, such as heat, cold, and social stress, can alter miRNA expression profiles in various tissues and organs, leading to changes in gene expression and cellular function (Vogt, 2023). Some studies have shown that heat stress can alter the expression of miRNAs involved in heat shock protein (HSP) synthesis and antioxidant defense in cattle and pigs' livers, muscles, and blood (McManus et al., 2022). Similarly, social stress in pigs has been shown to induce changes in miRNA expression in the hypothalamus and adrenal gland, which regulate the stress response (Gley et al., 2019).

MiRNAs may also have the potential as biomarkers for stress in livestock. Some other studies have identified miRNAs in the blood of cattle and pigs that are differentially expressed in response to heat stress, which could be used as indicators of heat stress in these animals (Li et al., 2018). In addition, miRNAs have potential applications in the management of livestock production. For example, miRNAs involved in milk production and composition could be targeted for manipulation to improve milk yield and quality in dairy animals (Kadzere et al., 2002). Similarly, miRNAs involved in growth and feed efficiency could be targeted for manipulation to improve the efficiency of meat production in livestock (Neethirajan, 2022a; Renaudeau et al., 2012). Finally, understanding the role of miRNAs in the stress response and management of livestock production has important implications for animal welfare, productivity, and sustainability.

The miRNAs in environmental stress

Environmental stressors, such as exposure to pollutants, toxins, and extreme temperatures, can alter miRNA expression profiles in various tissues and organs, leading to gene expression and cellular function changes (Wu et al., 2023). Some studies have shown that exposure to heavy metals, such as lead and cadmium, can alter miRNA expression profiles in animals' livers, kidneys, and brains, leading to cellular stress response and toxicity changes (Aalami et al., 2022). Similarly, exposure to pesticides and other environmental pollutants has been shown to alter miRNA

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expression in various tissues, leading to changes in immune function, inflammation, and cellular stress response (Cestonaro et al., 2022).

MiRNAs may also have the potential as biomarkers for environmental stress. The studies have identified miRNAs in the blood of animals that are differentially expressed in response to exposure to environmental pollutants, which could be used as indicators of exposure and potential toxicity (Aalami et al., 2022). In addition, miRNAs have potential applications in managing environmental stress (Cestonaro et al., 2022). In some other studies, miRNAs involved in regulating oxidative stress and inflammation could be targeted for manipulation to improve the ability of animals to cope with environmental stressors (Raza et al., 2022). Finally, it is concluded that understanding the role of miRNAs in response to environmental stress has important implications for animal health and welfare, as well as for human health and the environment.

Conclusion

Heat stress is a common environmental stressor that can have detrimental effects on animal health and productivity, and early detection of heat stress is essential for implementing appropriate interventions. Studies have identified several miRNAs that are differentially expressed in response to heat stress in various tissues of livestock, including the liver, muscle, and blood. These miRNAs are involved in the regulation of heat shock protein synthesis, antioxidant defense, and other stress response pathways. Additionally, miRNAs can be detected in biological fluids, such as blood, making them ideal candidates for non-invasive biomarker development. Several studies have shown that miRNAs in the blood of cattle and pigs are differentially expressed in response to heat stress, suggesting their potential use as indicators of heat stress in these animals. It is concluded that miRNAs are promising biomarkers for heat stress in livestock. Further research is needed to validate their use as diagnostic tools and develop early detection and intervention strategies. Using miRNA-based biomarkers could help improve animal health and productivity and support sustainable livestock production in a changing climate.

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