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Reducing Systemic Heat Stress in Livestock through Ayurveda

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Abstract:

Climate change severely impacts the environment by disrupting traditional livelihoods through erratic rainfall, thunder and lightning, rising temperatures, and extreme weather, leading to reduced rice yields, lower animal yields, increased pest issues, water stress, forest fires, and significant economic hardship. Heat stress adversely affects livestock by reducing feed intake, growth rate, production, fertility, and immunity, thereby lowering productivity and increasing economic losses for farmers dependent on livestock production systems. Studies on herbal plants such as olive, wormwood, milk thistle, fennel, thyme, and rosemary have shown potential to alleviate thermal stress in poultry. The article aims to explore cheaper, locally available herbal interventions that farmers can easily adopt to mitigate heat stress in livestock & poultry reeling under the heat stress.

Keywords: Heat stress, Climate change, Herbal plants, Livestock production

Introduction:

Climate-induced heat stress is a major threat to global livestock production, causing severe physiological, metabolic, and oxidative duress in animals. When ambient temperatures exceed the thermoneutral zone, the resulting overproduction of cellular reactive oxygen species (ROS) triggers lipid peroxidation, mitochondrial damage, and systemic inflammation. Visually and physiologically, this leads to broken intestinal barriers (leaky gut), elevated cortisol/corticosterone levels, a distorted heterophil-to-lymphocyte (H/L) ratio and a sharp drop in feed intake and performance. To combat this sustainably, veterinary science is focusing on phytogenic feed additives.

Effect of Herbal Plants on Heat Stress:

Integrating locally available herbal plants such as olive, wormwood, milk thistle, fennel, thyme, and rosemary as natural, sustainable, and economically feasible interventions for thermal stress alleviation.

Although research highlights the antioxidant, immunomodulatory, and thermoregulatory properties of these herbs that were reported in the recent past, their application in livestock remains largely unexplored. Alligator weed, mulberry leaf, curry leaf, water leaf, ginger, black and white turmeric and Indian laurel are beneficial for ameliorating heat stress in poultry. The thermoprotective mechanisms of three prominent botanicals are as follows.

- **Aparajita Flower:** Rich in anthocyanins and flavanols that upregulate endogenous antioxidant enzymes via the Nrf2 pathway.
- **Vetiver Roots:** Packed with dense sesquiterpenes that stabilize cellular membranes and suppress hyper-inflammatory enzymes (iNOS/COX-2).
- **Mint Leaves:** utilize monoterpenes like menthol to stimulate cold-sensing TRPM8 receptors, providing sensory cooling and preserving metabolic homeostasis.

Common Name	Local Name	Scientific name	Parts for use	Medicinal uses
Butterfly Pea	Blue Aparajita	*Clitoria ternatea*	Flower	Anti-stress, Brain tonic
Vetiver	Benachara	*Chrysopogon zizanioides*	Roots Young leaves	Cooling, Perfume
Peppermint	Pudina	*Mentha piperita*	Leaves	Digestive, Cooling

Table 1: Details of herbal plants in reducing heat stress

1. Butterfly Pea/Aparajita flower:

➢ ***Phytochemical Profile:***

- **Anthocyanins:** Driven by highly stable, acylated anthocyanins, predominantly delphinidin glycosides (including unique ternatins), cyanidin-3-glucoside, and malvidin.
- **Flavonols and Phenolic Glycosides:** Rich in quercetin, kaempferol, rutin, and luteolin glycosides, which act as high-efficiency radical scavengers.
- **Pentacyclic Triterpenoids:** Contain taraxerol and taraxerone, alongside variable concentrations of phytosterols, saponins, and alkaloids.

➢ ***Mechanism of Action:***

Delphinidin and quercetin glycosides function as donor antioxidants, directly neutralizing singlet oxygen and lipid peroxyl radicals via electron donation. At the molecular level, these bioactives stimulate the Nrf2 signalling pathway, which upregulates critical endogenous antioxidant enzymes:

- **Superoxide Dismutase (SOD):** Accelerates the dismutation of toxic superoxide radicals (O2) into hydrogen peroxide (H_2O_2).
- **Catalase (CAT) and Glutathione Peroxidase (GSH-Px):** Convert H_2O_2 into inert water, preventing the formation of highly destructive hydroxyl radicals (O) via the Fenton reaction. This cascade markedly reduces malondialdehyde (MDA) accumulation, suppressing lipid peroxidation across

cellular and mitochondrial membranes. Furthermore, taraxerol and flavonols suppress the activation of **NF-κB** by inhibiting the phosphorylation of its inhibitory subunit. This blocks the downstream transcription and systemic release of primary pro-inflammatory cytokines: TNF-alpha, IL-1beta, and IL-6, while restricting secondary enzymes (COX-2 and iNOS).

By reducing HPA axis hyper-reactivity, the butterfly pea flower lowers circulating glucocorticoids (cortisol/corticosterone) and stabilizes the H/L ratio, preserving cell-mediated immunity. Polyphenols and flavonoids quench localized ischemia-induced ROS within the enterocytes, maintaining tight-junction proteins (claudin, occludin) to prevent "leaky gut" and restrict pathogens like *Salmonella enterica*. It stabilizes the hypothalamic thermoregulatory centre, preventing extreme spikes in respiratory rate and panting-induced respiratory alkalosis.

2. Vetiver Grass:

- ***Phytochemical Profile:***

- **Oxygenated Sesquiterpenes**: Dominated by tricyclic and bicyclic sesquiterpenes, most notably khusimol, vetivone (alpha- and beta-vetivone), vetivenic acid, zizanal, and episolizanol.
- **Phenolic Acids and Flavonoids:** Include high baseline concentrations of ferulic, caffeic, vanillic, and chlorogenic acids.
- **Phytosterols and Triterpenoids:** Contain structurally diverse sterols, including beta-sitosterol, which stabilize cellular membranes.

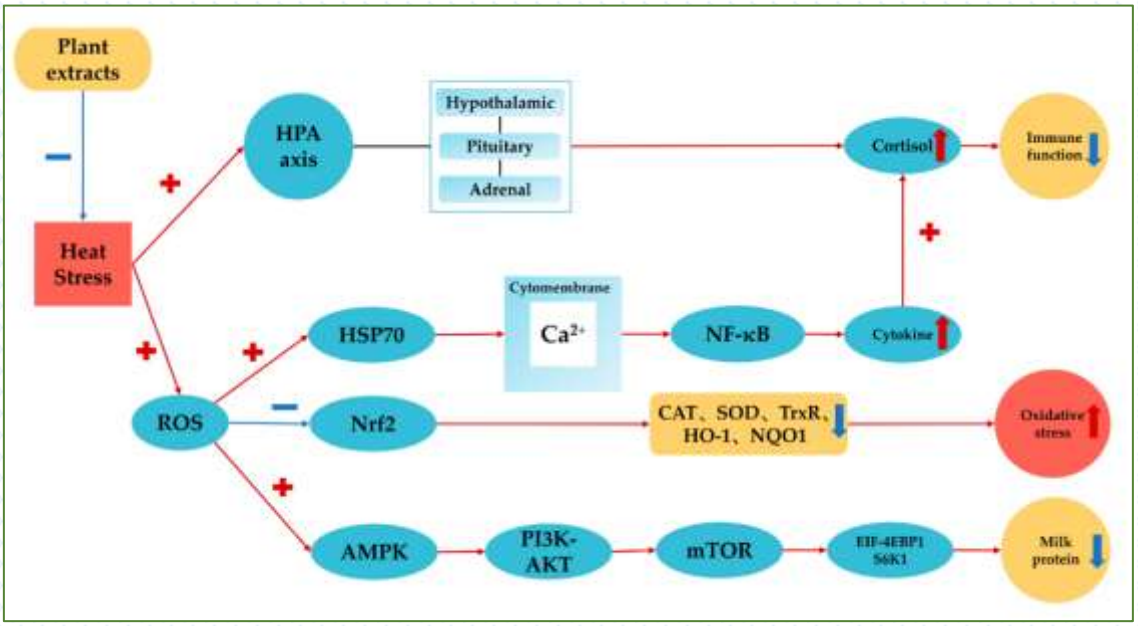


Figure 1. Mechanism of action of plant extracts in alleviating heat stress

- ***Mechanism of Action:***

Due to their high lipid solubility, oxygenated sesquiterpenes integrate smoothly into the phospholipid bilayer of cellular and mitochondrial membranes, neutralizing lipid peroxyl radicals directly within the hydrophobic core. Concurrently, vetiver extracts stimulate HO-1 (Heme Oxygenase-1) expression and

preserve endogenous reduced glutathione (GSH). At the cellular level, major sesquiterpene fractions downregulate the gene expression of iNOS and COX-2, and this double blockade effectively curtails hyperthermic tissue oedema, inflammatory cell infiltration, and systemic acute-phase protein response. Components like khusimol act as natural GABAergic modulators, interacting with central nervous system pathways to induce an anxiolytic, calming effect. By dampening hyper-excitation in the hypothalamic thermoregulatory centre, vetiver prevents uncoordinated shifts in breathing frequency (hyperventilation/panting) that induce respiratory alkalosis and subsequent renal mineral flushing.

Vetiver's complex flavour and bitter, cooling principles stimulate central orexigenic (appetite-stimulating) centres, encouraging normal dry matter intake (DMI) under thermal stress. This protects the hepatic parenchyma and renal tubules from heat-induced hypoxia, preserving baseline metabolic clearance and energetic homeostasis.

Lipophilic sesquiterpenes reinforce the mucosal barrier of the gastrointestinal tract, maintaining the mechanical assembly of tight-junction proteins. This prevents the transmigration of luminal lipopolysaccharides (LPS) into portal blood flow, protecting the animal from hidden endotoxemia.

3. Mint Leaves:

- ***Phytochemical Profile:***

- **Monoterpenes and Terpenoids:** Dominated by cyclic monoterpenes, primarily menthol, menthone, isomenthone, 1,8-cineole (eucalyptol), and menthofuran.
- **Phenolic Acids:** Deposits exceptional quantities of rosmarinic acid, alongside chlorogenic, caffeic, and ferulic acids.
- **Flavonoids:** Rich in flavanones and flavones, including menthoside, eriocitrin, luteolin-7-O-glucoside, and rutin.

- ***Mechanism of Action:***

Rosmarinic acid and associated mint flavonoids function as highly effective, hydrogen-donating antioxidants that neutralize hydroxyl and superoxide radicals. At the gene level, these compounds stimulate the Nrf2-ARE pathway, upregulating downstream networks SOD & CAT are the primary defence against mitochondrial electron leakage and singlet oxygen. GR & GST maintain the reduced glutathione pools and xenobiotic detoxification. This comprehensive upregulation keeps MDA accumulation low, preserving mitochondrial structural integrity and maintaining baseline ATP production. Furthermore, menthol suppresses the activation of NF-κB, halting the transcription of TNF-alpha, IL-6, and IL-12, while directly reducing the hyperactivation of COX-2 and iNOS.

Menthol acts as a natural agonist of the TRPM8 ion channel, a specialized cold-sensing receptor located on afferent sensory neurons. When ingested or inhaled, menthol triggers a chemical signal that mimics a cooling sensation without physically lowering environmental temperatures. This sensory

feedback signals the central nervous system to reduce hyperventilation, preventing severe panting and subsequent respiratory alkalosis, while limiting the extreme shunting of blood to the skin to maintain stable visceral perfusion. Menthol's sensory cooling effect, combined with the aromatic properties of mint essential oils, stimulates appetite centres in the brain to maintain baseline feed consumption. In monogastrics and poultry, rosmarinic acid and luteolin reinforce intestinal epithelial tight junctions (occludin, ZO-1), blocking luminal LPS from entering circulation. In ruminants, mint bioactives stabilize volatile fatty acid production, prevent rumen stasis, and lower the H/L ratio.

Conclusion:

Mitigating thermal stress in production animals requires a combination of antioxidant, anti-inflammatory, and neuroendocrine support. These herbal plants act through complementary molecular and physiological pathways. Together, their bioactives safeguard animal welfare and maintain global production performance in a warming climate.

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