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A new way of thinking about soybean meal - its impact on swine respiratory disease and, specifically, PRRSV mortality

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Mechanistic insights into key soy-derived bioactives (isoflavones, saponins): Modulating immunity and improving disease resilience in swine

Swine respiratory disease (SRD) involves complex interactions between host immunity and a range of viral and bacterial pathogens. Nutritional interventions that target immune modulation represent a promising approach to improve resilience. Soybean meal, long used as a protein source in swine diets, also contains bioactive compounds (most notably isoflavones and saponins) that are proven to exert immunomodulatory, anti-inflammatory, and antiviral effects. These compounds offer mechanistic potential for mitigating the pathophysiological impacts of SRD.

Methods

Evidence was synthesized from *in vivo* and *in vitro* studies in swine and model systems to evaluate biological pathways influenced by soy-derived isoflavones and saponins. Emphasis was placed on immunological, molecular, and physiological endpoints relevant to respiratory disease pathogenesis, including cytokine signaling, epithelial barrier integrity, oxidative stress, and adaptive immune cell profiles.

Results

Isoflavones, particularly genistein and daidzein, inhibit NF-κB activation and downstream pro-inflammatory cytokines such as TNF-α and IL-6. These effects are associated with reduced immune-mediated tissue damage and improved systemic resilience during pathogen challenge. Saponins, owing to their amphiphilic structure, influence mucosal immunity and barrier function, potentially reducing pathogen entry and secondary bacterial complications. Both compound classes have demonstrated antioxidant activity and the ability to modulate acute-phase responses and hematological parameters. Although bioavailability varies across soy processing methods, strategic inclusion of soy protein sources or concentrated bioactive fractions can support immune homeostasis during respiratory infection (Table 1 and Figure 1).

Conclusions

Soy-derived isoflavones and saponins exert complementary effects on host immune function through suppression of inflammatory signaling, maintenance of epithelial integrity, and modulation of cellular immune responses. These mechanisms are relevant across diverse SRD pathogens and support the broader use of soy-based functional ingredients as part of an integrated strategy for disease resilience in swine production.

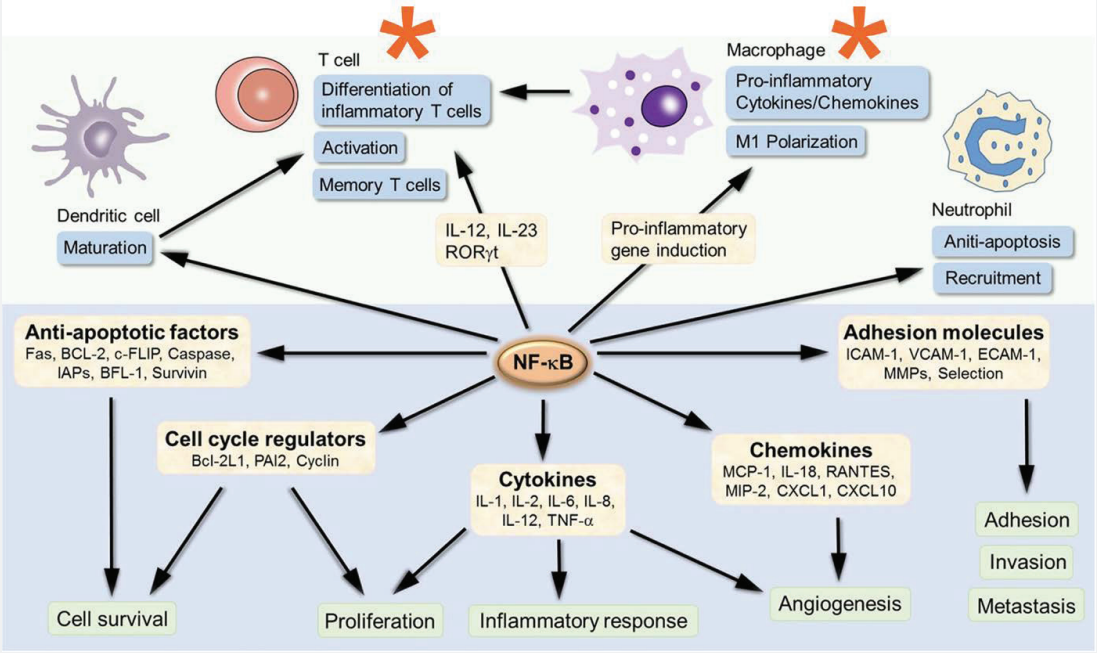
Table 1: Mechanisms of action

Isoflavones	Saponins
Modulate inflammatory signaling	
(NF-KB, cytokines)	Strengthen epithelial barrier and reduce potential for opportunistic secondary pathogens
Antioxidant defense, reduce ROS	Stimulate mucosal IgA responses
Support adaptive immunity (CD4:CD8, neutralizing antibody production)	Modulate inflammatory signaling (NF-KB, cytokines)
Direct antiviral activity (↓ viral load)	Antioxidant defense, reduce ROS
Phytoestrongenic receptor activity	Direct anti-protozoal activity

ROS = reactive oxygen species

Figure 1: Meditating inflammation and immunity isoflavins and saponins.

- Inhibit NF-κB/ STAT-1
- ↓TNF- α, ↓IL-6
- Alter T-cell profiles
- Limit immune-mediated tissue damage
- Multiple avenues for soy bioactives to support immunity associated with respiratory disease



Signal Transduct. Target Ther. 2:17023

Key SBM functional compounds reduced pathogen-related mortality in growing pigs infected with PRRSV: Results and clinical description

This presentation will serve as a review of previously published research[1] evaluating the effects of dietary soy isoflavones (ISF) on the clinical response and wean-to-market growth performance of pigs infected with porcine reproductive and respiratory syndrome virus (PRRSV) during the early post-weaning period.

Methods

Ninety-six weaned barrows were housed in a biosafety level-2 containment facility and allotted to 1 of 3 experimental treatments that were maintained throughout the entirety of the study: noninfected pigs fed an ISF-devoid control diet (NEG, n = 24), infected pigs fed the control diet (POS, n = 36), and infected pigs fed a diet supplemented with total ISF in excess of 1,600 mg/kg (ISF, n = 36). Following a 7-day adaptation period, pigs were inoculated intranasally with either a sham-control, phosphate buffered saline (PBS) or live PRRSV (1×10^5 $TCID_{50}$/mL, strain NADC20). Following inoculation, individual blood samples (n = 8-12/treatment) were routinely collected to monitor viral clearance and hematological parameters, including serum neutralizing anti-PRRSV antibody production. Pen-based oral fluids were utilized to monitor population PRRSV clearance at later growth stages. Comparison of experimental treatments were performed by 1- or 2-way ANOVA depending on whether an outcome was repeatedly measured.

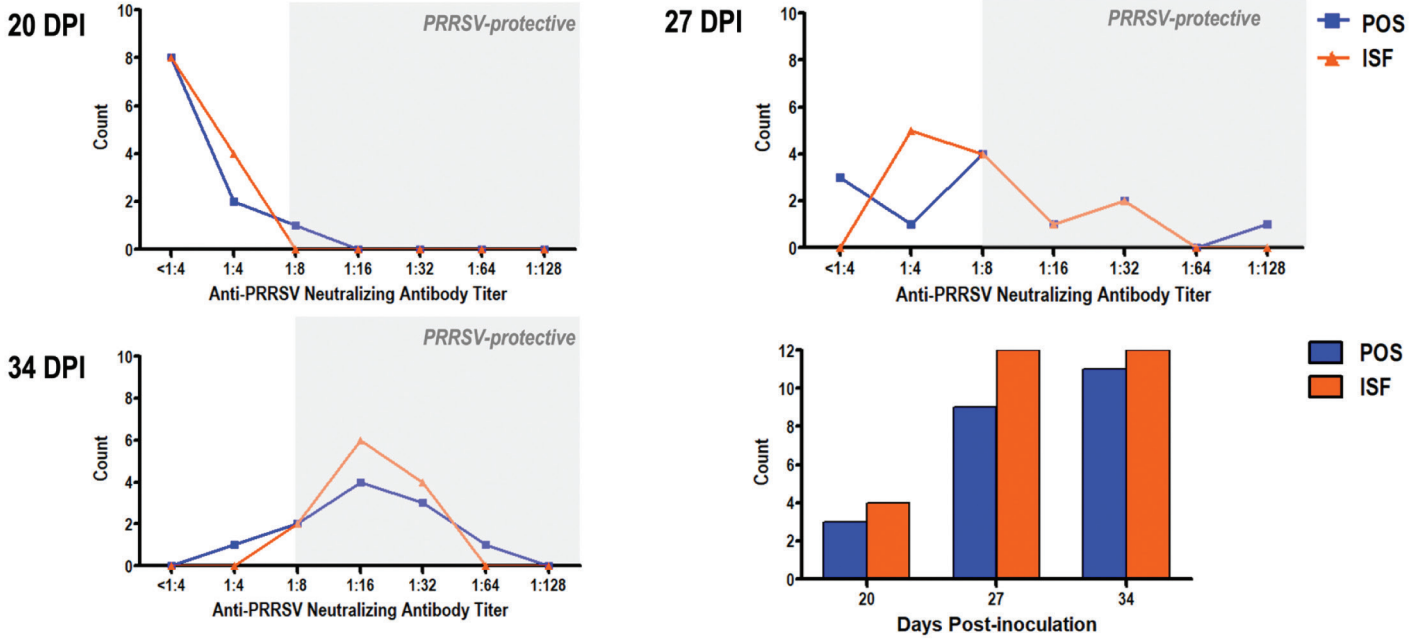
Results

Dietary ISF increased ($P < .05$) neutrophil cell counts and the relative proportion of peripherally circulating memory T-cells. Dietary ISF also elicited an earlier, more robust anti-PRRSV neutralizing antibody response when compared to POS pigs and decreased ($P < .05$) the time to full PRRSV clearance from oral fluids. Regarding regional PRRSV control efforts, this potential to improve viral clearance may be beneficial due to decreased viral shedding. Additionally, and most notably, POS pigs experienced ~50% greater wean-to-market mortality compared to the ISF pigs ($P > .05$). Regarding growth performance, as anticipated, PRRSV infection decreased growth performance during early growth phases which resulted in 5.4% lower average final body weights (BW) for POS vs NEG pigs ($P < .05$), though this difference was not observed at the time of harvest.[2] Dietary ISF resulted in inconsistent effects on growth performance throughout the growth period. Despite variable impacts on growth performance and lack of statistical differences in live body weight between treatments at the time of harvest (potentially due to sample size), when the data were modeled and applied to current packer pricing grids, the lower mortality experienced by the ISF treatment resulted in an approximately 27% increase in projected revenue relative to the POS treatment (Figures 2-4).

Conclusions

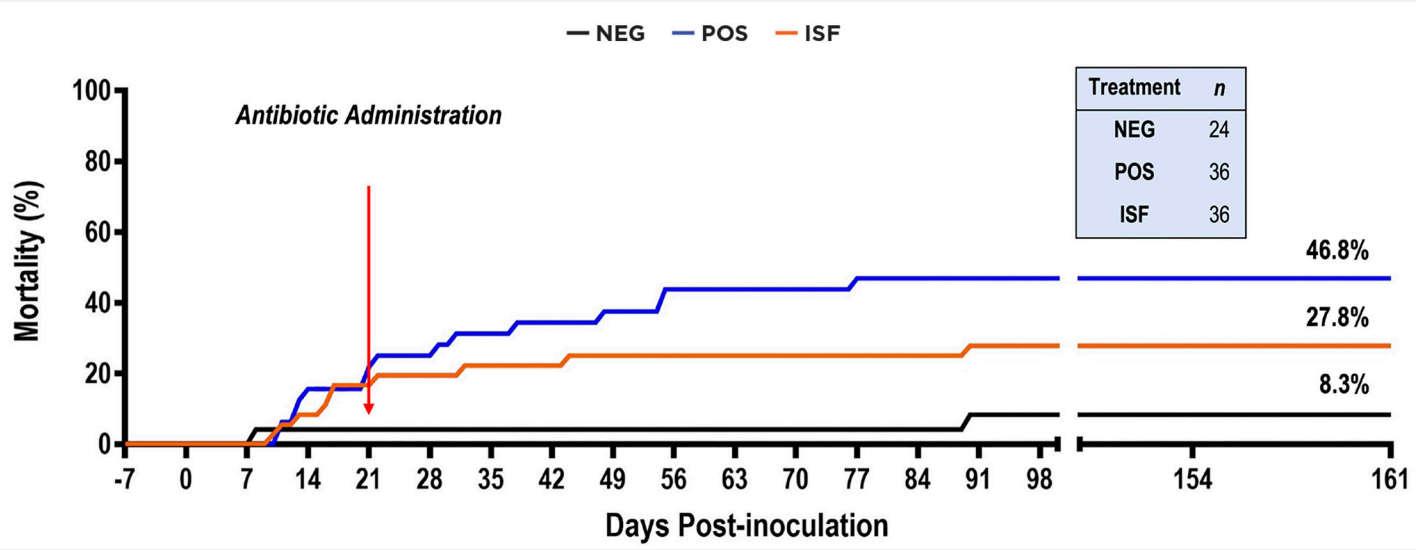
Dietary ISF supported beneficial immune responses and reduced mortality in PRRSV-infected pigs. Decreasing mortality has direct financial implications to producers. While biological mechanism of these effects remains unclear, these findings suggest that further investigation of soy isoflavones or other soy-derived bioactive components and their application under pathogenic challenge is merited.

Figure 2: Results: Viral clearance – neutralizing antibodies.



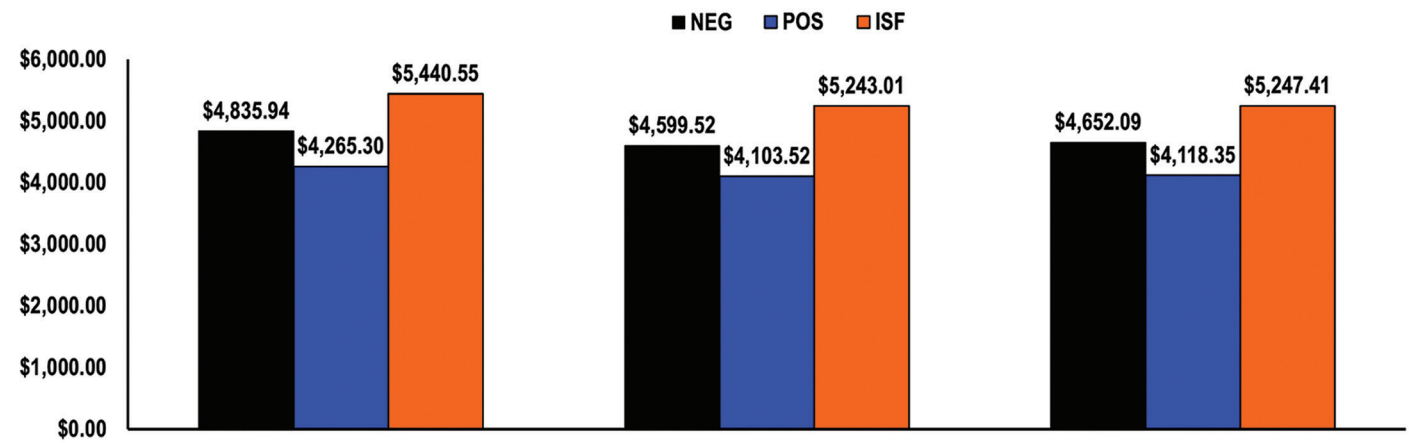
DPI = days post inoculation; PRRS = porcine reproductive and respiratory syndrome; POS = infected pigs fed the control diet; ISF = infected pigs fed a diet supplemented with total isoflaones in excess of 1,600 mg/kg soy isoflavones.

Figure 3: Results: Mortality under PRRSV challenge.



PRRSV = porcine reproductive and respiratory syndrome virus; NEG = noninfected pigs fed an ISF-devoid control diet; POS = infected pigs fed the control diet; ISF = infected pigs fed a diet supplemented with total ISF in excess of 1,600 mg/kg

Figure 4: Results: Projected revenue by packer.



	Tyson			Wholestone			JBS		
	NEG (*n*=22)	POS (*n*=20)	ISF (*n*=26)	NEG (*n*=22)	POS (*n*=20)	ISF (*n*=26)	NEG (*n*=22)	POS (*n*=20)	ISF (*n*=26)
Extreme Lights	18.18%	40.00%	34.62% ↓	18.18%	20.00%	30.77% ↑	13.64%	10.00%	30.77% ↑
Lights	22.73%	35.00%	34.62% ↓	22.73%	50.00%	38.46% ↓	31.28%	65.00%	38.46% ↓
Target	59.09%	25.00%	30.77% ↑	50.00%	25.00%	26.92% ↑	54.55%	25.00%	30.77% ↑
Extreme Heavies	--	--	--	9.09%	5.00%	3.85% ↓	--	--	--

NEG = noninfected pigs fed an ISF-devoid control diet; POS = infected pigs fed the control diet;
ISF = infected pigs fed a diet supplemented with total ISF in excess of 1,600 mg/kg

References

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