The future of animal feed

Sustainability and food safety implications of alternative protein feed sources for pigs

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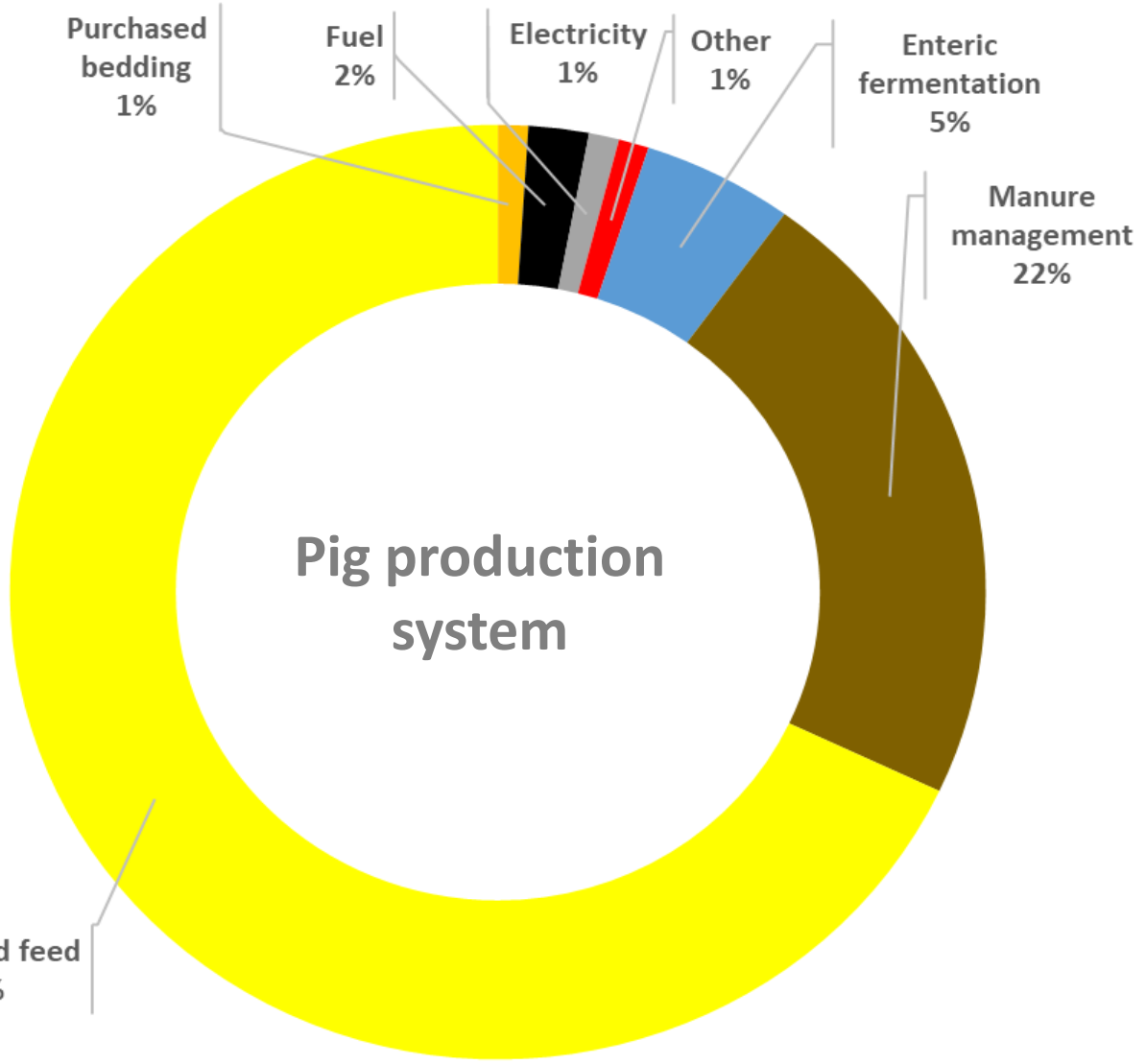
Contributions to overall carbon footprint of a pig farm (kg CO_2eq/kg deadweight)



NET ZERO & LIVESTOCK

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Overview

- Drivers to shift from conventional protein feeds
- Alternative protein sources for livestock feeds: implications to sustainability and food safety
- Engaging key stakeholders to explore commercial implementation of alternatives
- Recommendations for future research
- Key recommendations for policy

Drivers for change

- Pig systems rely on unsustainable protein sources (i.e., imported soy)

- High Feed vs Food vs Energy competition exists for resources

- Conventional protein sources are associated with environmental impacts
- Economic and geo-political uncertainties exist (i.e., energy prices, trading partnerships)

Drivers for change

- **Livestock feed ➔ largest coverage agri land globally (~2 x food production)**
- **Expansion of soy production in global South ➔ land degradation, deforestation, biodiversity decline, GWP, water depletion**
- **Transportation over long distances ➔ emissions, costs, vulnerable supply chains to interruption**
- **Feed & food safety of conventional feeds**
    - **chemical contamination due to production practices (e.g., pesticides)**
    - **biological contamination due to long-term storage and transportation (e.g., mycotoxins)**

Questions Considered

What **alternatives** could help **substitute** conventional, unsustainable protein feed ingredients (e.g., imported soy)?

How **environmentally** friendly, **commercially** viable, **affordable**, and **safe** are they likely to be?

Do they pose any significant risks to **feed & food safety** and **security**?

How can they contribute towards **sustainable development** of the **livestock sector**?

GM/GE protein crops

Soy ➔ MON 87708 × MON 89788

Potato ➔ AmA1 protein

Maize gluten meal ➔ Mon 810

Home-grown protein crops I

Home grown legumes ➔ faba beans, peas, lupins

Home-grown protein crops II

Duckweed

Seaweed (macroalgae) ➔ *Ulva lactuca, Fucus vesiculosus*

Grass/ **Leaf Protein Concentrate**

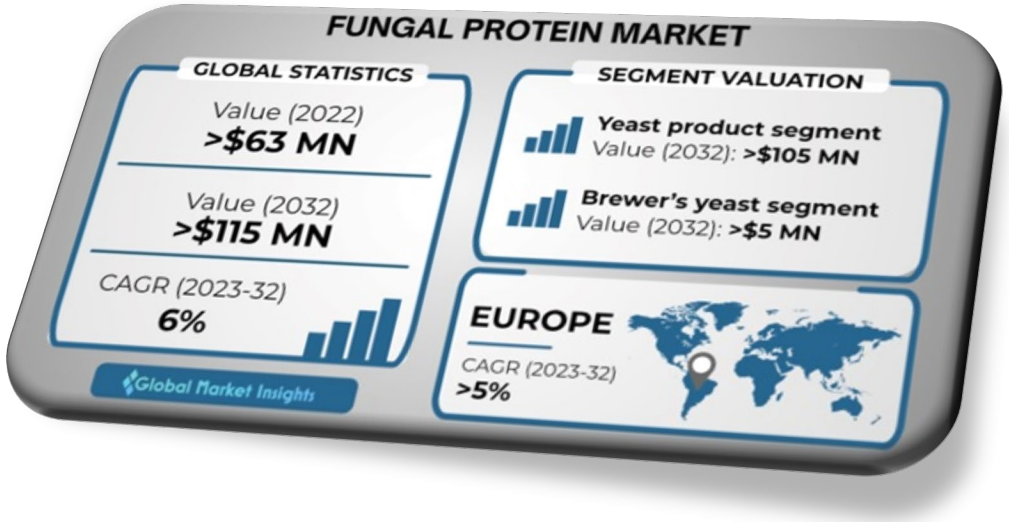
Hydroponic fodder from cereal grain

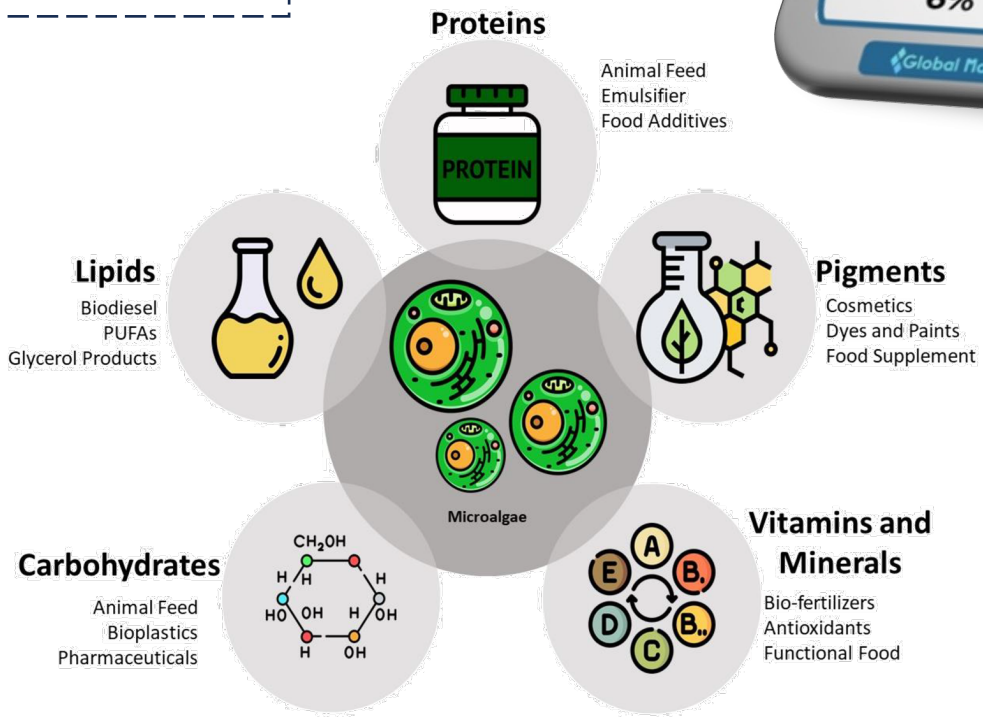
Cellular agriculture for protein feeds

Bacterial protein

Fungal protein

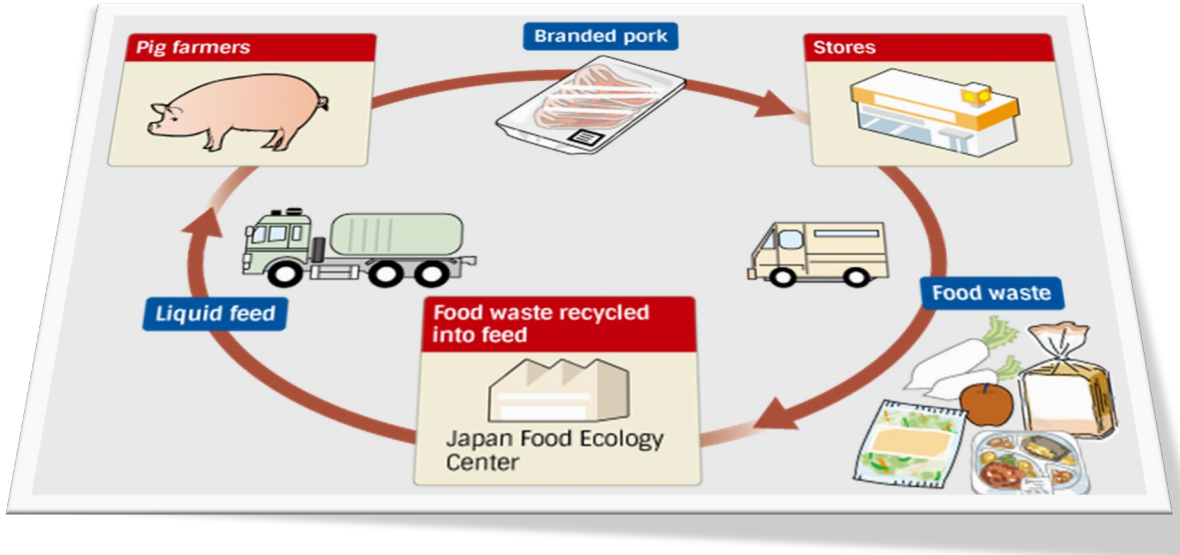
Microalgae

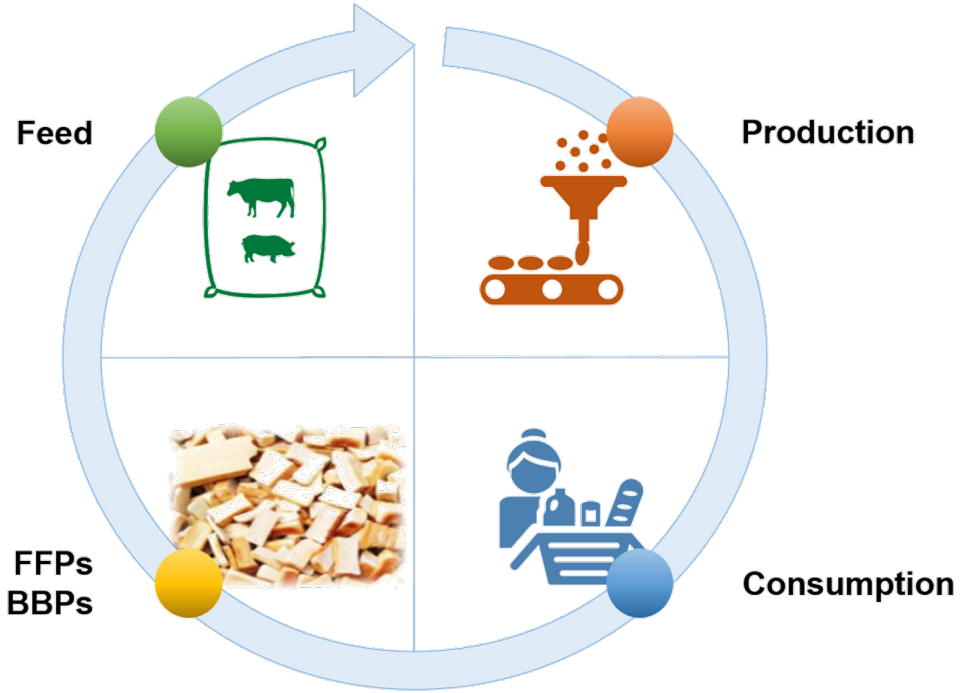




Circular streams as protein feeds I

Food waste (and I mean waste)





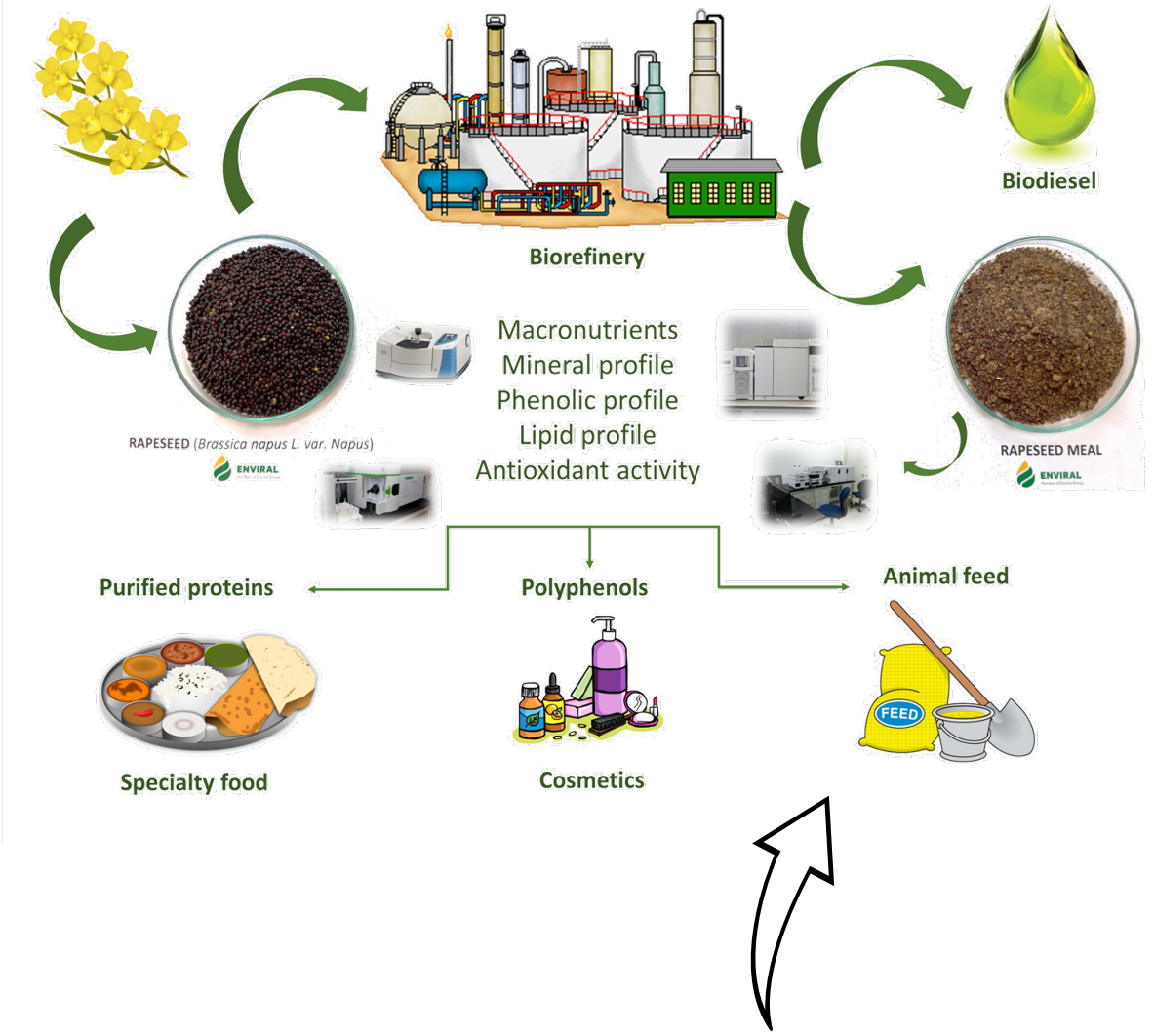
Former foods & food industry by-products

Circular streams as protein feeds II

Crop production residues

Biorefinery

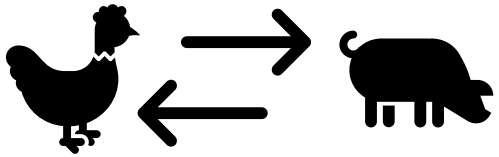
Brewery

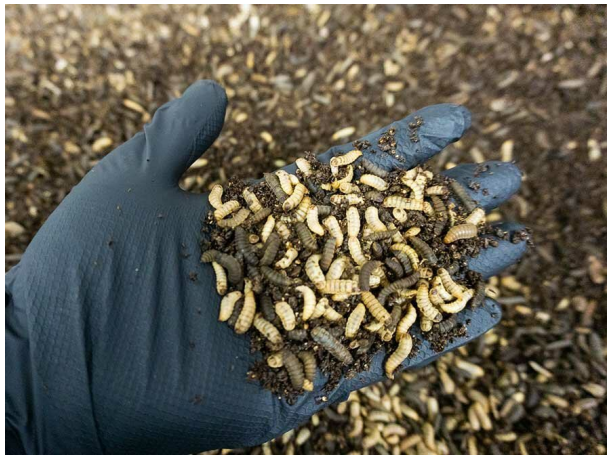


Animal by-products (PAPs)

Poultry / ruminant??? by-products

Insect-based feeds





Novel ingredient impacts

The environmental burdens of soymeal and several alternative (novel) ingredients

Ingredient	GHG (CO_2 eqv.; kg kg^{-1})	ALU (m^2 kg^{-1})	Total N content (kg kg^{-1})	Total P content (kg kg^{-1})
Soymeal (imported)	**3.05**	**3.11**	**0.075**	**0.006**
Microalgae	2.31	0.034	0.093	0.014
Macroalgae	2.10	0.021	0.037	0.002
Duckweed	1.03	0.004	0.048	0.004
Yeast protein concentrate (YPC)	1.08	1.26	0.108	0.013
Bacterial protein meal (BPM)	1.49	0.026	0.117	0.015
Leaf protein concentrate (LPC)	0.611	1.98	0.093	0.005
Insect meal	**2.91**	1.06	0.084	0.008

Pig performance on Peas and Beans compared to soya (Green Pig Project)

Grower Phase (30-55kg)	SBM	Prophet (peas)	Fuego (field beans - high tannin) - Spring	Tattoo (field beans - low tannin)	Wizard (field beans - high tannin) Winter	sed	Diet	SBM vs. pulse	Peas vs. faba bean	P values High vs. low tannin	P values Spring vs. Summer sown
Feed Intake (kg)	48	48	46	46	47	1.8	**0.838**	**0.482**	**0.371**	**0.825**	**0.824**
Daily liveweight gain (kg/day)	0.92	0.95	0.99	0.96	1.02	0.035	**0.065**	**0.027**	**0.190**	**0.156**	**0.464**
Feed Conversion Ratio	1.92	1.91	1.86	1.85	1.87	0.074	**0.834**	**0.481**	**0.367**	**0.821**	**0.827**
Finisher Phase (55-95kg)											
Feed Intake (kg)	122	119	118	116	122	5.6	**0.810**	**0.429**	**0.997**	**0.455**	**0.547**
Daily liveweight gain (kg/day)	1.13	1.19	1.17	1.1	1.14	0.049	**0.482**	**0.561**	**0.226**	**0.256**	**0.558**
Feed Conversion Ratio	3.05	2.97	2.95	2.9	3.04	0.14	**0.811**	**0.430**	**0.997**	**0.454**	**0.546**

White, G A, et al, (2015) Animal Feed Science and Technology, 209, 202 - 210

Environmental implications

Opportunities

Land use related

GHG / C-footprint / GWP

Insect farming 90% ↓ land than soy

↓ x11 times land degradation

↓ up to 95% reduced GWP

Environmental implications

Opportunities

Biodiversity

Acidification
Eutrophication

Water quality
Resource depletion

- 97% / 98% EP / AP
- Synthetic / chemical inputs
- Wastewater through upcycling

Environmental implications

Risks

Land use related

GHG / C-footprint / GWP

Land abandonment

Land use change in global North

↑ Energy demand

Environmental implications

Risks

Biodiversity

Acidification
Eutrophication

↑ Weediness / invasiveness of GM genotypes

↑ N and P in livestock manure

Economic implications

Opportunities

Production & supply (P&S) economics

- ↓ Input costs
- ↓ Transportation compared to import
- ↑ Access to labour = local P&S and less heavy-duty operations

Robustness to economic uncertainties & extreme events

- ↓ Damages, poor yield, and supply interruptions
- ↓ Interruptions in P&S

Economic implications

	Opportunities	Risks
Production & supply economics	↓ Input costs ↓ Transportation compared to import ↑ Access to labour = local P&S and less heavy-duty operations	↑ Capital costs at commercial scales ↑ Reduced tech availability for commercialisation ↑ Operating costs = energy
Robustness to economic uncertainties & extreme events	↓ Damages, poor yield, and supply interruptions ↓ Interruptions in P&S	↑ Volatility of prices due to energy ↑ Cost of production = reliance on advanced biotechnology and future tech trends

Social implications

Opportunities

Animal health & welfare

↑ CP = ~ 93%
↑ Gut health
↑ Enhanced of nutrients

Social development

↓ Heavy-duty on-farm labour
↑ Innovation in P&S
↑ Tech knowledge creation

Consumer perspectives

↑ “Feel good” factor “saving the planet”

Social implications

	Opportunities	Risks
Animal health & welfare	↑ CP = ~ 93% ↑ Gut health ↑ Enhanced bioavailability of nutrients	↓ Livestock acceptability, inefficient feeding and impaired growth ↑ Biochemical contamination due to poor hygienic processing
Social development	↓ Heavy-duty on-farm labour ↑ Innovation in P&S ↑ Tech knowledge creation	↑ Unemployment due to automation in novel P&S ↑ Impoverished global South
Consumer perspectives	↑ “Feel good” factor “saving the planet”	↑ Misinformation, biases, “disgust” factor ↑ Feed & food fraud to improve marketing

Food safety implications

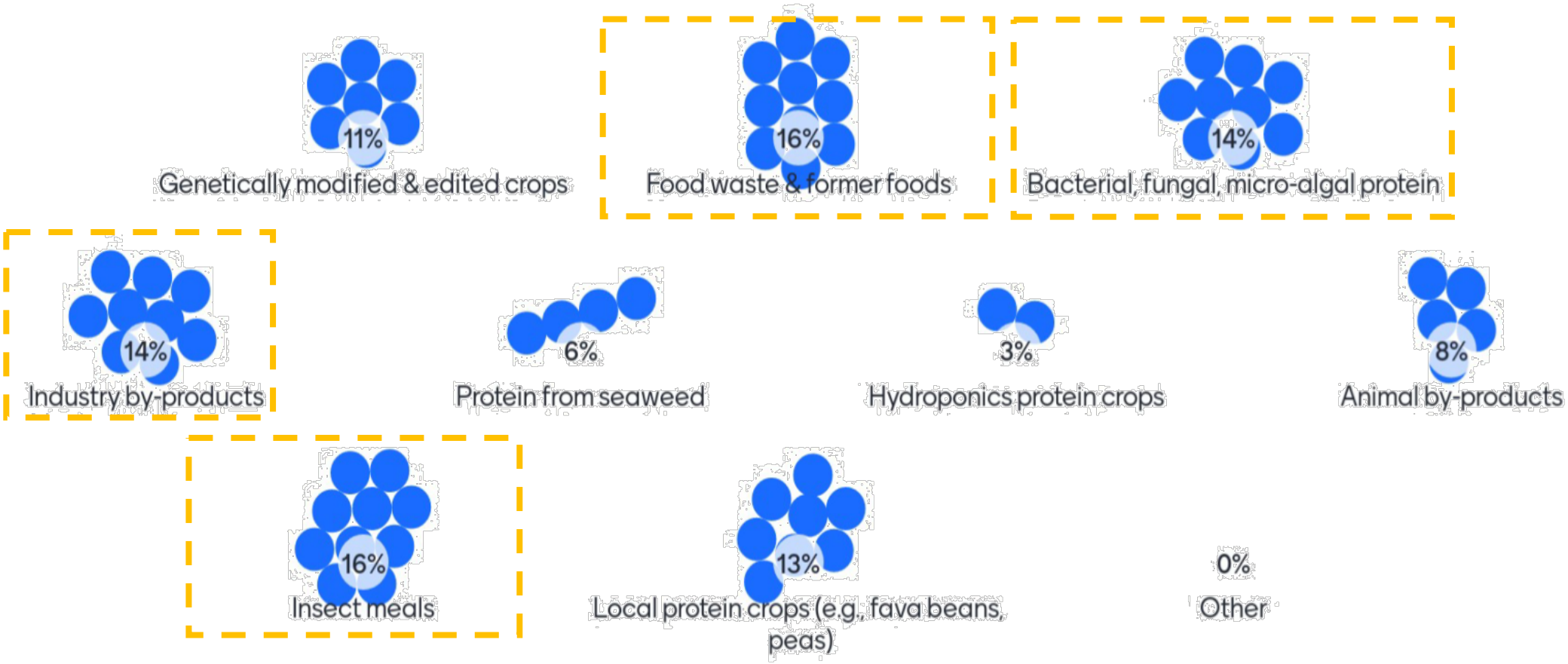
Opportunities

Bio-contamination	↓ Mycotoxin contamination due to transportation & long-term storage
Chemical contamination	↓ Bioaccumulation of pesticides, heavy metals
Allergenicity	↓ GM/GE crops reducing allergy inducing proteins

Food safety implications

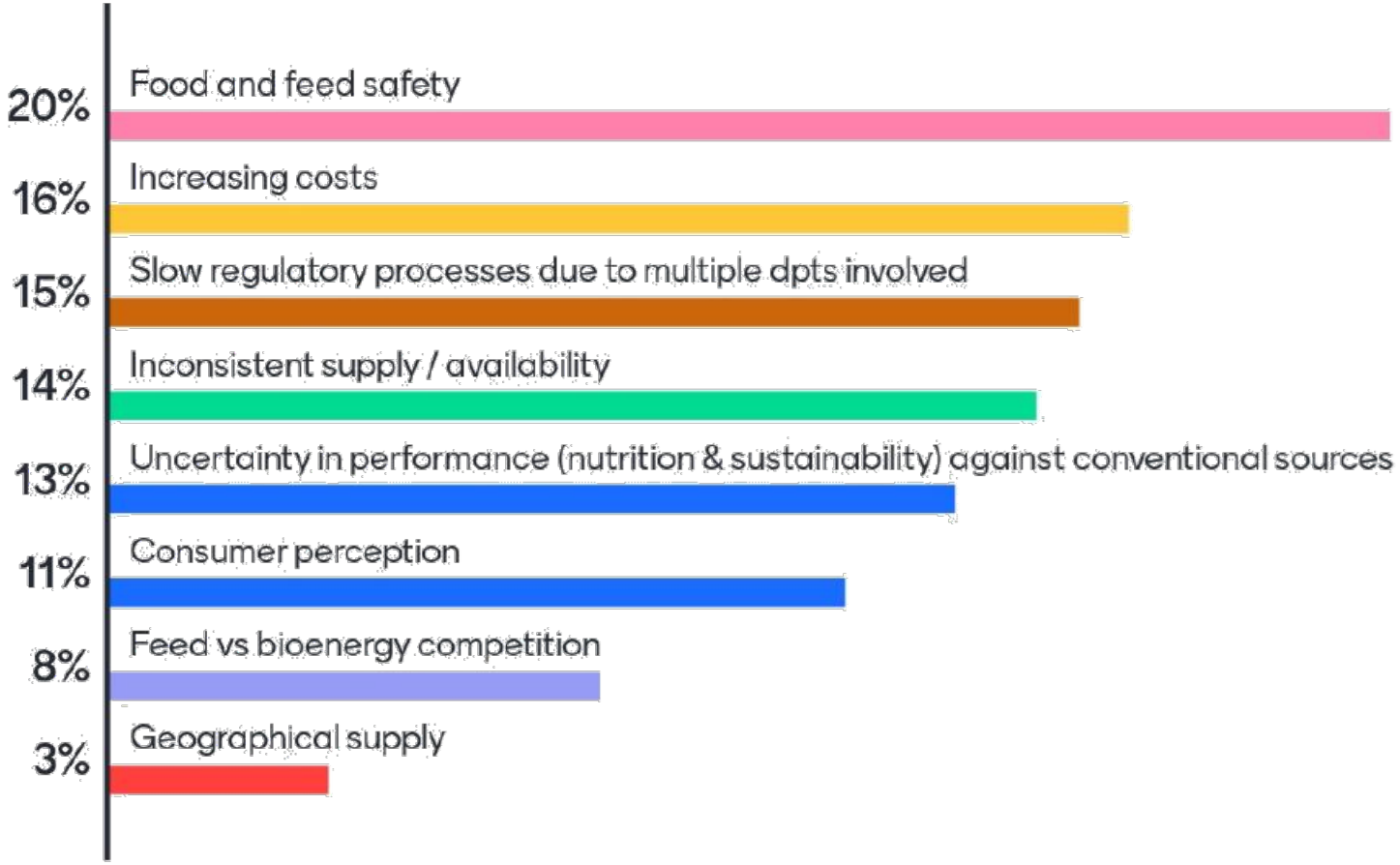
	Opportunities	Risks
Bio-contamination	↓ Mycotoxin contamination due to transportation & long-term storage	↑ disease outbreaks e.g., BSE/TSEs ↑ pathogens due to poor hygienic processing of food waste and waste substrates
Chemical contamination	↓ Bioaccumulation of pesticides, heavy metals	↑ Bioaccumulation of nanoplastics, micro-plastics, and packaging residues from waste streams
Allergenicity	↓ GM/GE crops reducing allergy inducing proteins	↑ Major allergens present in several alternatives

Stakeholder Focus within 5-10 years



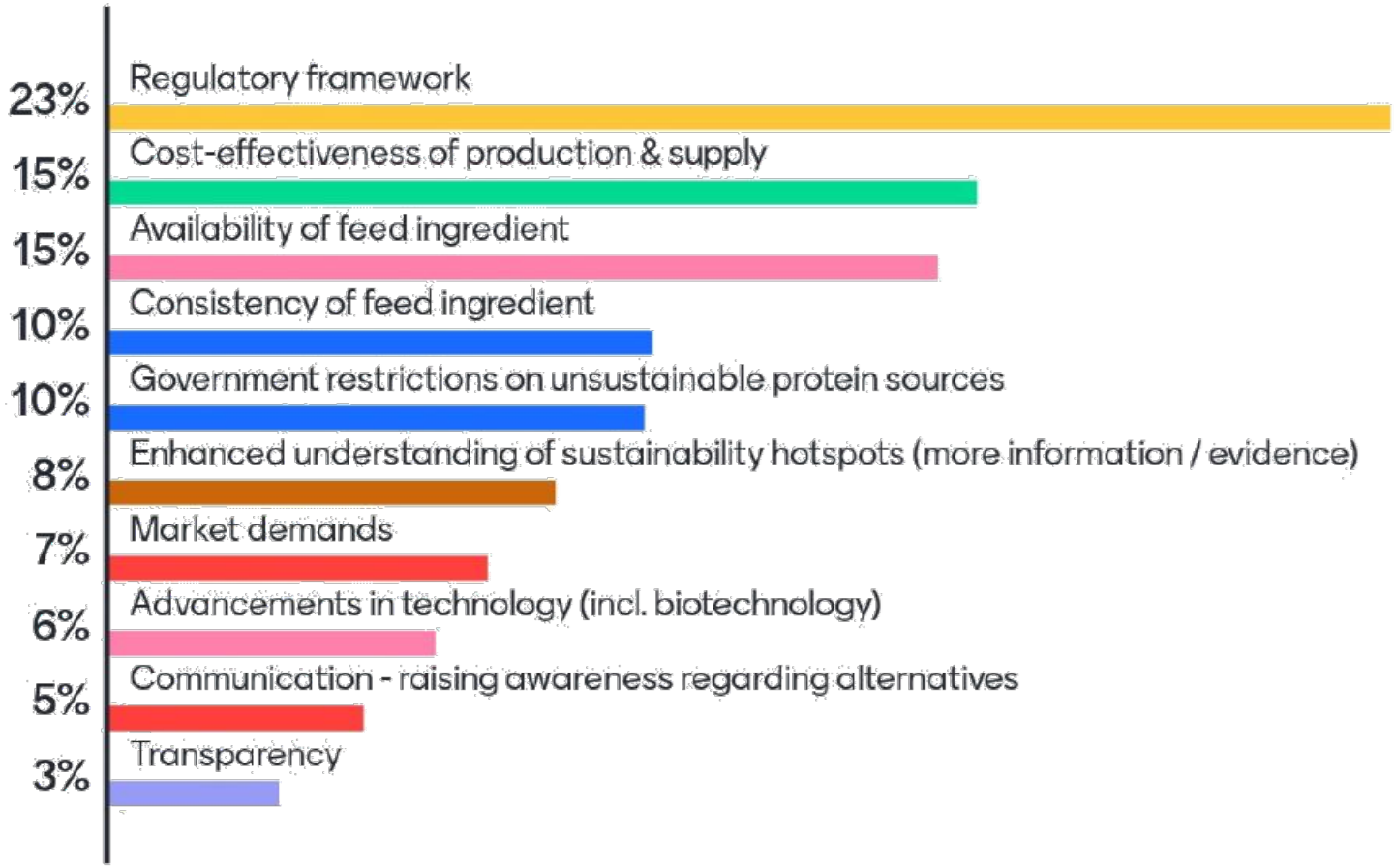
Disruptive factors

Priority considering urgency to address



Enabling factors

Priority considering urgency to address



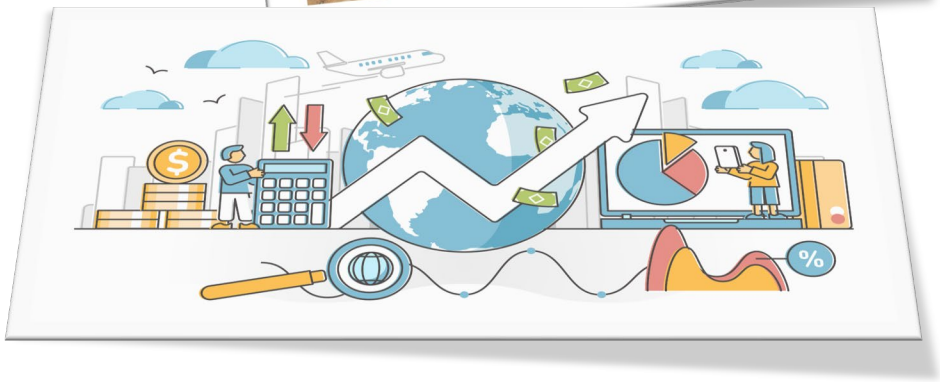
Where should research effort be directed to?

Consider different production & supply scenarios

- Enhance knowledge around nutritional profile of alternatives
- Detailed LCA and compilation of LCI of primary data

Better understand factors affecting public / customer acceptability (eg for use of circular feed solutions)

Micro and macroeconomic investigations of livestock farm profitability using alternatives

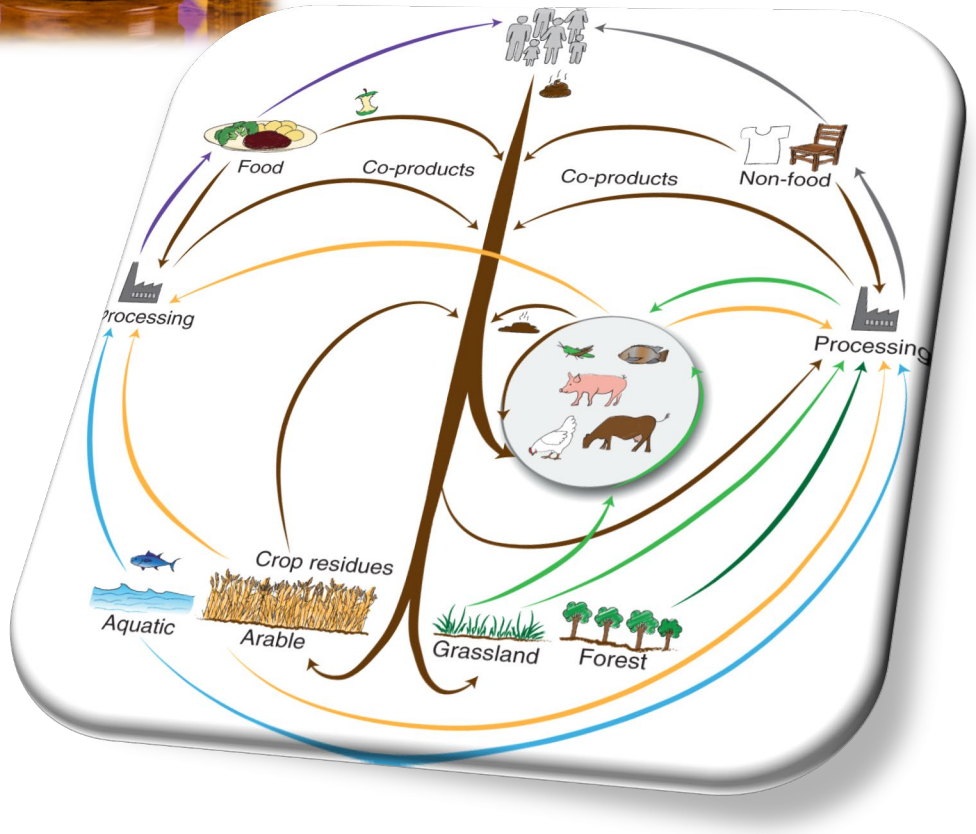


Recommendations for policy making

Parity with EU legislation for insect and PAP production & use (UK relevant)

Revise and aim to **reduce legal barriers**

Accelerate **circular bioeconomy**



Recommendations for policy making

Decouple protein feed production from fossil fuel

Further enrich the feed and **food regulatory system**

Find out more about this work in:

Food Standards Agency

The Future of Animal Feed: Acknowledgements

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The future of protein sources in livestock feeds: implications for sustainability and food safety

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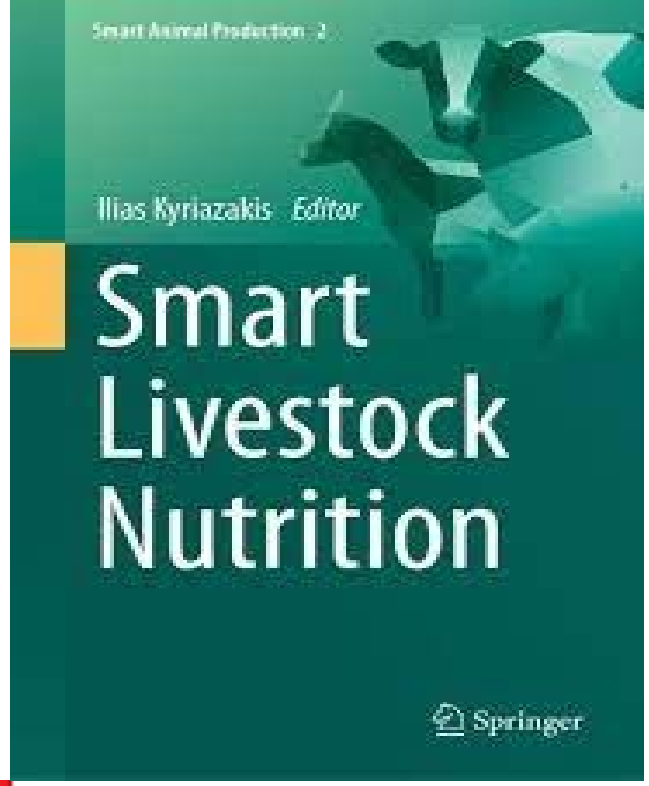
The feed-food competition for environmental and economic resources raises increasing concerns about the production and supply of protein for the global livestock sector. Risks to food-security and approaching deadlines for global sustainable development, means exploring alternative protein feed ingredients is imperative. This *Review* discusses the potential for soilless, local and circular protein feed sources to provide solutions for key sustainability and food-security threats to the global livestock sector, through their partial incorporation in future livestock feeds and feeding systems. In doing so, it offers a holistic insight into the potential opportunities, but also risks associated with such alternatives. Through this analysis, a four-point strategic plan is synthesized to facilitate higher-level policy making that may enable implementation of these alternative ingredients at commercial scales, building toward a more sustainable and resilient livestock industry.

KEYWORDS

alternative protein sources, cellular agriculture, circular agriculture, environmental impact, food policy, food safety, soya production, sustainable development



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