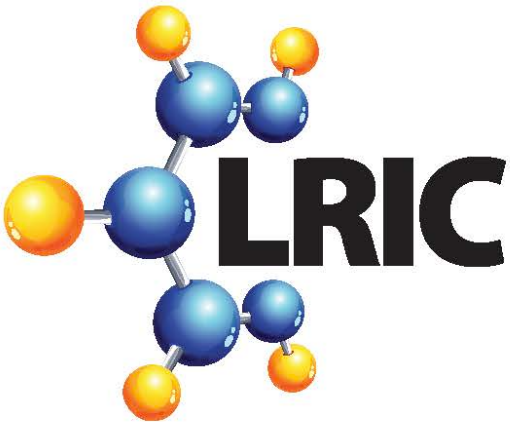

Cross Sector Livestock Research Priorities

Livestock Research and Innovation Corporation

March 2024

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The End Goal:

The goal of livestock research in Ontario should be the innovation and sustainable growth of the livestock sector as a key pillar in Ontario's economy, environment and food security. In this report, we identify some specific research questions both by sector, and across sectors, however, we strongly encourage creativity and welcome research that helps move industry forward with respect to the end goal identified above.

A New, Holistic Approach:

Arising from a meeting with the University of Guelph Department Chairs of Animal Biosciences, Food Science, and Human Nutrition, LRIC is furthering discussion regarding a more holistic approach to protein science. This was inspired by the recent work of Dr. Michael Rogers, Food Science, Ontario Agricultural College. His work compared plant-based products with real meat right through the human digestive system. Research to date has been ignoring the critical element of the impact of protein products on human health, including the gut microbiome. View Dr. Rogers at https://www.youtube.com/watch?v=5xS9OhPNIFI. Further, there is a lack of data comparing actual resource use and environmental impacts of various protein sources. There is a clear and urgent need for research that would take a new cross discipline, cross sector approach to protein. The overarching objective of this research will be:

- Enable comparison of protein options (animal, plant-based, cellular) including all relevant factors (impact on human health, GHG emissions, negative and positive impacts on environment, economy, etc).

This approach would also expand the base of possible industry funders for research beyond producer organizations.

LRIC actions to update and expand sector priority areas:

Aquaculture
LRIC participated in an industry priority setting workshop initiated by Dr Neil Rooney, University of Guelph. We confirmed completeness with RJ Taylor, Executive Director with Ontario Aquaculture Association and Steve Naylor, Senior Regional Aquaculture Specialist, Fisheries and Oceans Canada. While noting that the focus of these workshops was environmental issues, both felt that the resulting list (Appendix 1) was complete while a more fulsome engagement would lead to a list in which fish health would rank higher.

Poultry
LRIC facilitated a meeting of the poultry sector in advance of last year's priorities identification. Building on that for this year, several points of contact within the industry were consulted to seek their thoughts on a document created by the Poultry Innovation Partnership. This document (Appendix 2) sets forth desired outcomes and supporting research strategies that are needed.

Engineering

Over the past two years, LRIC has worked with industry to identify challenges and opportunities that could have an Engineering solution. The resulting document was presented to the School of Engineering at the University of Guelph, however, beyond a small effort by MEng students, little happened. This year, LRIC canvassed progressive producers in each sector to develop a more robust and complete list of these challenges and opportunities. Response rate was very high, indicating that this is an area of need as far as research in the livestock sector. Several areas of focus emerged across sectors, shown in the table below. The full listing of challenges and opportunities by sector can be seen in Appendix 3. We met with the Deans of Engineering at the Universities of Guelph, Waterloo and Windsor, as well as RH Accelerator and an Innovation Fellow at Western University to make them aware of the opportunities in the livestock sector. As one Dean said, "You need to open the eyes of faculty to the opportunity and understand what drives them: publications and tenure." To that end, we compiled and shared a list of funding opportunities available for research in this area.

Table 1: Key areas of focus for Engineering research to meet industry challenges and seize opportunities

Automation of tasks and data capture Silage dry matter Calf activity monitor Expanded capability for existing automated feeders Weight / temperature assessment Manure and feed storage levels Medicinal records Infrared cameras Environment resistant security cameras Feed bin, feeder, water meters Auditory as measure of animal comfort Egg quality prehatch Floor egg / Mortality pick ups Accurate bird count in aviary systems Routine barn environment assessment Barn cleaning Bird catching Drone reading of RFID tags (May need longer range tags) Drone data capture, administration of treatment, vaccine **Better animal identification** RFID tags Facial recognition **Quick tests / Predictions** Cow side Calcium level in blood Feed available in a grazing paddock (days) Chick sexing prehatch / In barn fertility AI to analyze past and predict trends (environmental impact) AI for grading roosters	**Energy** Recovery from compost, manure Retention via insulation New sources (e.g. heat pumps) For truck wash centers **Ventilation** Disease identification and elimination Heat recovery, gas recovery for energy use Cooling Measuring and reducing ammonia/dust from ventilation **Design** Manure management to lower GHG emissions Barn design for more extreme weather Feeders for lower feed waste, precision feeding Portable shade and windbreak structure Portable fencing and watering systems Submersible fish net pens In barn hatching Avoid feathers in feeders (blockages) Bird movement: avoid smothering in loose housing Biofilter systems that work at lower temperatures Sow scratchers Foot baths for sows Sensors to determine function of hidden fans

The Top Three Issues:

Climate change

- There are two elements to this priority: adapting production to the climate changes we are already experiencing and reducing the environmental impact of livestock production per unit of production.
- The report from the Provincial Climate Change Impact Assessment highlighted many challenges for livestock production as a result of climate change.
- Research is needed to:
    - Document an accurate baseline of livestock impacts and also to find and make available products and management techniques that reduce GHG emissions from livestock production. Of note, livestock production can have positive impacts on soil health and biodiversity and these need to be documented and more broadly recognized;
    - Help the livestock sector meet the emerging challenges that result from climate change;
    - Document the livestock sector impact on climate change and design a report card to be used to show progress;
    - Identify most appropriate measure of GHG emissions, for example GHG per unit of product is vastly different than GHG per amount of product required to provide a set contribution to daily protein and vitamin requirements;
    - Develop feed additives that can be used to reduce GHG emissions while maintaining high productivity;
    - Identify additional means of improving feed efficiency as a way of reducing GHG and improving production efficiency;
    - Quantify the impacts of livestock on soil health.

Adapting to a world with reduced use of antimicrobials

- This will involve production practices, genetics, alternatives (e.g. probiotics), treatments (e.g. antivirals), etc and involves every livestock sector.
- Access to products, particularly those that assist with a transition away from antimicrobials is paramount.
- Research is needed to:
    - Develop vaccines for common diseases in livestock;
    - Identify, develop and commercialize feed additives and management strategies that stimulate animals immune system and reduce disease incidence and severity;
    - Identify management techniques to lower stress and morbidity associated with transportation and other stressful occurrences.

Emergency preparedness

- Major disease outbreaks such as AI are known to be highly costly and disruptive
- We need new approaches to keep pathogens out of the province, detect when they arrive and track movement, understand the specifics (e.g. genotype), enhance biosecurity, explore means other than the use of controls zone and culling, etc.
- Research is needed to:

    - Develop improved surveillance techniques;
    - Develop effective systems to monitor movement of disease, including via fomites;
    - Identify better options for effective depopulation and disposal.
- One area of potential requires further investigation and discussion, that being the use of genetically edited animals.
    - There has been recent work in the UK focused on AI-resistant poultry
    - Work at University of Guelph has focused on use of a gene drive in a GE pig that, released into the wild, produces only male or infertile female offspring. Over a small number of generations, the wild swine population would be decimated. A key vulnerability for Canada in reopening international markets following an ASF intrusion would be the ASF reservoir we currently have in wild swine.
    - Not only do we need to be doing reaserch in this area but we also need to be having serious policy discussions to enable the use of new GE options in a timely manner

Sector specific research questions:

While high level research priority areas do not change significantly over a short time, the industry does have more timely and specific research questions that they need answered. Following are some priority specific questions.

1. How can the sheep industry capitalize on the potential uses for wool?
2. How can the broiler industry minimize and manage E.coli?
3. How do grazed livestock contribute to healthy soil?
4. What species and varieties of forage will provide increased yield, nutrition and longevity?
5. What feed additives can be used to reduce the GHG emissions from ruminant livestock while not impeding production?
6. What management practices and facility modifications will enable livestock producers to maintain highly efficient production in the face of changing climate?
7. What are control strategies for reovirus? This can include the development of live and inactivated vaccines for reovirus.
8. How can we control, reduce and eradicate Salmonella Dublin on farms?
9. What are additional options to control Varroa mites?
10. How can barn design and ventilation be improved to the benefit of animal and human health?
11. Can meat tenderness be determined automatically using camera systems?
12. How can feed efficiency be improved as a means of improving sustainability and lowering GHG impacts?
13. What alternative materials can producers use to reduce their plastic wastes?
14. What practices are needed to optimize carbon sequestration?

Appendix 1: Aquaculture Research Priorities

1. **Effects of Nutrient Loading and Energy subsidies**
    1. Effects of net-pen on wild fish populations
    2. Effects of net-pen farming on benthic invertebrate communities
    3. Effects of net-pen farming on planktonic communities - high temporal and spatial resolution
    4. Effects of net-pen farming on shoreline communities (including invasives)
2. **Feed composition and effects**
    1. Studies on diet composition for alternative farmed species (e.g., whitefish)
    2. The effects of alternative feed sources on bethnic communities
    3. Development of feeds to promote thermal tolerance
    4. Insect meal, probiotic and prebiotic effects on farmed species
    5. The economic viability and public perception of different feed sources
3. **Effects of Climate Change**
    1. A multivariate review on the temperature range tolerance for fish and for different pathogens, density tolerances for trout and at what other markets have done to mitigate the effects of climate change
    2. Development of endogenous vaccines for Ontario specific bacterial pathogen strains which are increasing in prevalence and severity due to warmer weather
    3. Investigation into alternative treatments (currently only have access to two antibiotics) for fish diseases which are increasing in prevalence and severity due to warmer waters
4. **Fish Disease (new due to the Laccocuss)**
    1. Tools for disease monitoring and prevention
    2. Emergency management - planning for how the industry would respond to, and recover from, a disease emergence
    3. The efficacy of current vaccines under different administrative schedules
    4. Expanding the number of pathogens that can be vaccinated against
5. **Fish farm location, operation and decommissioning**
    1. Is fallowing a viable strategy for mitigating environmental effects
    2. Net-pen siting including hydrological considerations
    3. The carbon footprint of Ontario net-pen farms compared to the carbon footprint of Ontario land-based farms
    4. Net-pen decommissioning
6. **Genetics**
    1. Breeding rainbow trout to tolerate higher temperatures
    2. Comparative genetic analysis of farmed and wild rainbow trout stocks
    3. Development of genetic tools (e.g., SNP) to characterize the genetic profile of wild fish species (e.g., whitefish) in the regions around communities with interest in farming these species
7. **Socioeconomic considerations**
    1. Scientific communication analysis: what is the best way to share data with the public
    2. Exploring social license from farmed fish
    3. Off-grid options for renewable energy power

Other Topics of importance that were raised.

Other potential options:

- life cycle analysis of environmental costs of farmed vs. wild fish
- potential for expansion of land-based aquaculture: costs and benefits
- modelling of the potential for nutrient inputs under a warmer climate to stimulate local algal blooms (possible for inclusion in a location siting theme)
- The research priorities seem focused on the existing net-pen based industry with less support for emerging RAS farms.
- Exploring land-based options for mitigating all the detrimental effects currently from cage farm operations in the public waters. "growing the industry beyond the cages".

Appendix 2: Poultry Research Priorities

These research outcomes were initially created by the Poultry Innovation Partnership (PIP) with the Alberta Poultry Producers and included a national scan and consultations. LRIC is consulting with members of the Ontario Poultry Industry to ensure relevance of the strategies and prioritize the outcomes for Ontario. As national initiatives have been identified, LRIC will continue to collaborate and build synergies with PIP and other research and industry organizations for the benefit on Ontario's Poultry and Livestock Sectors.

Outcome: Improved Production Efficiency

Research Strategies

- Support development of integrated training and decision support models and tools that improve economic bottom line
- Review, revamp, and focus Heritage Flocks (Shaver at University of Gueplh) and collaborate with other heritage programs to provide genetic alternatives to a narrowing gene pool
- Analyse and consolidate global meta-analyses into best practices for Ontario poultry production
- Continue to conduct specific production efficiency research that is applicable to Ontario conditions, including feed efficiency research, recognizing that feed is the single largest input cost in poultry production

Outcome: Improved Business Risk Management

Research Strategies

- Assess new and emerging global solutions and their practical application to managing crisis situations (e.g. depopulation management)
- Review global analytics to discover and document responses to the most critical existential risks to poultry production in Ontario

Outcome: Improved Environmental Sustainability Via Stewardship of Resources and their Impact on Air, Water, and Soil Associated with Poultry Production and Processing

Research Strategies

- Continue both institutional and on-farm research into integrated manure management, including biodigesters for small to medium sized farms, water recycling, deadstock disposal, soil health, nitrogen and micronutrient

efficiency, odour, impact of barn environment on caregiver health, pathogen destruction and protection of water resources
- Support economic analysis and engage producers on new sustainability opportunities, including green energy sources, for suitability of implementation in the Ontario poultry industry context

Outcome: Industry Has the Knowledge and Tools Available to Achieve Thoughtful and Sustainable GHG Reductions

Research Strategies

- Continue to encourage research that develops and assesses viable genetics, including longer laying life cycles, local feed and energy sources, and technologies that pursue true sustainability without offsets, shorten days to market, support animal welfare, and improve efficiency thereby reducing carbon footprint
- Support the work of national organizations in developing and implementing complete life-cycle quantification protocols and benchmarks to enable industry to measure and document progress in GHG reduction

Outcome: Reduced Need for Antibiotics & Increased Effectiveness Through Research and Promotion of Cost-effective Animal Health

Research Strategies

- Review world literature regarding full bird microbiome to assess applicability of antibiotic alternatives
- Continue research into best management practices and tools on farm and in hatcheries to reduce use of antibiotics, inhibit antimicrobial resistance, and support improved production efficiency in raised without antibiotics programs

Outcome: Improved Bird Welfare and Productivity Through Greater Understanding and Mitigation of Poultry Welfare Issues Practices

Research Strategies

- Continue to review world literature to update best welfare practices in support of national animal welfare committees
- Evaluate new animal welfare measures in Eastern Canadian context (PIP considering Western Canada) and continue to develop verifiable measures and practices that support bird welfare
- Support research into interactions of caregiver with flock in an effort to improve welfare and reduce stress and consequent use of antibiotics

Outcome: Improved Bird Welfare and Productivity Through Greater Understanding and Mitigation of Poultry Welfare

Research Strategies

- Conduct research to develop and refine practical management innovations in poultry health that proactively prevent problems from occurring:
    - water quality - engineering and indoor environment control
    - pullet health - ammonia, litter, and particulate matter
    - stress factors - gut health
    - myopathies
- Conduct research targeting chick quality at the front end of the supply chain, and animal health and nutrition responses for evolving strains of birds including myopathy multi-factorials
- Support efforts participating in global research process to better understand impact of Avian Influenza on both bird and human health

Outcome: Improved Consumer Food Quality Experience with Poultry Products

Research Strategies

- Investigate and benchmark management factors that could contribute to myopathies as poultry food quality issues, improve product quality for spent hens, and improve egg quality parameters
- Assess the suitability of new technologies for product quality and packaging improvements including freshness, reduced pinking, reduced yellow colouring, and freezing techniques
- Investigate novel feeds and feed additives that improve poultry meat quality within the Ontario production context

Outcome: Best in Class Food Safety Along the Poultry Supply Chain

Research Strategies

- Evaluate global meta analyses on specific feed ingredients that can augment/replace antibiotics in food safety pathogen reduction
- Conduct survey on barriers to implementation of on farm food safety best management practices
- Continue and expand food safety research into feed and water systems that improve/reduce food safety issues (e.g. cleaning water pipelines, recycling water in processing plants, raw material in feeds, mycotoxins, salmonella, high mineral content/alkaline water sources, reverse osmosis, immunocompromising factors, food safety in an organic environment)
- Investigate the benefits and implications of artificial intelligence as an on-farm food safety decision tool

Research and Extension will help to support and drive creative and collaborative process into the future for Ontario's vibrant poultry industry continues to grow and contribute to the health well-being of all Ontarians.

Appendix 3: Engineering research opportunities by sector

Sector	Input
Dairy	**Rapid moisture of feed** used for rations (i.e. haylage and corn silage): This would help to fine tune and improve the accuracy and cost effectiveness of the dairy ration. We are constantly adjusting feed amounts to compensate for rain or hot dry weather. However, we are usually a day behind **Cow side blood Ca test** for cows: Milk fever can be a problem in many farms and a rapid cow side test would help in the accurate treatment of this condition Computer app to plug into **tractors to download repair** codes and correct the problem **Universal data format** or conversion software: There are many forms of data and formats on farms (i.e. Lely vs. DeLaval milk wts and activity). It would be great if different technology on different farms could be universally formatted for research and government purposes **Activity monitor for calves**: There is no system or collar for calf activity. This would help with early disease detection **Remote and rapid body temperature of animals**: Ideally this is not a bolus put in the cow or calf and is a remote sensor that records body temperature in real time and sent to a phone or computer program. NOTE, this exists. **Measure and record dry matter intake** in the cattle: To truly know the most efficient animals in the herd the dry matter intake in relation to the milk production would be great (high production with lower intake). The most feed efficient cows would be kept. This tool would also be useful for early detection of sickness and low

	intake. **Young stock development**: Improved robotic feeder that measures feed intake, calf weight, cost and return over cost
Beef	Knowing **how much feed is available in a paddock** for grazing: Use satellite imagery to measure. (presentation at GRAS, Living Labs announcement). Calculate number of days of grazing available. Data sent to phone to allow best use of grazing lands. **Routine data capture**: Example, we have an individual animal scale coming that will weigh the front two feet of a steer and correlate that with its live weight standing in the pen. Its Marty Metzger's system that's being marketed through Gallagher. The amount of date that's going to be available I feel can change how we feed and market cattle in Ontario. The predictive analytics that can come out of the data will help us manage and market feeder cattle at their maximum dollar amounts based on any time and date. Another example is the use of a thermal camera that can scan a pen of cattle for elevated or fevered animals in the pen. This could also be used in extreme heat and cold to help adjust feed rations for animals affected by temperatures. **Knowing the value of excellent compost**: The aerated static pie composting system we are installing at Walkerton will allow us to produce a high quality compost at our feedlot using forced air and sensors to do the work instead of a compost turner. Producing a fungal dominant compost is what we are after for our crops. I think this type of system could be widely adopted here in Ontario with the number of ruminants here in the province. We know the NPK and S values of the compost we are producing now but that only makes up the 75 kgs in a Metric ton. **How to use heat from a composting system**: This could be used to heat a shop or farm office among other buildings around the farm. Most floor surfaces of an ASP system are 65C and a heat recovery could easily happen to transfer heat through water to adjacent buildings.
Pork	**Automated data capture**: Within the electronic feed station to have the ability to scan or measure the sow for temperature, backfat scale, time it takes to eat her ration, ability to measure her weigh without a scale. This data would be recorded from her RFID tag that could send the information to the office to precision feed, inform the farmer of health challenges (early detection) Development of **top dressing within an ESF station**, must automated unit Development of a tool for **facial recognition & temperature of piglets** through to sows for better herd health management Development of a **scanner** (mobile unit or pen based) to read the **weights of a pen of pigs** or individual from grow finish hogs. Air **ventilation systems that could UV light filtration** or something else to destroy particles before they enter the barn (Attic ventilation system to retro into existing facilities) **Ventilation** system that could **recycle heat** loss through fans, clean the air and have it enter the barn again. Air recycling Development of an **air-cooling system**, energy efficient, low cost to cool a barn minimum of 5 degrees. **New energy source**: Could there be a geothermal system that could be commercially scaled. Development of a **better RFID tag**, or way to control it so that VFDs (variable frequency drives) don't interfere with the individual animal tags.

	Development of a light-weight device for injectables (vaccinations & records) per sow and her litter that could **scan her RFID tag, the medicine bottle** and provide all the information for the quality insurance program around food safety. Development of an instrument that could **detect manure levels, concentration of ammonia and nitrogen** like a manure sample before spreading the manure on the fields in the spring and fall – could it detect other things like phytase. A device that could **trap emissions from the fans** and use it as an energy source. What other **energy sources** outside natural gas, propane, and electricity (grid is not strong enough) that could be used to fuel a commercial operation. **Manure separation** for the hog operation (like the dairy industry) **Manure pit solutions to lower GHG emissions**. Downsize the existing manure pits or add lids. Development of an **infra-red or night vision camera** mountable to detect piglets during farrowing. Ability to have a device that could **detect virus or virus load in the air**. (PRRS is an aerosol)Development of a disease management tool. Many diseases are walked into a facility, is there any way to **detect viruses in entry systems**. Could the surface be scanned, or litmus tested to improve biosecurity. Just like a fire alarm, **ammonia detection** for hog facilities – ability to send an early warning message to the user's phone for overheated panels, plugs, electrical connections, motor connections, ammonia levels (emergency preparedness) Due to the nature of hog facilities (corrosion) could there be a **security system** that reports open doors or security along with cameras that can withstand the barn environment that can be seen on a mobile device. **Hanging heaters** in the barn- box heaters are heavy and even with 2 men are difficult to hang especially in amongst the pigs in a pen. We have been using a modified lift cart, but it could be better. **Monitor feed bins**. I know there is tech out there. Is there a system that monitors consumption and alerts to when a bin will be empty? NOTE, this exists. **Monitor feeders**. We still have trouble with prox switches where feed sticks. Can we monitor feeders to tell when they are empty? **Smart water meters**- probably exists but monitor water consumption to know when there is leakage etc. **Truck wash facility** – right now this is a high energy, high water volume , high labour chore. Anything to improve this. Ideas -Vacuum cleaning, microwave disinfection, lower volume of water required etc
Eggs	Engineering issue of having free range barns with **popholes**… is there a better way to design them? Improve range design to encourage birds to use it? In terms of welfare monitoring and AI, there is some work that could be done on using **robots**: a. to monitor the environment (e.g. physically pick up eggs/deads, monitor litter/air quality, early warnings of issues), b. spacing behaviour monitoring (i.e. to help predict / mitigate piling behaviour, potentially using heat signatures), or c. sound monitoring (e.g. ID disease vocalizations – there has been work done on this but still early and could be gaps still). Layer Barn Design Issues: related to work by ZHAO in Ohio. 1. **Ventilation** in general / new ways to ventilate? a. environmental impact b. Disease reduction c. Particle reduction in air d. Emission reduction 2. **Barn design**: severe weather resiliency etc

	3. **Artificial Intelligence** in monitoring barn environment • **Geothermal heating and cooling**. We excavate a lot of dirt to build the barn so the most cost effective would be laying pipes under the barn. • **Ventilation** to reduce disease spread, somehow controlling all the intake air through one opening. • Ways to increase barn **insulation** without large cost increases • Balance between environmental issues vs economic impacts of farming. Technology - **AI** to look at data & observations, past trends, predictions for future • Climate change - is there a way to reduce the need for **supplemental heat**? • Flock verification - how to accurately **count the number of birds** in enriched or free run/aviary systems • **Air Quality**: Ammonia issues, dust, what is coming out of a barn? with respect to climate change. • **Feathers in the feeders** (causing blockages) • **Preventing smothering** in loose housing system (how & why the birds move the way they do) • Bird Health - detecting hot spots (fevers), **early detection of diseases** • Other methods of energy production for barns other than wind, solar
Broilers	**Automation**: Labour is biggest issue, example sanitizing barns (Hydroxyl is one trade name, water based, medical grade) using fans or misters; picking up mortalities; culling; environment checks (temp, moisture, flighty birds poultry hoc to carry mortalities); id bacteria etc in barn and how to eradicate Better ways to **purify the barn environment** (filter UV misting) Options to **lower heating cost** **Catching units** like turkeys have
Turkeys	**Energy** use, need to find alternatives, heat exchangers • Research to rate existing options, advantages and disadvantages (new research barn?) • Ground/water heat source heat pump?
Hatching	More **vaccines** that can be administered in-ovo. **Chick sexing** pre hatch **In barn hatching** **AI grading** of roosters **Automatic sorting** in the pullet barn **Auto leak/crack detection** of eggs. Identify soft shell eggs, hair line cracks, toe punches etc. Auto fertility pre incubation (**fertility checks** that can be done in barn)
Sheep	1. **Automated data capture**: On-farm data capture still requires some degree of manual (or touch) entry • Can data capture be fully automated? Minimize or eliminate the need to manually enter / selection program options. Method to easily incorporate market and slaughter data from auction marts, abattoirs. • A second component of this is the analysis of on-farm data…many programs are great at recording data, but less so on the analysis side. Visual presentation shows improvements/ changes in a more impactful format. • *Work with existing Canadian software companies to address these challenges* 2. **Design a better bale feeder** (round and large square) • Many different style of feeders currently (basket, collapsible) • Besides useful life span, other issues include hay waste, mortality by crushing/ trampling and hanging and wool contamination • *Work with existing manufactures to address these challenges*

	• *Evaluate the feeders currently available to validate best and poorest* • *Demonstrate to ON equipment manufacturers the impact of galvanizing over powder coating under our environmental conditions (inbarn and outdoors).* 3. Design a **feed front** that provides correct head space AND eliminates / reduces callous development on top of neck/shoulders • Indoor housing systems use either a feed table or a bunk system for mangers. Specifically for the feed table systems, the feed front has a horizontal opening that enables sheep to put their head through but prevent them from squeezing into the feed alley. The "neck rail" is generally adjustable to accommodate replacements (smaller) and rams (larger head space needed). The neck rail (bar) is also set in-line with the brisket board or off-set into the pen resulting in excessive rubbing and callous development on the neck/shoulder region. • *Design and validate a feed front that eliminates or greatly reduces this. Note that most feed fronts are currently built with 2x lumber and steel upright supports.* 4. **Portable shade and wind break structures** for grazing sheep that meet animal welfare needs (humane standards), is affordable AND minimizes soil degradation. • Providing adequate shade/shelter can be particularly difficult for producers who are grazing crop residue and cover crops in their neighbourhood where fence rows and trees are few or non-existent. • Canadian Code of Practice for the Care and Handling of Sheep has a requirement for shade to be offered during periods when heat stress are likely. As well, observations from producers grazing solar farms would indicate there may be positive production responses to offering shade. • For pasture-based lambing farms, Spring storms represent a risk of chilled neonatal lambs. Similar to shade, the ability to deploy windbreaks where and as needed would improve welfare and survival in extensive lambing operations • *Design and validate portable shade structures that meet these criteria.* **Opportunities** 1. Forage based production in Eastern, Central and Northern Ontario • There is considerable land across Ontario (including south-west eastern, central and Northern Ontario) that should never see a plow and certainly not suitable for continuous cash cropping practices. These provide the opportunity for the existing land user to add livestock to their operation, or a neighbouring sheep or beef producer to utilize as grazing with **portable fence and water systems**. 2. Silvo-pasture • Again, perhaps a higher emphasis in eastern, central and northern Ontario to incorporate grazing into existing bush/ forested areas. 3. Vegetative Abatement – solar and wind farms, municipalities, government, private landowners including cover crop grazing. • Province wide opportunity • OSF is currently developing (in conjunction with UoGuelph) training materials for existing and new producers that are interested in offering these services, but don't have the current capacity to do so.
Veal	None received
Aquaculture	**Submersible net pens**: Designing a floating net-pen in the Great Lakes that can be submerged 2m below the surface for 1 - 2 week periods while ice moves around lake surface — The trend is to move net-pen sites further offshore in the Great lakes to take advantage of cooler water and more water movement, but this brings additional challenges for lake freezing periods ("ice in" and "ice out"). Most net-pens worldwide are in marine environments with (i) no freezing and (ii) more buoyancy in salt water. We need a made-in-the-Great-Lakes solution.

	Recirculating aquaculture systems in Ontario face challenges with **getting biofilters to work at cooler temperatures** (typically cooler than other places, like 10 or 12C versus 14 - 16C in more tropical places), and also continue to see challenges in proper "offgassing" or C02 in the water. The right solution needs to balance the intricacy of fish health with adequate engineering.

Appendix 4: Research priority areas by sector

Using all of the sector specific priority documents, each area by sector was scored as high priority (H) or medium priority (M). Using a scoring method of 2 per H ranking and 1 per M ranking, the table below shows the resulting relative ranking of priorities across all livestock sectors. A case could be made for weighting individual sector scores by industry size; however, a test of that approach showed no change in rankings.

Table 1: Priority areas by sector (changes from 2024 bolded)

	Beef	Pork	Dairy	Poultry	Sheep	Goat	Veal	Aqua-culture	Equine	Bees	Score
Health	H	H	H	H	H	H	H	**H**	H	H	20
Environment	H	H	H	H	H	H	H	H		H	18
Nutrition	M	H	M	H	H	H	H	**H**	H		16
Welfare	H	H	H	H		H	H	M	M		14
Genetics and Reproduction	M	H	M		H	M		**M**	M	M	10
Production systems		H	M	M		H	M			H	9
Forage	H		M		H	M			M	M	8
Product quality/development	M	H	H	M	M					M	8
Data	M		M	M			M			M	5
Economics		H	M	M							5
Food Safety	H		H	H							6
Marketing		M								M	2

Table 2 – Health

Sector	Areas of Research Need
All	AMU and alternative management and products Emerging disease resulting from climate change Emergency preparedness
Beef	Antimicrobial Resistance/Antimicrobial Use (AMR/AMU): benchmarking and alternatives Improving gut health Chute-side test for vaccination immunity Better understanding/prevention of Bovine Respiratory Disease (BRD) and lameness
Pork	AMR/AMU and alternatives Herd health Causes of Sow Mortality **Avoidance, detection and response to ASF**
Dairy	Strategies to mitigate targeted infectious diseases and new emerging diseases: mastitis, paratuberculosis, salmonellosis, leucosis, bovine viral diarrhea, pneumonia Lameness and injuries prevention, management and treatment Dairy cow transition period related health and welfare issues Pain mitigation and euthanasia BMPs and science-based decision-making tools Sustainably reduce the use of antimicrobials while maintaining farm biosecurity, dairy cattle health and welfare.
Broilers	Development of vaccines (all poultry) **Avoidance, detection and response to AI**
Eggs	Bronchitis is the significant issues with layers Re-emerging pathogens as birds are housed on litter Air quality in barns
Turkey	Production systems that enable a reduction in AMR, Better ways to implement biosecurity on farms Investigate the epidemiology of reoviruses, and the emergence of novel reovirus strains
Hatcheries	Understanding metabolic disorders in developing chicks
Sheep	Withdrawal times for off label products, AMR/AMU and alternatives Ewe vaccinations to reduce mortality and morbidity of lambs Effective determinants of parasite loads
Goat	Improved control of Caprine Arthritis Encephalitis (CAE) ,Withdrawal times for off label products Kid health
Veal	Establish the benefit of all producers receiving calf health and age records. Mitigating the effects and transmission of S. Dublin and bovine respiratory syncytial virus. Identifying diseases and ways to identify alternative treatments and management programs will improve the health and welfare of the calves while reducing antibiotic use.
Aquaculture	**Avoidance, detection and response to fish diseases**
Equine	Real time assessment of impacts of physiological stress Rapid stall-side testing (e.g. respiratory)

Table 3 – Environment

Sector	Areas of Research Need
All	Documentation of impacts (positive and negative) of livestock production Identification of ways to reduce environmental impact Identification and ways to mitigate emerging threats resulting from climate change
Beef	Need for documented, comprehensive role/impact of beef production Specific priority to capture information on GHG emission and carbon sequestration in Ontario grasslands Quantify the positive impact of livestock on soil health Facility design and management adapted to changing climates

Pork	Improving ecological footprint Environmental sustainability Disposal procedures after mass depopulation Facility design and management adapted to changing climates
Dairy	Reduced environmental footprint including GHG (enteric methane), energy, wastes and water Soil quality and retention Understanding the role of biodiversity on dairy farms to complement or enhance farm management practices Facility design and management adapted to changing climates
Broilers	Improved housing environment for workers and birds (all poultry) Facility design and management adapted to changing climates
Eggs	Lighting types (energy efficient) for layers/pullets: colour, flicker, effects of delayed lighting, delayed calcium under spring & fall conditions with present barns & under ideal light tight systems. Facility design and management adapted to changing climates
Sheep	Need for documented, comprehensive role/impact of sheep production, particularly wool as a replacement for synthetic fibers Quantify the positive impact of livestock on soil health.
Goats	**Adapt to, and limit impact on, climate change**
Veal	Ventilation systems have changed over the years and veal producers would like to know ways they can improve the health and welfare of veal cattle by understanding how to improve ventilation.
Aquaculture	Development of scalable recirculating aquaculture systems Development of benthos and sediment monitoring systems Facility design and management adapted to changing climates
Equine	Documentation of the environmental footprint of the industry

Table 4 – Nutrition

Sector	Areas of Research Need
Beef	Improving feed efficiency and the nutritive value of alternative feeds (different by-products, grains, and forages). Improving calf feeding systems.
Pork	Feed costs Precision feeding Slowing pig growth (in the case of market disruption)
Eggs	To enhance performance & shell quality in all housing systems Pullet nutrition & management as it relates to False Layer
Turkey	More precisely defined nutritional requirements for various life phases
Broilers	Improving feed efficiency
Sheep	Impact of grazing winter wheat or rye Strategies to optimize ewe body condition score in accelerated rearing systems
Goat	Need updated, meat and dairy goat-specific ration formulations Better understanding of nutrition related diseases (e.g. pregnancy toxemia)
Veal	In the Code of Practice for the Care and Handling of Veal Cattle one of the requirements is the inclusion of fiber and producers would like to know more about the benefits of including fiber in a ration. Determine feeding practices that reduce number of days on feed, specifically the appropriate corn to supplement ratio.
Equine	Effect of high protein diet on acid/base balance Effect of dietary antioxidants on post-exercise inflammation resolution

Table 5 – Welfare

Sector	Areas of Research Need
Beef	Effective pain control Welfare during transport (need for rest stops, impact on behaviour and physiology) Impact of housing and ventilation on welfare
Pork	On-farm euthanasia techniques, barriers to euthanasia, transportation, behaviour vices, space allowance
Dairy	Improve the health and welfare of calves and cows and optimize productivity and longevity by understanding the behavioural, social and economic barriers or incentives to BMP adoption Understanding the social licence for dairy cattle health and welfare for existing management practices and alternatives. **Improving cow comfort (e.g. compost bedded packs)**
Broilers	Advance science regarding welfare requests from a consumer perspective (e.g. natural lighting)
Eggs	Improved welfare outcomes in various housing systems **Early determination of egg fertility and chick sex**
Turkey	Improved transportation
Goat	Effective pain management Euthanasia
Veal	Reducing disease transfer in co-mingled calves in various production systems Improving welfare of male dairy calves throughout the supply chain
Aquaculture	Best practices for culture, euthanasia, shipping and slaughter

Table 6 – Production systems

Sector	Areas of Research Need
Pork	Improving barn environment (temperature, ventilation, light cycle)
Dairy	Sustainable barn design for conventional and alternative dairy cattle housing systems (new national/provincial building & electrical codes, social impact)
Eggs	Create a facility in which new and evolving systems can be evaluated and compared Identification of fertile eggs on farm to avoid infertile eggs being shipped to hatcheries
Turkey	Improved litter management to avoid breast blisters
Hatcheries	Identify factors affecting hatchability, substandard chick quality and livability Determination of chick gender prehatch
Goat	Housing and handling equipment
Veal	Investigate breeding strategies and engage the dairy sector to determine those that can benefit dairy and veal producers

Table 7 – Genetics and Reproduction

Sector	Areas of Research Need
Beef	Genetics that provide high fertility and high feed efficiency
Pork	Hyperprolific sows and related issues (runt pigs, lactation, etc) Improving longevity of breeding stock
Dairy	Dairy cattle genetic improvement (fertility, productivity, feed efficiency) Dairy cow reproduction (including alternative tools and practices to reproductive hormones use)
Broilers	Selection for improved immunity (all poultry)
Eggs	Selection for hens that retain shell and egg white quality later in life
Turkey	Solutions for leg problems, roundheart
Sheep	Genetics that have lower lamb mortality and morbidity
Equine	Genetics of muscle disorders
Goat	Genetic evaluations for meat and dairy

Veal	Evaluate the relationship between high immune responding cows and calf health
Aquaculture	Develop a formal breeding program for Ontario Rainbow trout

Table 8– Forage

Sector	Areas of Research Need
Beef	New species and better genetics Comprehensive systems approach to pasture management
Dairy	Forage breeding and management for improved yield, resistance, conservation, quality and digestibility
Sheep	Pasture management to reduce parasite loads
Equine	Forage quality and respiratory conditions
Bees	Investigate methods to increase pollinator forage and habitat in order to offset land use that has negative effects on pollinator populations.
All	Need for documented, comprehensive role/impact of including forage into livestock production systems, including soil health and biodiversity Fertilizer recommendations that match today's genetics Methods to accurately and effectively measure on farm forage yields Identify yield of comparable options to alfalfa Extending the grazing season through crop selection, genetics and management

Table 9 – Product Quality and Development

Sector	Areas of Research Need
Beef	Improved grading system
Pork	Meat quality and safety
Dairy	Effect of farm practises (feed, equipment...) on the quality, shelf life and processing of milk Identify the methods to naturally modulate the composition of milk and improve its quality and value, potentially enabling new dairy product development.
Eggs	Prolonged shelf life
Sheep	Impact of dietary ingredients on meat quality
Goat	Organisms affecting milk quality
Veal	Determine factors that will improve meat quality

Table 10 – Data

Sector	Areas of Research Need
Beef	Functional traceability that benefits all along the supply chain
Dairy	Big data: systematic analysis of trends and associations of data to improve profitability
Broilers	Data for benchmarking regarding sustainability
Eggs	Benchmark data needed to plot progress in environmental impact
Sheep	Need for benchmark industry data
Goat	Need for benchmark industry data
Veal	Benchmark production practices and correlate with health outcomes
Equine	Effective traceability Baseline of disease trends

Table 11 – Economics

Sector	Areas of Research Need
Dairy	Farm economic performance & impact of trade: risks and opportunities
All (not Broilers)	Cost of production for various production (e.g. housing) systems

Table 12 – Food Safety

Sector	Areas of Research Need
Beef	Avoiding and quickly addressing food safety issues Rapid and cost effective in-plant detection of microbial agents
Dairy	Microbiology – better understanding of the impact of microbes on milk and dairy products composition and quality as well as human health Chemical, physical and biological hazards and indicators (including addressing relevant risk management strategies for hygienic practices in milk and dairy production and processing)
Broilers	Feed additives / probiotics as alternatives to antibiotics and importation considerations
Veal	Develop best practices for sharing of information between dairy and veal producers through tools such as traceability Drug Labelling & Approvals/Depletion Studies that take into consideration the metabolism of calves and veal cattle

Table 13 – Marketing

Sector	Areas of Research Need
Pork	Marketing and consumer trends
Bees	Conduct market research and product development for honey and hive products.

Appendix 5: Sector-specific documents

Sector	Documents
Beef	Report from the LRIC-facilitated meeting of Beef Farmers of Ontario (BFO) Research Committee Oct 2019 (reviewed fall 2020), also drew on Beef Cattle Research Council (BCRC) document
Pork	Pork Research Call Document (2019) which has an overall focus on: "Testing potential improvements to swine industry practices" Initial meeting with Ontario Pork to investigate a new approach to priorities, work to be completed in 2023
Poultry	Poultry Research Strategy 2014-2020; the Canadian Poultry Research Council (CPRC) research priorities document; 2020 EFO priorities; and the Canadian Hatching Egg Producers research document. Output from LRIC hosted collaborative session October 2022. **Research priorities document prepared by Poultry Innovatiojn Partnership.**
Dairy	Priorities approved by the DFO Board in fall 2020
Sheep	Report from the LRIC-facilitated session on behalf of Ontario Sheep Farmers (OSF) in 2018
Goat	Report from LRIC-facilitated session of the Goat Value Chain Roundtable Dec 2019 Updated by industry in 2022.
Veal	2020 Veal Farmers of Ontario (VFO) research priorities
Aquaculture	Report from LRIC-facilitated session on behalf of the Ontario Aquaculture Association (OAA) in Feb 2019; **Results of two research priority setting workshops initiated by Dr Neil Rooney**
Forage	Report from LRIC-facilitated session for Ontario Forage Council (OFC) in Oct 2019: BFO, Dairy Farmers of Ontario (DFO) and OSF participated
Equine	Report from LRIC-facilitated industry session in 2018, Equine Research Priorities 2019-2024 plus results of a survey of Ontario Equine Veterinarians.
Apiculture	Research priorities document from the Ontario Beekeepers Association