

Enhancing the use of food waste through ensiling

Dr. Tim A. McAllister

Agriculture and Agri-Food Canada
Lethbridge Research &
Development Centre

Monday July 21, 2025



Agriculture and
Agri-Food Canada

Agriculture et
Agroalimentaire Canada

Canada

The Problem

Food Loss & Waste (FLW) in the Food Chain



Food Lost: 13.2% lost between harvest & retail



Food Wasted: 19% wasted by households, food services, and retail



GHG Emissions: FLW contributes ~7% of global GHG emissions



Land Use: FLW uses 30% of global agricultural land

Food loss vs. Food waste

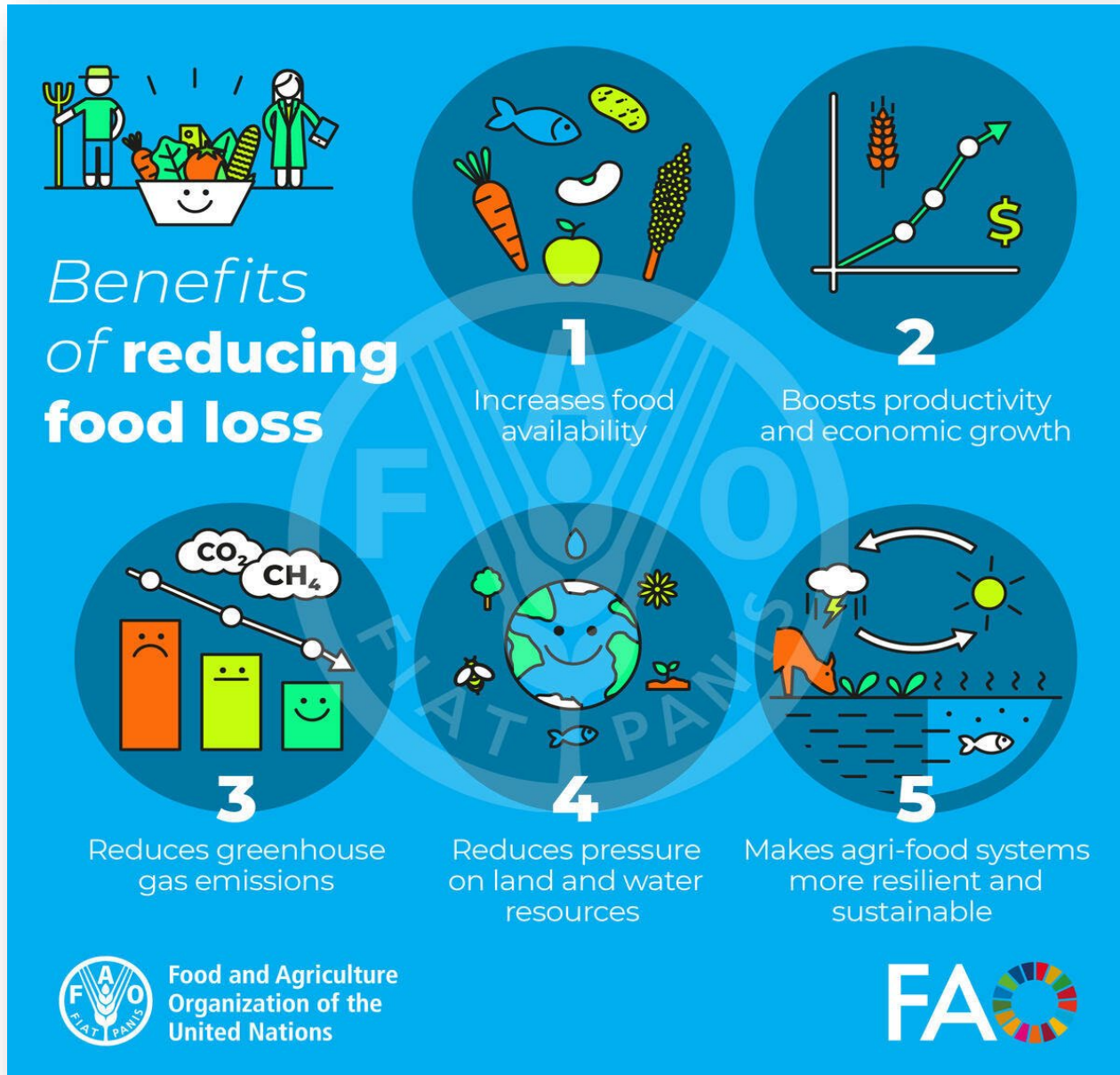


(image source: FAO)

Food Loss and Waste: A Global Issue



Food Loss and Waste: A Global Priority

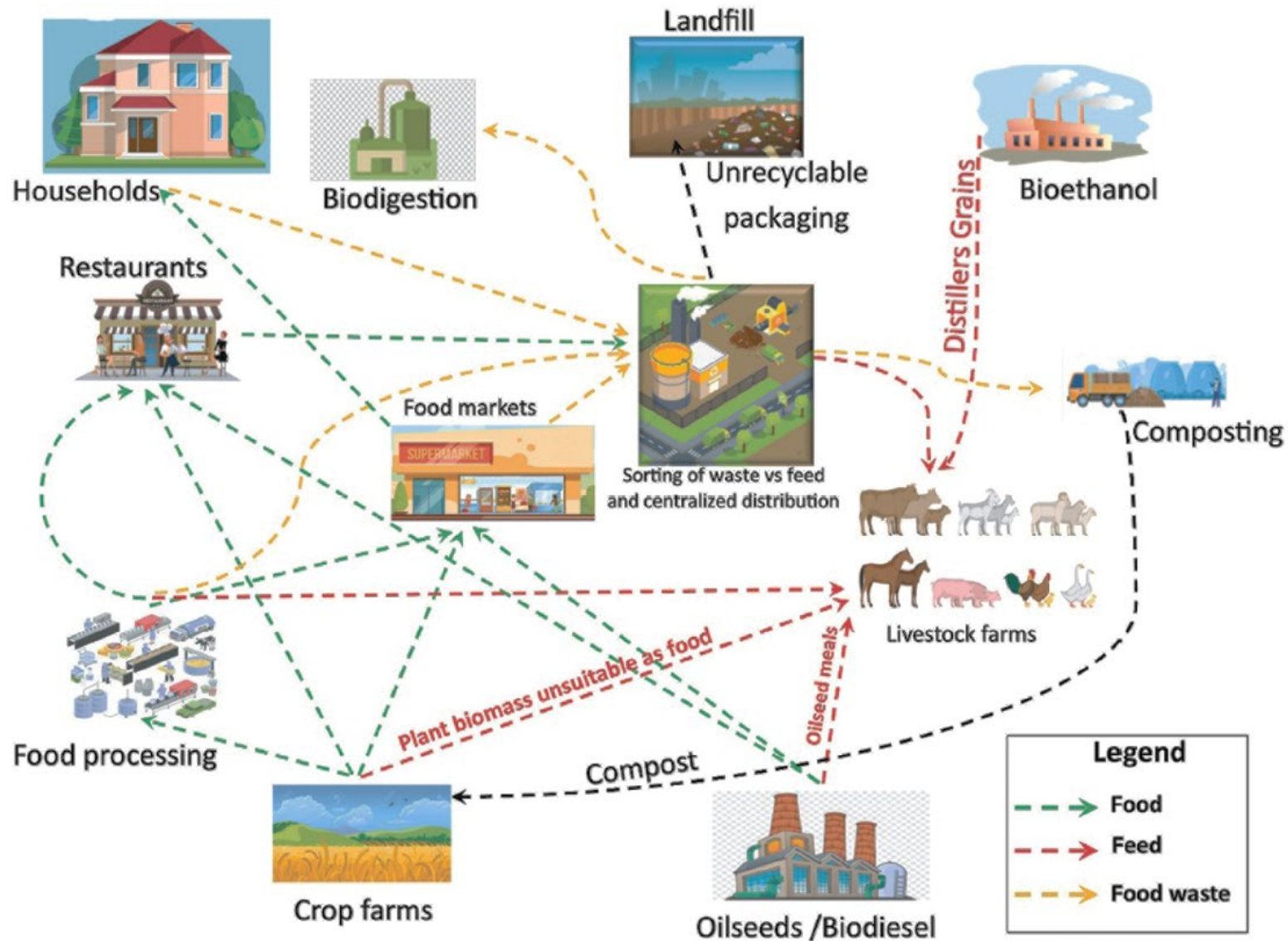


- Minimizing food loss is an important strategy to improve global food security and improve management of land, water, and energy resources in food production systems.

Hierarchy of Recovery



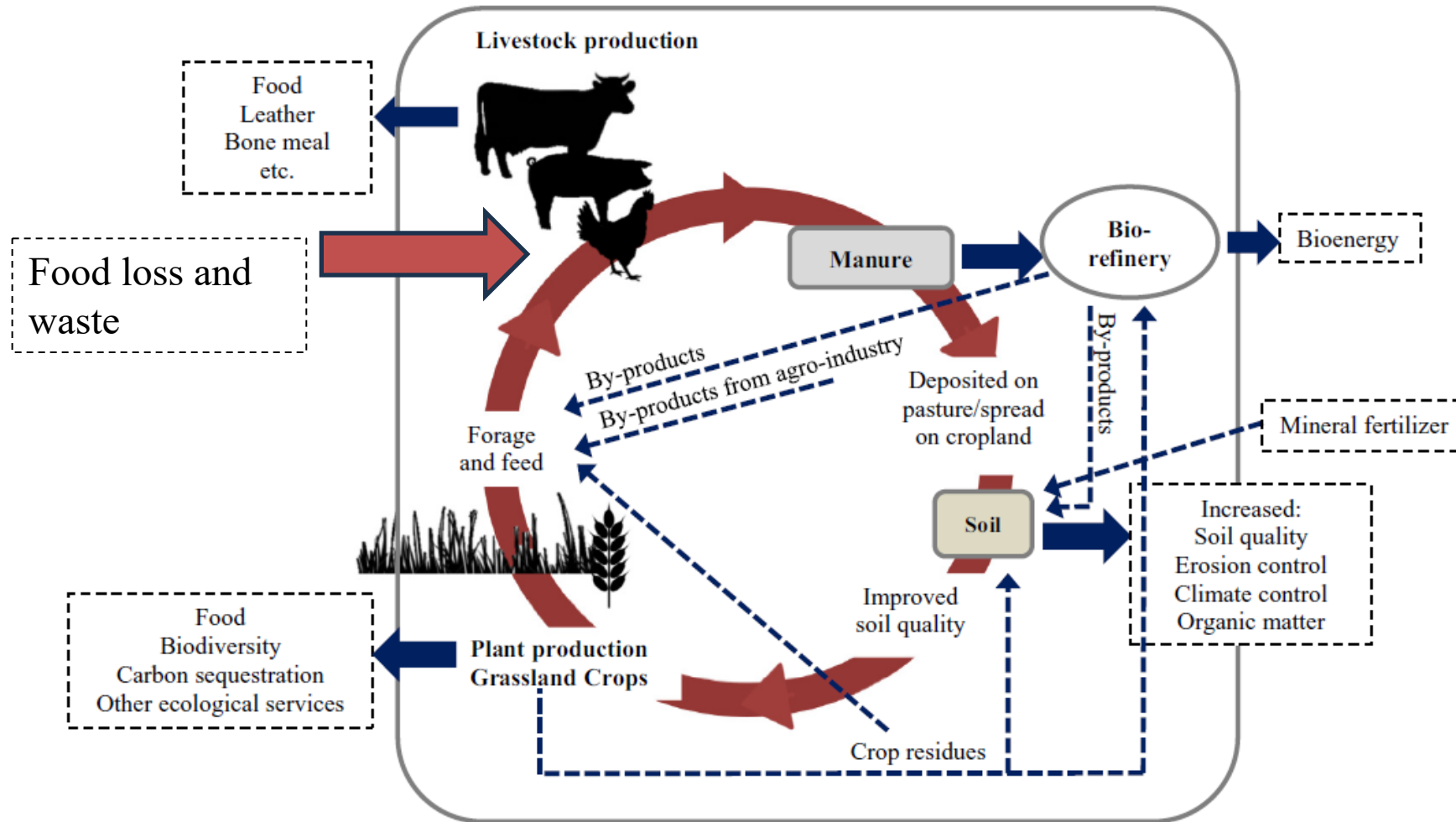
Where is food waste generated?



Opportunities to include food loss and waste in livestock diets

- Japan:
 - 40% of food waste recycled for animal feeding with the majority from manufacturing by-products
- South Korea:
 - 45% of food waste recovered as animal feed
 - Food waste dried or treated wet, with the former facilitating transportation far from processing site

Role of Livestock in Sustainable Production Systems



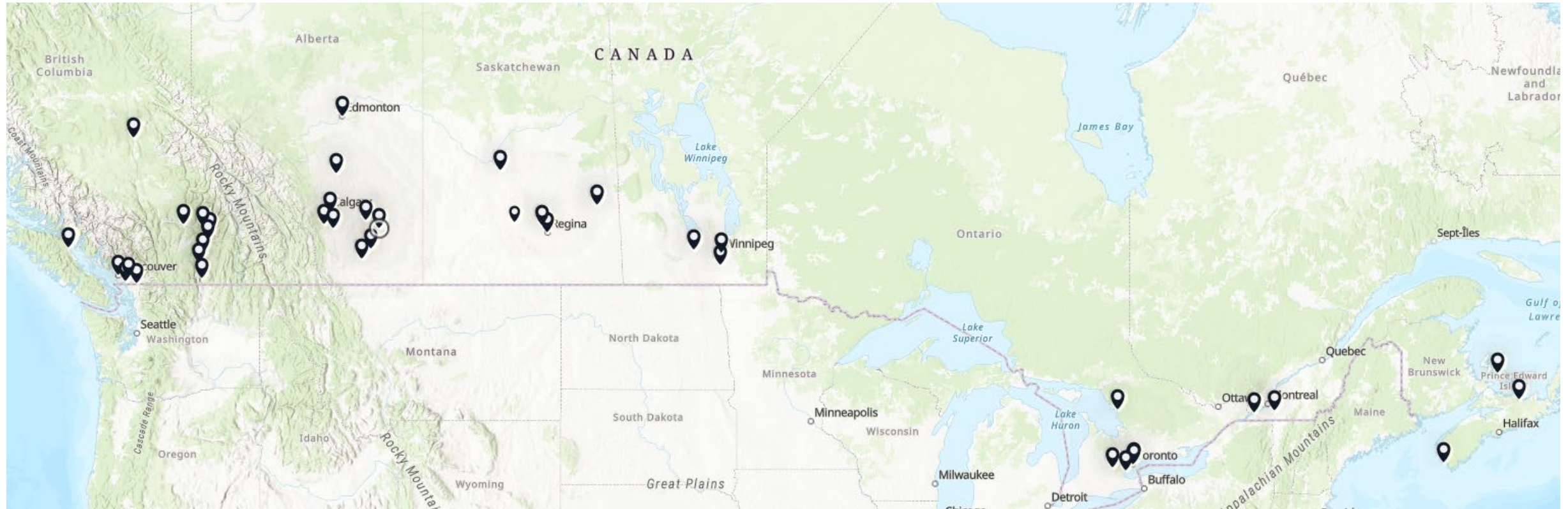
Nutrient composition of animal feed recovered from retail food waste

Nutrient composition of food waste at retail and consumption stages

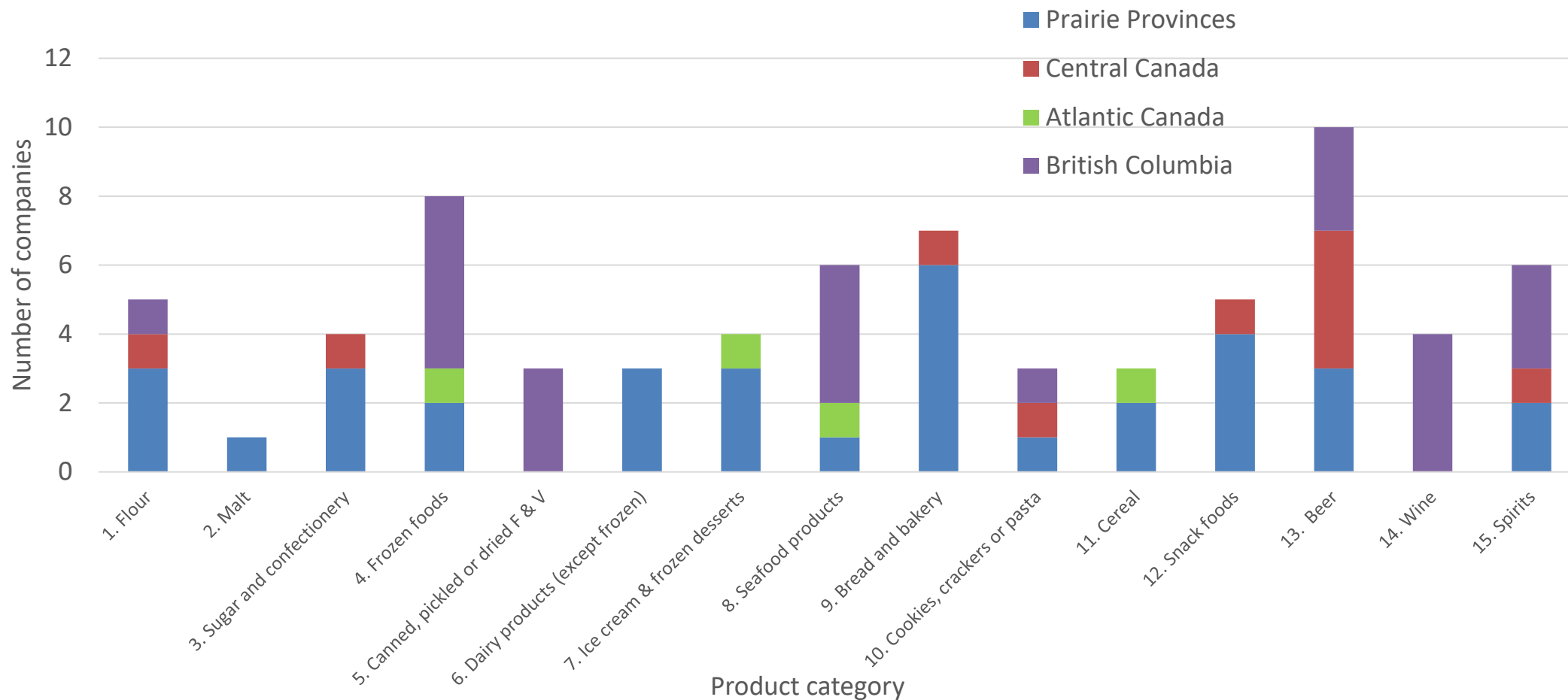
	DM%	CP%	EE%	NFE%	CF%
n	20.0	23.0	21.0	8.0	15.0
Minimum	19.1	12.9	7.0	32.3	0.8
Maximum	97.9	31.1	27.2	81.7	15.3
Mean	78.3	19.3	13.5	53.7	7.3

Rajeh et al. (2020)

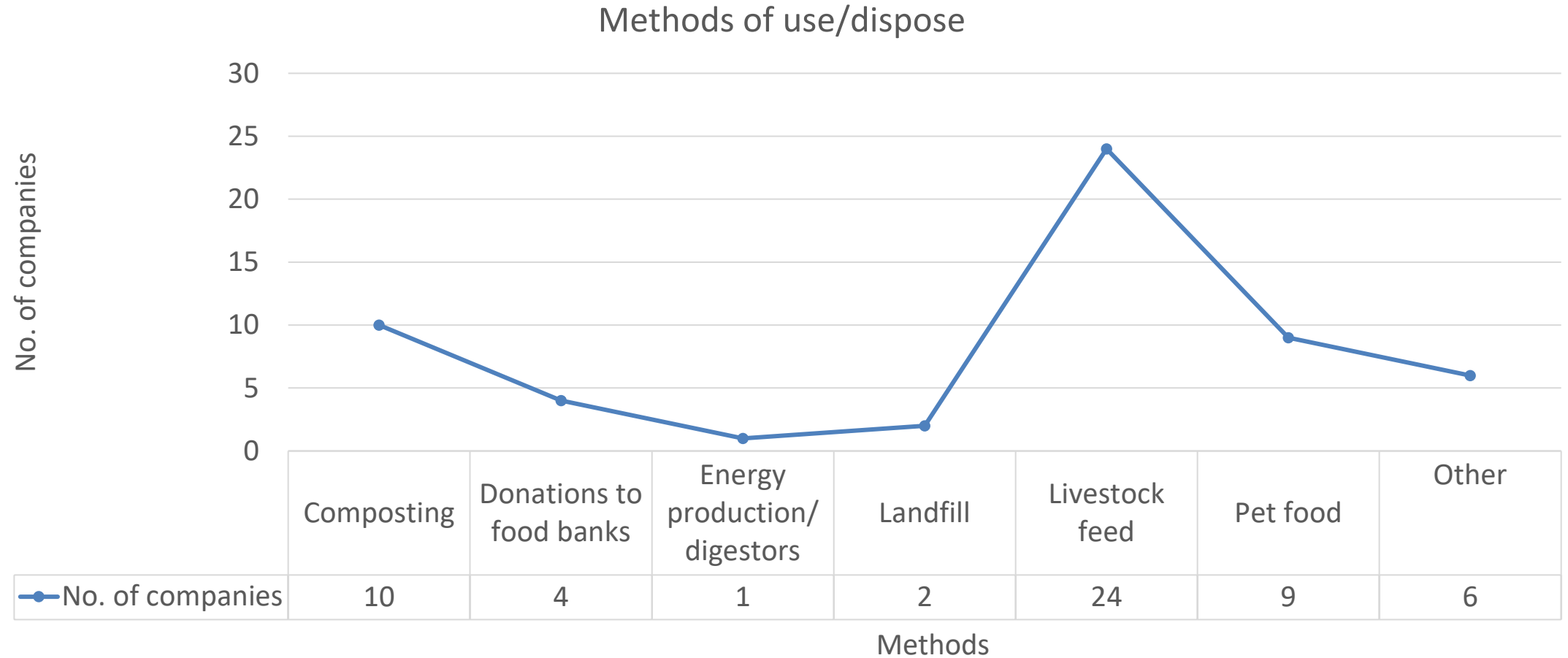
Survey of food companies producing food waste across Canada



Food loss products produced in Canada regionally differ



Current uses of food loss by Canadian food processors



Ensiling = Preserving wet materials for livestock feed

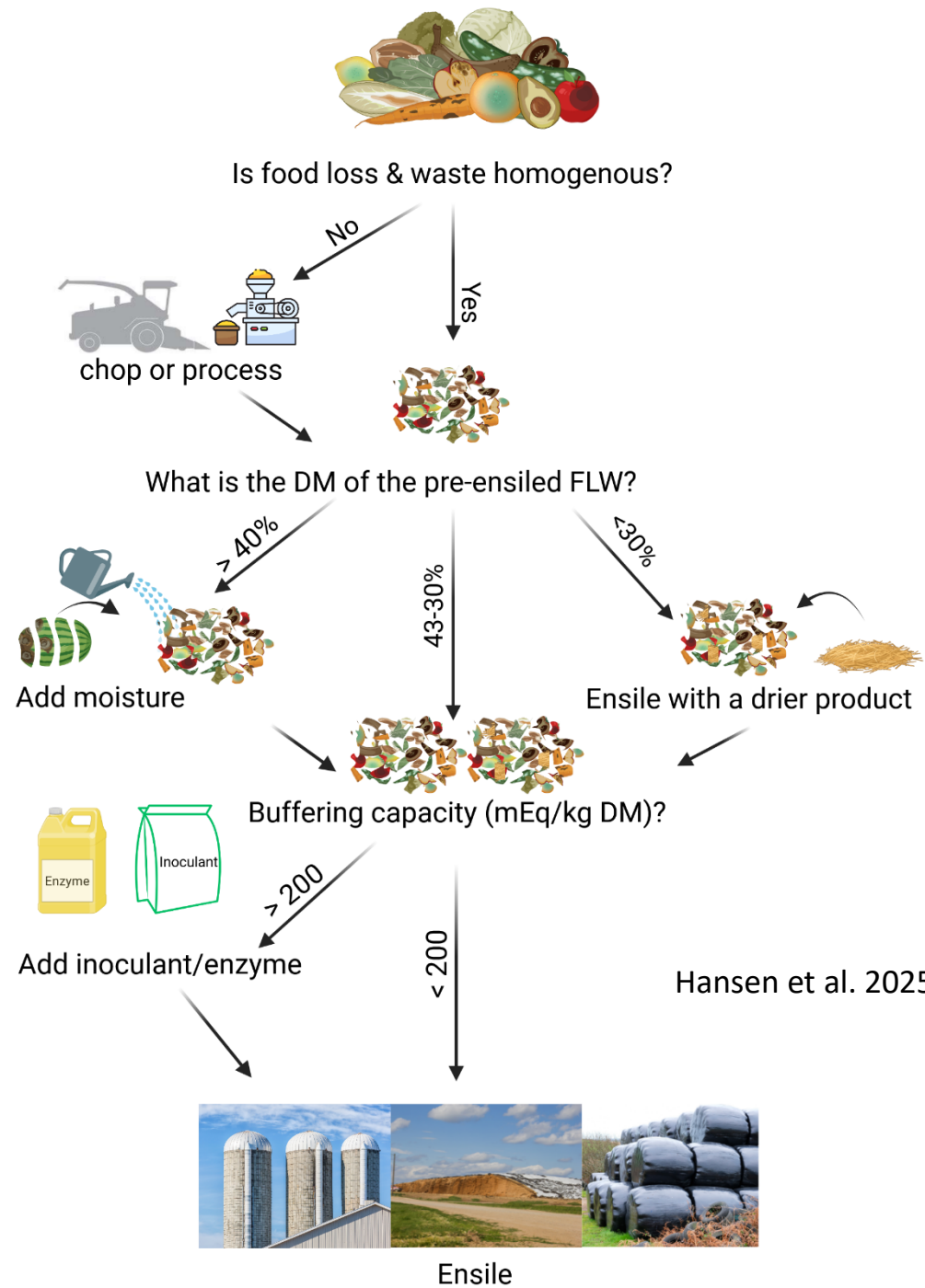
 +  MIX moist (fruits/veg) with dry (bakery) waste to create ensilable mixtures

Benefits:

- Preserve nutrients
- Reduce spoilage

Practical Barriers:

-  Irregular FLW supply & volume
-  Variable nutrient content & composition
-  Risks of toxins/anti-nutritional factors if FLW decomposes
-  Regulatory restrictions on some FLW sources



Hansen et al. 2025. Canadian Journal of Animal Science (In press).

Table 1. Fermentation characterizes after ensiling

Items	
Fruit/Vegetable * weight D0, %	59.53
Bread / Bakery * weight D0, %	40.47
DMFruit/Vegetable, %	12.53
Final Food loss Waste silage DM(D60), %	36.81
Final weight loss (D60), %	3.31
Initial pH	5.24
Final pH	3.91
Volatile fatty acids (% of FW silage DM)	
Acetic acid	2.04
Propionic acid	0.11
Butyric acid	0.01
Organic acid concentration (% of silage DM)	
Lactic acid	7.80
Succinic acid	0.35
NH ₃ (% of crude protein)	4.67
Microbial analysis (log ₁₀ CFU g ⁻¹ DM)	
Lactobacillus spp., D0	7.6
Lactobacillus spp., D60	5.3
Molds and yeasts, D0	6.5
Molds and yeasts, D60	N/D

Table 2. Feed quality of food waste silage

Item	After ensiling
Crude protein %DM	15.43
ADIN	0.52
ADF	5.22
NDF	6.67
WSC	1.23
Crude fat	6.09
Ash	5.22
Potassium	1.00
Phosphorous	0.26
Calcium	0.21
Magnesium	0.10
Sodium	0.50
Sulfur	0.16
Copper mg/kg DM	7.53
Manganese	18.40
Zinc	25.23
Iron	95.73



Small scale ensiling to assess the feed value of food loss and waste silage.



Table 1. Chemical composition of ensiled food loss and waste (% DM)						
	DM%	CP%	NDF	aNDFom	fat	OM
Apple	44.2-44.7	15.2-15.7	-	20.3-24.9	3.3-3.8	92.9-93.7
Artichoke	19	14.5	52.8	-	3	91.6
Broccoli	15.4	17.4	43	-	3.2	82.1
Carrots	28.9-35.3	5.5-8.5	41.6-44.1	45.5-49.1	4.1-4.5	-
Discarded dates	34.7-34.8	9.9-10.2	49.4-49.7	-	1.81	91
Dry tofu cake	42.6	15.2	43	-	5	92
Pineapple fruit residue	30-35	7.5	56	-	-	-
Pineapple waste	38.7	6.2	59.5	-	-	92.3
Potato hash	40.8	13.6	-	-	4.7	94.5
Pumpkins	22.4-35	5.7-8.5	43.3-43.5	46-48.2	3.8-4.3	-
Rice bran	43	11.9	42	-	8.3	90.7
Wet green tea waste	43.1	15.3	45.2	-	2.7	92.2
Cabbage and cauliflower leaves (3:1)	24.2	13.3	46.8	-	1.1	87.4
Food by-products	36.9-39.7	16-16.3	-	9.9-10.2	5.5-7.5	96.6-97
Food processing by-products	45.9-58.6	3.8-4	66.2-68.8	-	1.4-1.8	-
Grocery by-product	20.1-57.2	13.2-15.5	32.1-43.1	-	9.9-16.4	-
Grocery store food waste	36.8-38.1	15.2-15.7	6.1-7.6	-	5.9-6.3	-
Unsaleable fresh produce	11.6-23.4	7.4-18.1	-	-	1.6-8	-

Table 2. Fermentation quality and microbial analysis of ensiled food loss and waste							
	pH	Lactic acid (% DM)	Acetic acid (% DM)	Propionic acid (% DM)	Butyric acid (% DM)	NH ₃ -N (% total N)	Ethanol (% DM)
Apple	3.8-4	3.9-6.4	0.4-2.4	ND	ND	3.8-6	ND-5.2
Artichoke	4.3	4	5	-	ND	0.08% DM	1% DM
Broccoli	4.7	3	12	-	ND	0.18% DM	2% DM
Carrots	3.6-4	4.8-10.6 mM	8.0-19.8 nM	0.21-0.38 nM	0.06-0.12 nM	-	0.9-0.12
Discarded dates	3.7-3.8	5.2	1.7	0.23-.024	0.22-0.23	0.43-0.43 (% DM)	-
Dry tofu cake	4	3.3% FM	0.18% FM	ND	ND	3	-
Potato hash	4.6	6.5	0.24	<0.01	<0.01	3.4	-
Pumpkins	3.6-3.9	2.9-12.2 nM	9.0-22.5 mM	0.21-0.66 mM	0.07-0.12 mM	-	0.1-0.13
Rice bran	4-4.1	4.1	0.2% FM	ND	ND	4.5	-
Wet green tea waste	4	4	.17% FM	ND	ND	2.7	-
Cabbage and cauliflower leaves (3:1)	4.2	4.2	-	-	-	4.7	-
Food by-products	3.7	3.7	-	-	-	2.1-3.5	-
Food processing by-products	4.3	2	0.03-0.08	ND	0.05-0.06	-	-
Grocery by-product	3.9-4.6	3.3-20.7	0.4-3.8	-	-	-	-
Grocery store food waste	3.9-4	7.5-8.4	1.75-2.2	0.1-.11	0.01	4.15-4.9 (%CP)	-
Unsellable fresh produce	3.7-4.4	1.2-10.2	0.7-6.2	ND-0.9	ND	1.6	-

Table 3. Productive performance of ruminants fed food loss and waste silage.						
	Animal Type	Inclusion rate (%)	ADG (g/d)	DMI (kg/d)	Milk Yield (kg/day)	Milk fat %
Beef Cattle						
Grocery by-product	Yearling Holstein	0	-	5.59	-	-
		18.2	-	6.27	-	-
		36.3	-	6.15	-	-
		54.4	-	5.95	-	-
Pineapple waste	Growing Cattle (male and Female)	0	450	6.5	-	-
		25	540	7.7	-	-
Dairy Cattle						
Apple pomace	Multiparous lactating Holstein cows	0	-	23.8	25	3.4
		15	-	22.6	24.8	3.15
		30	-	23.7	24.93	3.32
Discarded dates (DD)	Crossbred Friesian cows	100	-	13.7-14.2	10.4-10.9	3.5-3.6
Pineapple fruit residue	Cross-bred dairy cows	0	-	12.9	13.2 (L/d)	4.1
		25	-	13	16.3 (L/d)	4.7

Table 3. Productive performance of ruminants fed food loss and waste silage.						
	Animal Type	Inclusion rate (%)	ADG (g/d)	DMI (kg/d)	Milk Yield (kg/day)	Milk fat %
Goats						
Artichoke by-product	Multiparous mid-lactation dairy goats	0	-	-	2.39	3.74
		25	-	-	2.33	3.97
		40		-	2.26	4.04
		60	-	-	1.91	4.2
Kinnow fruit residue	Male goats (8-10 mo.)	0	7.3 ⁶	0.55	24.8	3.15
		100	201 ⁶	0.56	24.93	3.32
Sheep						
Apple pomace (AP)	Suffolk wethers	100	-	0.93-1.01	-	-
Cabbage and cauliflower leaves (3:1)	Lambs (4-6 mo.)	0	110	0.33	-	-
		50	128	0.36	-	-
		100	141	0.44	-	-
Food by-products	Wethers	0	-	49.3 (g/day*BW ^{0.75})	-	-
		2% of BW DM basis	-	50.6 (g/day*BW ^{0.75})	-	-
		2% of BW DM basis	-	49.6 (g/day*BW ^{0.75})	-	-
Pineapple fruit residue	Female Rambouillet lambs (4 mo.)	0	142	1.1	-	-
		62	143	1.2	-	-

Improved sustainability from multiple perspectives



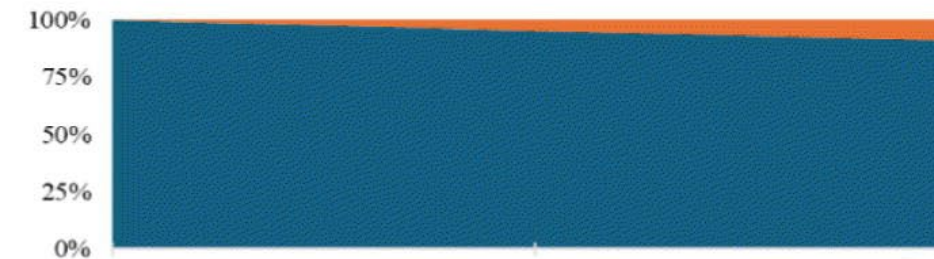
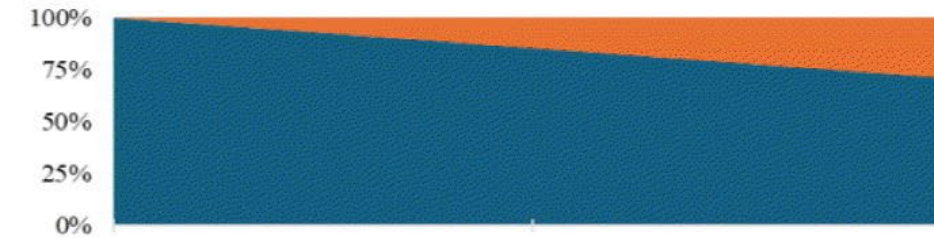
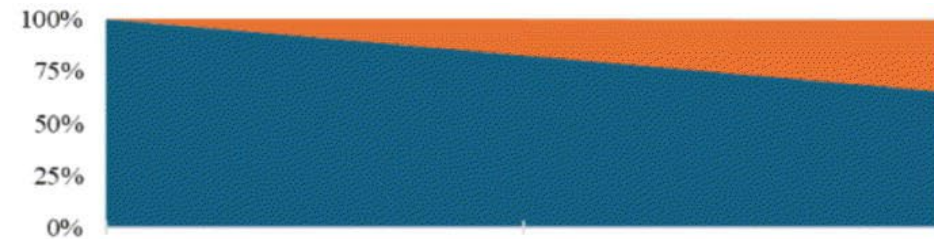
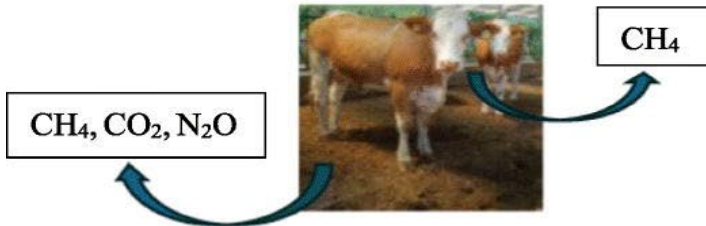
Feed conversion ratio
(kg human edible DM intake/kg beef protein)



Land use (ha/head)



Emission intensity
(kg CO₂e/kg live weight)



Decreases in
sustainability
metrics with
potato inclusion



0%

15%

30%

Dietary inclusion of potatoes in feedlot diets (DM basis)

Challenges



Economic Viability



Collection, transport, and handling of by-products and food waste may be cost-prohibitive for use in livestock diets



Some food processing by-products may be provided at little to no cost to livestock farms provided that the farms pay transportation costs and ensure timely pick-up



Food producers have made public commitments to reduce food waste including diverting surplus food for human consumption or reusing food as livestock feed, compost, or to generate renewable energy



Incentives maybe necessary to ensure the economic feasibility of recovering and recycling materials from food loss and waste, especially in the retail, restaurant, and household sectors

Regulatory Restrictions

Inclusion can be limited by regulatory policy as use of food loss and waste silage as feed in some countries requires approval by regulatory authorities.

Many novel by-products associated with new processing technologies and emerging consumer demand are not currently considered.

Existing regulations prevent or restrict use – e.g. animal based products

Policy supported by research has the potential to facilitate the safe use of food loss and waste silage.

Feed Safety

A wide range of potential contaminants can be found in by-products and food waste (mycotoxins, herbicides, fungicides, pesticide residues, pathogens, antinutritional factors (glycoalkaloids, tannins), and heavy metals as well as glass, metal, and plastic packaging (CFIA, 2019).

The high-moisture content of many fruit and vegetable by-products and food waste creates an ideal environment for the growth of bacteria and fungi that may produce toxins during decomposition.



Feed Safety

Advanced equipment are required to separate usable food waste from packaging and foreign contaminants prior to ensiling

Figure 5. Air entrainment system on compost screening

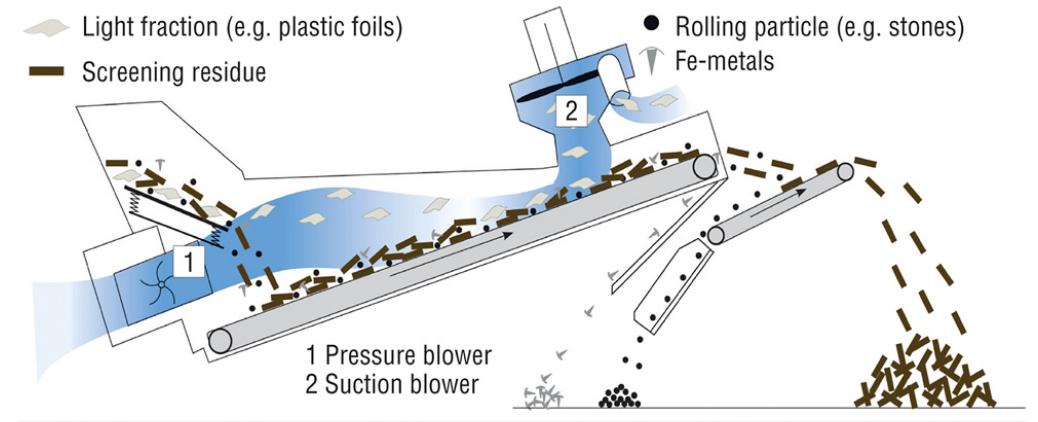
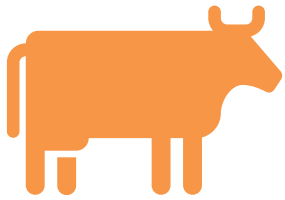


Illustration courtesy Komptech USA

Assessment of Nutrient Quality



Nutrient composition can vary considerably making it difficult to balance diets to meet livestock requirements.



Nutrient composition of these products must be measured frequently, and diets reformulated as necessary.



On farm near-infrared spectroscopy (**NIRS**) for rapid assessment of feed value, and the detection of mycotoxins and pesticides in food waste silage

Environmental Impact

Life cycle assessments (**LCAs**) have been conducted to determine the environmental implications of traditional disposal streams for food loss and waste (anaerobic digestion, landfill, and composting) compared to ensiling and their use as livestock feed.

“Up-stream” impacts along the food chain, including energy, fertilizer, water, and land use as well as greenhouse gas (**GHG**) and ammonia emissions are necessary

Environmental Impact

Trade-offs in food waste management practices:

- Energy required to dry and process food waste in centralized facilities - economically transported longer distances with reduced spoilage due to its low water content
- Ensiling reduce energy use for drying.



Conclusions

- Global assessments of food loss and waste as a percentage of food grown require a standardization approach to empower public policy change and the creation of accountability metrics that can be applied across the food supply chain.
- Redirection of food waste from landfills is necessary to improve global food security and resource sustainability issues.

Conclusions

Today's diversity of by-products and urban setting for much of our food waste requires a diversity of solutions.

Disincentives to waste food will be influenced by food prices and costs for food disposal.

Producer and processor incentives to recover more food and to redirect by-products away from landfill and nonfood recycling efforts will require investment to improve infrastructure, creating market opportunities.

Revised policy and regulation are essential to fully implement the spectrum of solutions.

Research to facilitate safe incorporation of by-products and food waste in animal feed is a critical step toward changes in policy and regulation.

Conclusions

Livestock with their capacity to “up-cycle” relatively low-quality feedstuffs into high-quality protein are an essential element of this solution.

Policy that encourages livestock producers to replace traditional human edible feeds with by-products and food loss and waste silage are needed.



The McAllister Team – thank you



Conclusions

Canada has some unique challenges:

- The large geographic area, with much of food processing and food waste occurring in large urban centers means that by-product and food waste sources are often large distances from the livestock and poultry farms.
- As a major food commodity exporter, Canada's food supply chain is heavily intertwined with multinational food processors and retailers affecting transportation costs. These companies will need incentives or regulation to shift current practices at the local or national level.



Conclusions

- As one of the world's most northerly food producers, Canada may have an advantage by using cold weather to reduce spoilage of by-products or food waste in storage to reduce storage and processing costs.
- Comprehensive LCA-type assessments are necessary to examine environmental benefits of treatment options including replacement of feed grains with by-products or food waste and the impact on the environment including GHG and ammonia emissions as well as land and water.
- A coordinated approach requiring input from producers, feed suppliers, researchers, policy makers, and retailers is critical for the development of successful strategies for inclusion of food loss and waste in livestock diets.