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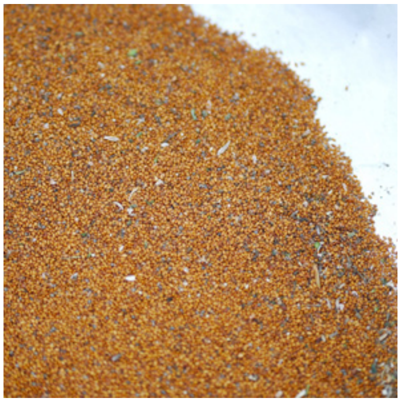

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WINTER CAMELINA

Opportunities and Challenges for Use as an Animal Feed Ingredient

MBOLD

ABOUT THIS REPORT

As part of its Protein Catalyst initiative, the MBOLD Coalition commissioned this assessment to evaluate opportunities to incorporate winter camelina into animal feed rations and contribute to the sustainability of animal agriculture through the development and inclusion of more sustainable feed ingredients. While bringing new crops to market and into animal feed rations is often a long and complex process, MBOLD is committed to building the knowledge base and exploring how crops like winter camelina can become a viable and valuable option for both farmers and supply chain stakeholders. Gaining a better understanding of winter camelina meal's safety and performance in various animal species' diets is central to this effort and to enabling camelina to scale on the landscape.

This report aims to capture the current state of knowledge on winter camelina's potential as an animal feed ingredient. The information was gathered from industry participants, researchers, animal nutrition specialists, supply chain stakeholders, and available literature. The findings aim to inform growers, agronomists, supply chain participants, policymakers, feed mills, nutritionists, and livestock operators as they evaluate winter camelina meal's potential for agricultural diversification and sustainable intensification.

MBOLD thanks its animal feed team for their feed ingredient and industry expertise which informed development of this report and for reviewing it in draft. We thank the Agricultural Utilization Research Institute (AURI) for preparing the report on our behalf and contributing research. We also thank Cargill for collaborating with us to advance winter camelina markets and for their review of the document. Lastly, our gratitude goes to Builders Vision and the McKnight Foundation for funding this assessment.

EXECUTIVE SUMMARY

Animal feed is a large and growing market opportunity for emerging crops, and that market today is predominantly comprised of soybeans, corn, and their derivatives. Even limited inclusion rates into livestock feeding programs can have a significant impact on the economic viability of crops such as winter camelina (WC).

The incorporation of winter camelina meal (WCM) depends on its nutritional profile, anti-nutritional factors, and energy content, and its cost, among other factors. Animal species vary in their ability to digest meals. Utilizing nutritionist input and feed rationing software, we found the price of mechanically pressed WCM may potentially need to be discounted between 15% and 60% relative to soybean meal (SBM) to account for camelina's nutritional profile, energy content, potential antinutritional factors, etc. Further work is needed to better understand the specific digestibility coefficients of mechanically pressed WCM for each species and valuation for incorporation into feed rations. A digestibility coefficient is the difference between the calculated or analyzed protein or energy values compared to the quantity digested or utilized by an animal.

Solvent-extracted WCM is expected to be more valuable than mechanically pressed WCM. An anticipated value improvement of at least 10 percent across species is expected due to its improved nutritional profile (lower oil/fat levels and higher protein percentage). Solvent-extracted WCM digestibility coefficients by species merit further exploration. Ways to overcome anti-nutritional factors in WCM, such as glucosinolates, are being explored via processing changes and seed-breeding programs to minimize their impact.

The WCM referenced in this report, which was produced through mechanical oil extraction, aligns with the AAFCO ingredient definition for Camelina Meal, Extracted (AAFCO OP 71.300), which specifies conditions of use including limits of up to 10% in certain poultry and beef cattle diets, subject to compositional requirements like residual oil content and specific glucosinolate content. Recent investigation into solvent-extracted WCM in 2025 in broiler chickens indicates higher inclusion rates are possible. Further animal feeding research work is needed to expand the definition of WCM.

WCM could become a competitive feed ingredient to help the livestock industry meet its sustainability goals. WCM most closely aligns with canola meal in terms of its nutritional profile.

WC is comparable with soybeans and corn today on a crop-to-crop basis regarding its carbon intensity score, but WC could bring additional system-wide benefits to improve the overall sustainability scores of rotational crops. Quantification of environmental benefits on a broader system-wide and rotational approach still needs further research.

Regulatory approvals, optimization studies, and market adoption for WCM in feed rations will be critical to delivering a positive economic return to producers and other value-chain participants to support the scaling of WC production and utilization.

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INTRODUCTION

The UN FAO estimates that by 2050 (using 2010 as a base), demand for food will grow 60% due to rising populations and income, with animal protein demand rising 1.7% per year, equating to a 70% increase in meat production, 90% for aquaculture, and a 55% rise in dairy demand (World Bank, 2025) (IFIF, 2025).

Global meat production was estimated at 365 million metric tons in 2025, and is projected to reach 406 million metric tons by 2034 (OECD/FAO, 2025) and 455 million metric tons by 2050 (FAO, 2012). This increased demand is driven by population growth (set to reach 9.6 billion by 2050), urbanization, and rising incomes (Suzuki & Pirlea, 2025) (Milford, Le Mouël, Bodirski, & Rolinski, 2019). Animal feed production already exceeded 1 billion tons, estimated at 1.4 billion tons in 2025 (IFIF, 2025), with U.S. feed production estimated at 270 million tons in 2024 (Alltech, 2025). More sustainable solutions for animal feed, which comprises a large share of animal agriculture's environmental footprint, will be important in helping reduce agriculture's emissions, along with land and water use, to enhance supply chain and planetary resilience.

Today's livestock diets rely heavily on corn and soybeans, often alongside other ingredients, such as canola and alfalfa. Soybeans and corn have achieved increased yields and production through many years of research and development that have improved their productivity and economic competitiveness as well as their sustainability profiles, yet the environmental footprint of corn-soybean production systems is an area of active discussion.

Alternative and supplemental feed sources, including winter-hardy annual crops and perennials, are grown on limited acreage and remain relatively under-researched. However, they add diversity to the landscape and diversify income opportunities for growers while also having the potential to lower the environmental footprint of agricultural production systems and animal feed. Adoption of these alternative crops in cropping systems may also improve the carbon-intensity (CI) scores of the overall crop system (including corn and soy) so that they, too, become eligible for additional low-carbon intensity (CI) market incentives,[1] while also supporting the emerging agricultural bioeconomy by supplying additional feedstocks for innovative biobased products.

This report explores the opportunities and challenges of including WCM in livestock feeds for beef, dairy, swine, and poultry (broiler chickens, laying hens, and turkeys), including nutritional, anti-nutritional, regulatory, and initial supply chain considerations. The findings are based on a combination of interviews with animal nutritionists, supply chain participant perspectives, researchers, animal feed users, feed rationing software programs, and literature reviews.

[1] Impacts on CI scores of the whole rotation include soil health and nutrient cycling, carbon sequestration, avoidance of indirect land use change (ILUC), and eligibility for incentive programs (Global Clean Energy, 2023).

MARKET POTENTIAL FOR NOVEL INGREDIENTS

New animal feed consumption data released in February 2025 (IFEEDER, 2025) indicated U.S. livestock, poultry, and aquaculture feed consumption was 284 million short tons in 2023 (excluding forages and roughages, which IFEEDER estimates to be approximately 50% of ingredient consumption). Of the non-forage and roughages fed, approximately 200 million short tons were corn-based ingredients, with the next largest ingredient being soy. Over time, corn inclusion rates have decreased, while soy-based inclusion rates have increased.[2]

Following is an example of the potential market size for WCM as an alternative ingredient for chicken (broilers) feed in the United States. Broilers consumed an estimated 61.5 million short tons of feed in 2023 (IFEEDER, 2025). If a novel feed ingredient, such as WCM, is included at a 10% rate in a broiler diet (this inclusion rate is based on the current AAFCO ingredient definition for WCM for use in broilers), it equates to 6.15 million short tons annually. This translates into millions of acres of WC production just to satisfy a 10% inclusion rate in broiler diets.

Feed markets incorporating WCM will likely develop close to where WC is grown and processed. Value-chain discussions and coordination with regional supply chain participants will be needed to determine the economic viability and feasibility of incorporating WCM. For example, Minnesota livestock consumed approximately 1.7 million short tons of soybean meal (SBM) and 230,000 short tons of canola meal in 2023, providing a snapshot of the total potential local market size to incorporate some level of WCM (Figure 1).

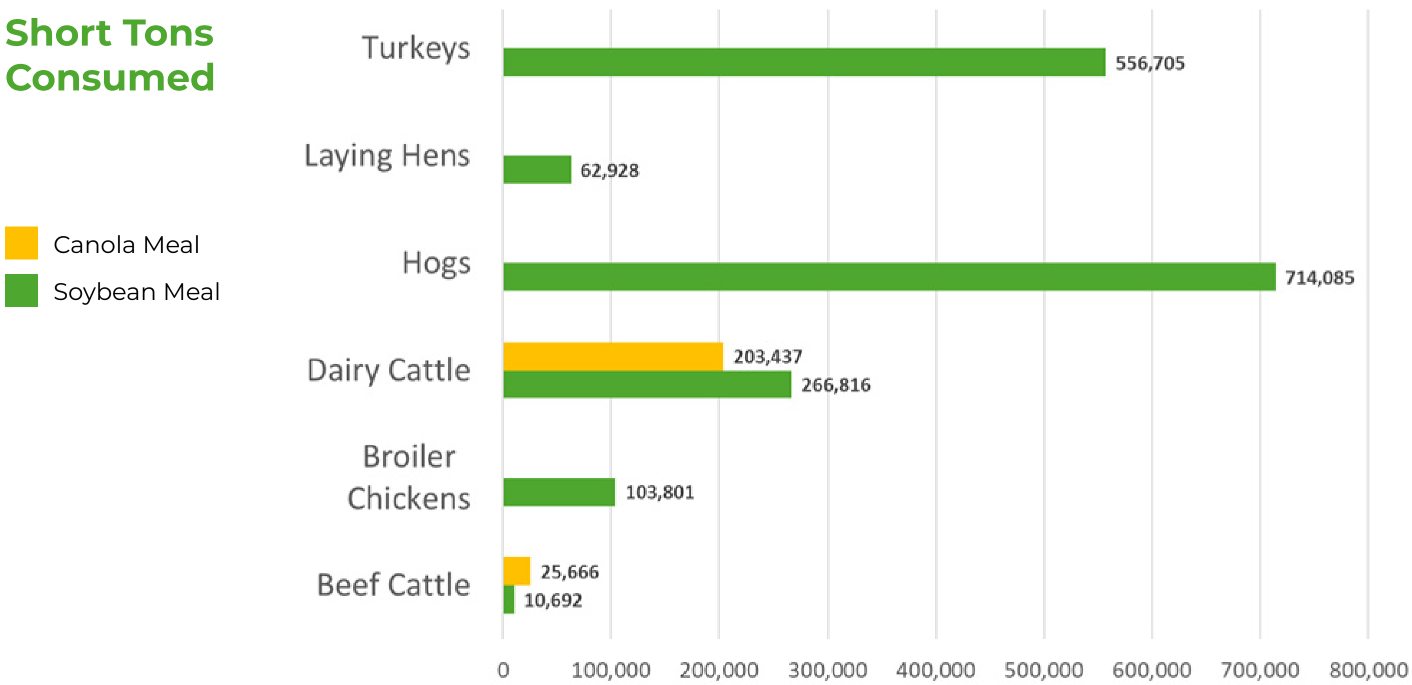

Figure 1: *Estimated Canola and Soybean Meal Consumption by Species in Minnesota, 2023 (IFEEDER, 2025)*

[2] The shift in inclusion rates is reported generally and does not specifically point to why this shift is occurring, for example, from an industry focus on biofuels and resulting additional meal available.

MARKET COMPETITIVENESS

While sustainability goals may improve consumer perception of a brand's value, price remains the main driver for decision-making by supply chain participants, along with the nutritional profile and conversion efficiency as related factors. Most alternative feed ingredients will need to be priced competitively with corn distillers dried grains with solubles (DDGs) and SBM, the standard protein in animal feeds, to work into a feed ration. Based on industry interviews, WCM would need to be priced at a discount to SBM due to its nutritional and energy profile for inclusion in feed formulations today. More detail on relative pricing by species is illustrated later in the report.

COMMERCIALIZING NOVEL FEED INGREDIENTS

AAFCO has an established ingredient definition for Camelina Meal, Extracted (AAFCO OP 71.300), for use in diets for "broiler chickens, cattle fed in confinement for slaughter (feedlot beef), and laying hens at an inclusion rate of no more than 10% of the diet (AAFCO, 2025, p. 445). These use rates and studies were based on meal produced using mechanical or cold-pressed systems. As WC production increases, processing will likely transition to efficient solvent-based extraction. Commercial solvent extraction is likely to reduce the meal's fat content, which could enable its incorporation into animal diets at higher levels.

A recent, unpublished, trial demonstrated higher inclusion of solvent-extracted WCM in broilers is possible. Ruminants are well known to be sensitive to higher levels of dietary fat. Solvent-extracted WCM could potentially enable a higher use of this ingredient in ruminant diets. Understanding the opportunities in greater detail will require additional studies and regulatory acceptance to expand the use of WCM in feed.

Commercializing novel feed ingredients is a complex and timely endeavor. Key steps include:

- **Understanding nutritional performance:** Ingredients are evaluated for their nutritional value, protein quality, fiber, energy levels, digestibility, and antinutritional factors, etc.
- **Safety assessment:** Alternative feeds are evaluated at various inclusion rates to assess safety concerns related to dietary incorporation within a specific animal species.
- **Regulatory approval: I**n the United States, in addition to the currently available regulatory pathways to gain premarket approval, a new pathway for reviewing novel animal food ingredients,[3] The Scientific Review of Ingredient Submissions (SRIS) via the Association of American Feed Control Officials (AAFCO) in partnership with Kansas State's Olathe Innovation Campus (KSO), is intended to complement the Food and Drug Administration's (FDA) current Generally Recognized as Safe (GRAS) designation. Regulatory pathways can be lengthy, costly, and complex, especially when international harmonization is lacking.[4]
- **Optimization assessments:** Feed will also be evaluated for its efficiency in different species at various rates and at different life stages to minimize costs and maximize performance, while also taking into consideration the matrix effects including the presence of fiber components, antinutrients, etc.

[3] AAFCO has introduced a new animal food ingredient review process after its memorandum of understanding with FDA expired in October 2024. AAFCO does not approve, certify, or endorse any animal food products, and ultimate authority for regulating substances used in animal foods lies with the FDA and states. AAFCO has partnered with KSO to create the SRIS program under an initial three-year agreement. In the new AAFCO process, KSO assumes the role previously filled by the FDA's Center for Veterinary Medicine and replaces AAFCO's previous Ingredient Definition Request process (Won, 2025)

[4] For example, discrepancies in the approval and classification of the pelleting aid lignosulfonate—used to improve feed texture and reduce dust—have created barriers to global market entry. While lignosulfonate is approved in the U.S. as a feed ingredient, its classification and data requirements vary significantly across jurisdictions such as the EU, Canada, and China, complicating international trade and regulatory compliance.

Alongside regulatory clearance and commercial validation, market development is critical. This includes feeding trials, processing demonstrations, safety assessments, performance testing in end-use applications, and targeted engagement with stakeholders such as processors, manufacturers, retailers, and consumers. Collaborations with industry partners, academic institutions, and early adopters help generate the data and case studies needed to build confidence across the value chain. Certifications and third-party verifications can further enhance credibility and market access, thereby accelerating trial and adoption.

At every stage of this process, economic considerations shape stakeholder decisions and influence adoption. Farmers assess return on investment and risk; processors evaluate throughput costs and infrastructure needs; regulators consider safety and regulatory compliance; retailers and end-users weigh price-performance tradeoffs and market positioning. Understanding these dynamics is essential to aligning incentives and ensuring the crop's long-term success across the supply chain (National Institute of Food and Agriculture, 2025).

CARBON INTENSITY

Feed efficiency is a key variable of interest to the livestock industry and one that holds great potential in reducing greenhouse gas (GHG) emissions. Carbon intensity (CI) and GHG emissions are the metrics by which most sustainability goals are reported and measured against. WC holds potential to increase carbon capture, as it adds living cover to the soil in the autumn, winter, and spring months when the soil would otherwise be bare in a typical crop rotation system.

Determining the CI score of WC grown under various conditions and practices remains a work in progress. A 2025 study (Berti, Morocho-Lema, Anderson, & Lizarazo-Torres) indicates that the use of a single CI score to estimate WC oil-based jet fuel will not be comprehensive and is highly impacted by yield and nitrogen application rates[5] under varying scenarios. There is strong evidence that higher WC yields and more efficient fertilizer applications could consistently improve CI scores and provide a net benefit for WC production systems compared to monocrop systems.

Because WC is intended to be utilized on the same crop land as other conventional row crops during a typical bare-plot, post-harvest period (fall through spring in northern climates), it can create additional value and increase net output on the same acreage. This not only avoids the transition of new land to crop production (avoidance of indirect-land-use-change), but it can also be seen as an enhancement to the overall cropping system, as opposed to a replacement or substitution in existing crop production systems.

MBOLD contracted the consulting firm LEIF, LLC in 2025 to conduct a literature review of current data comparing WC production to traditional monocrop systems consisting of corn and soybeans.[6] The Midwest mean CI score on a crop-only basis (i.e. not grown in a relay rotation with soy) indicates that current average emissions are roughly similar across all three crops: WC scores at 0.40 (kg CO_2e[7]/kg seed) while corn and soy emissions were 0.42 (kg CO_2e/kg grain) and 0.41 (kg CO_2e/kg soybean) respectively.

[5] Nitrogen application rates should be below 40 kg N ha^{-1} to minimize CI due to N fertilizer and N_2O emissions (Berti, Morocho-Lema, Anderson, & Lizarazo-Torres, 2025).

[6] See https://www.mbold.org/news-resources/winter-camelina-environmental-agronomic-insights

[7] CO_2e refers to carbon dioxide equivalent, "a metric used to compare the emissions from various greenhouse gases based on their global warming potential (GWP). GWP is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon relative to carbon dioxide. It is a way of normalizing the fact that different GHGs have different physical properties. CO_2e is expressed as a function of the amount of a gas, its GWP, and the time period considered. It allows for a common basis for comparing the potential future impact on global warming of emissions of different gases" (Arbor, 2025).

While this may be a surprising finding, it is a logical outcome when comparing on a crop-to-crop basis. Many of WC's environmental benefits are better attributed to a systems approach in which it is used in a relay system with corn and soybeans to achieve desired sustainability goals such as biodiversity, water quality, soil health, pollinator presence, reduced wind and water erosion, and other environmental factors. Incorporating a winter relay crop, such as WC, can bring many qualitative environmental benefits, but more research is needed to quantify the holistic CI improvements in a rotational systems approach that incorporates WC.

REGULATORY CONSIDERATIONS

In 2025, MBOLD and MBOLD member Cargill jointly funded a controlled feed safety trial study that evaluated solvent-extracted WCM at 10%, 20%, and 30% inclusion rates in broiler chicken diets. This unpublished and non-peer reviewed research indicates a potential use case to include 'up to' a 20% inclusion rate for solvent-extracted WCM in broilers and is based on the specifications for the meal as tested. The outcome aligns with research that incorporated low-fat (<5% fat) meal into broiler diets (Yalçın, et al., 2025) (Aziza, Quezada, & Cherian, 2010). This published research indicated no safety-related outcomes at the maximum level investigated of 25%. Use rates of WCM could be higher if the incorporation rates and safe use are approved based on the overall content of substances of concern such as glucosinolates.

MBOLD and Cargill also co-funded a literature review focused on WCM safety across multiple animal species to provide insights into different species' safety and efficacy in response to feeding WCM and to identify any knowledge gaps and potential research needs to guide next steps in advancing a regulatory approach. Multiple published studies exist for mechanically extracted WCM across various animal species, but fewer exist for low-fat meal, which would be more comparable to solvent-extracted processing. Following is a table from this unpublished report by Food Edge Solutions (2025) indicating safety threshold inclusion rates and practical threshold guidance for different species:

Species	Safety Threshold
Poultry	Inclusion level of 11% to 32% depending on camelina meal glucosinolates concentration with a goal of less than 5.2 micro moles per gram dietary glucosinolates
Swine	Feeding camelina meal up to 18% in nursery diets and 15% in grower finisher diets did not result in changes that would indicate toxicity, but practical inclusion levels may be limited unless taste characteristics that may result in feed aversion are addressed in dietary formulation.
Ruminants	Inclusion levels of up to 14% camelina meal

Table 1: *Safety-related dietary inclusion thresholds for solvent-extracted camelina meal with low residual oil concentration (<5%)*

FUNCTIONAL OVERVIEW OF WINTER CAMELINA AS A FEED INGREDIENT

Nutritional Profile

As part of this report, AURI explored the potential for WCM to be incorporated as a supplemental ingredient in traditional feed rations that utilize corn and SBM as base ingredients, along with other feed ingredients currently used by industry. Based on this research, we believe that as of now WCM is unlikely to be a one-for-one replacement for SBM, and to a lesser extent corn dried distillers' grains (DDGs) due to its nutritional profile and lower protein content, higher fiber content, anti-nutritional factors, and quality characteristics. However, WCM could be incorporated into a blend of various ingredients to meet the nutritional and energy needs of specific animal diets.

Three main nutritional considerations for an alternative protein source are:

1. Protein (digestible amino acids)
2. Energy
3. Phosphorus

Since amino acids form the foundation of proteins, it is crucial to understand the amino acid composition of any protein source to evaluate protein quality and ensure an animal's diet is well-balanced to support optimal growth, development, and the overall health of an animal. Additionally, information on nutrient digestibility estimates, including amino acid digestibility, is critical in optimized and meaningful feed formulation to incorporate WCM in practical diets.

AURI conducted interviews with 11 nutritionists from U.S. animal feed manufacturers, livestock feed end-users, and researchers with varying backgrounds and expertise in animal nutrition. In addition to their expertise, nutritionists typically use ration-balancing software to optimize ingredient mixes against nutritional and energy targets by species. These programs provide valuable insights into the desired percentage and costs to optimize outcomes. These models can also be forced to theoretically accept an ingredient and provide valuations on the price point needed to work into a feed ration.

Findings from those interviews and ration modeling program results regarding the inclusion, performance attributes, barriers, and relative pricing of WCM into a species-specific diet are highlighted below and are based on market conditions from the summer of 2025.

AURI provided the following nutritional profile for mechanically pressed WCM (Table 2) to nutritionists to model and hypothesize which species would be the best targets and which price points and inclusion rates would be viable against other commonly used feed ingredients. The WCM is from a mechanically pressed system that was analyzed by AURI, although we note that solvent extracted meal will likely be used as camelina acreage expands leading to a more favorable nutritional profile and improved value.

Nutritional Analysis	Measurement	Winter Camelina Meal	Amino Acid Analysis	Winter Camelina Meal W/W% (DM)
Moisture	%	12	Aspartic Acid	3.08
Dry matter	%	88	Threonine	1.26
Crude Protein	% DM	38.1	Serine	1.36
Fat	% DM	4.1	Glutamic Acid	6.3
Fiber	% DM	17.6	Proline	1.82
Ash	% DM	6.6	Glycine	2.36
Sulfur (total)	% DM	0.84	Alanine	1.75
Phosphorus (total)	% DM	1.11	Cystine	0.66
Potassium (total)	% DM	1.51	Valine	1.8
Magnesium (total)	% DM	0.59	Methionine	0.56
Calcium (total)	% DM	0.55	Isoleucine	1.17
Sodium (total)	%DM	0.1	Leucine	2.22
Iron (total)	ppm (DM)	166	Tyrosine	0.95
Manganese (total)	ppm (DM)	36.5	Phenylalanine	1.34
Copper (total)	ppm (DM)	11.9	Lysine	1.51
Zinc (total)	ppm (DM)	60.9	Histidine	0.78
Net Energy (Lactation)	Mcal/lbs.	1.0	Arginine	3.2
Metabolizable Energy	Mcal/lbs.	1.7	Tryptophan	0.41
Digestible Energy	Mcal/lbs.	1.9		

Table 2: *Analytical Data for Mechanical Pressed Winter Camelina Meal (AURI, 2025)*

Market conditions, digestibility coefficients, relative pricing of other feed ingredients, processing pathways, energy values, nutrients, fiber, genetic changes, anti-nutritional factors, etc. will all have an impact on valuations of feed ingredients.

The following section is based on the quality factors in Table 2, 2025 pricing levels for soybean meal, and the book value inclusion for energy, nutrition, and fiber without utilizing a digestibility coefficient. Valuations will vary based on market conditions, and the estimates below provide a snapshot of potential valuations for mechanically pressed camelina meal without incorporating a digestibility coefficient, as one was not readily available at this time to incorporate into the calculations. Dialogue with several industry participants and researchers indicated WCM would likely be benchmarked against canola meal.

Poultry

- Nutritional density[8] is especially important in poultry due to the relatively high nutritional demands relative to other species. A poultry diet is formulated to be high in protein.
- There are potential concerns related to amino acid inhibitors (and glucosinolates) in mechanically pressed meal.[9] It is anticipated that a solvent-based extraction process will minimize and potentially eliminate these concerns, but additional research is needed to verify this approach and outcome.
- To incorporate mechanically pressed WCM into a poultry diet, it would likely need to be discounted relative to SBM to price at approximately 45% of SBM value[10] in turkey diets, around 50% of SBM value in layer hen diets, and 40% of SBM value in broiler diets.

Swine

- In a swine finishing diet, WCM displaces corn DDGs, and, to a lesser extent, some high-protein SBM.[11] This is due to reduced amino acid levels in WCM meal, specifically lysine, the first limiting amino acid in swine diets. DDGs are also limited in this amino acid, which is why they can be most easily displaced with WCM. Secondly, mechanically pressed WCM is high in unsaturated fat, similar to DDGs, which can present challenges, such as soft marbling, when used in swine finishing diets.
- To be competitive in a swine-finishing diet, mechanically pressed WCM would need to be valued at approximately 70% of SBM value. The WCM valuation in swine finishing diets is due to its lower amino acid and energy content when compared to SBM.
- Swine diets vary in nutritional needs based on the animal's growth stage; inclusion amounts will differ by stage of growth due to varying nutritional and energy needs.

Beef or Dairy

- Beef requires the lowest level of protein supplementation beyond its base diet (approximately 2-5lb of protein/head/day), which often consists of a least-cost ration, including corn silage, grass hay, alfalfa hay, and mineral supplementation.
- In standard beef diets, a roughly 25% discount to SBM is needed for mechanically pressed WCM. The WCM would mainly compete with wet distiller grains or DDGs, which are the most economical protein source for most beef diets.
- In dairy, based on preliminary sensitivity analysis, ration balancing software includes mechanically pressed WCM at around 5lbs/head/day if priced at an estimated 15% discount to SBM.
- However, more research is needed to understand digestibility, levels of undegradable protein (bypass), and degradable protein effects in the rumen.

Aquaculture via Mealworms

- As of 2025, feeding trials were underway with a Minnesota-based aquatic species producer, utilizing WCM as a feed ingredient to increase the fatty acid (FA) and omega-3 content of mealworms that are fed to farmed finfish.

[8] Nutrient density for livestock refers to the concentration of essential nutrients—such as protein, vitamins, and minerals—relative to the feed's energy (or calorie) content. This measure helps define the nutritional value of a feed and how efficiently it supports animal health, growth, and performance. A feed with high nutrient density provides a substantial amount of beneficial nutrients without an excess of calories (Jia, Lei, Dong, Guo, & Zhang, 2024)

[9] If meal comes from mechanical pressing, an additional heat-treatment step would be required to limit these ANFs.

[10] For example, in a turkey diet, if SBM costs $300/ton, WCM would be valued at $135/ton, or 45% the value of SBM.

[11] High-protein soybean meal (Hi-Pro SBM) and regular soybean meal differ primarily in their protein content, with high-protein meal typically containing 47-49% crude protein compared to the 43-44% found in regular meal. This difference arises from the removal of hulls (outer layers) during processing of high-protein meal (Menegat, et al., 2019)

Species Summary

- A digestibility coefficient was not used to arrive at the estimated valuation levels by species. Estimated values were based solely on the quality or book value of the mechanically pressed WCM meal listed in Table 2, and SBM pricing in 2025. This assumption of 100% of nutrients fed being absorbed was used since no digestibility coefficient was readily available at this time. Nutritionists reported that dairy would have the best valuation, at an estimated 15% discount to SBM, while broiler diets would likely see the highest discounts of around 60% to SBM. WCM does not currently have AAFCO definition for use in dairy cattle.
- Solvent-extracted WCM would likely see reduced discounts relative to SBM due to the positive improvements in the nutritional profile and reduction of anti-nutritional factors. The price improvement for solvent-extraction WCM over mechanically pressed meal is expected to be around 10 percentage points.
- As WC production increases, processing will likely transition to a solvent-extraction process.
- It is important to note that aside from nutritional performance and price competitiveness, WCM utilization in animal diets will depend on a reliable and adequate year-round supply.
- Many nutritionists and researchers drew parallels to canola on WCM opportunities.

INTERPLAY BETWEEN MARKETS FOR WINTER CAMELINA OIL AND MEAL

The market opportunity for WCM will be based on the oil value, meal value, and other less quantifiable attributes. A significant demand-pull for winter oilseeds like WC is likely to be biofuels. Renewable diesel markets are well-established and are expected to have strong demand for the foreseeable future.

Growing interest in sustainable aviation fuel (SAF) is also driving interest in winter camelina oil as a potential feedstock. SAF is expected to be a driver for increasing WC production, although camelina demand and the attractiveness for camelina producers will ultimately be influenced by the price and availability of SAF made from other feedstocks and technologies, as well as the evolution of WCM's CI scores given future improvements to breeding, yields, soy yield lag, and other factors.

Developing markets for the meal will be critical to camelina's overall economic competitiveness and resulting market adoption. For this reason, it is imperative that WCM utilization is identified and developed to achieve the crop's overall value potential. Incorporation into animal diets, where analogous oilseed crops, such as canola have found success, is a pathway for WC to follow.

CONCLUSIONS AND RECOMMENDATIONS

More work is needed to position WCM in the feed market. While a definition exists for extracted WCM, there is an opportunity to expand the definition using WCM that has been bred for lower antinutritional factors and processed in commercial crush plants using solvent-extraction processes. New, commercially relevant feeding research can be completed as commercially produced, low-fat WCM becomes widely available. Expansion of the definition will take time and resources, as each species and use case requires its own research plan.

Price competitiveness against SBM and DDGs, palatability, anti-nutritional factors, nutritional performance, and consistent supply are hurdles to incorporating WCM into animal diets. WCM will need to meet or exceed the performance of current feed ingredients or be priced at a discount to SBM and DDGs to gain inclusion in feed rations.

From a CI score level, WC performed similarly on a crop-to-crop basis with corn and soybeans, but other environmental attributes from a rotational and systems approach are promising but not well quantified to illustrate system-wide benefits. While price and performance are key attributes for market adoption, better quantification of the environmental benefits that contribute to environmental goals along the supply chain will support decision-making and incorporation into feed rations.

Recommendations

The following are recommended next steps:

- Following promising results from the 2025 broiler safety assessment for solvent-extracted meal funded by MBOLD and MBOLD member Cargill, additional feeding trials will be needed to determine the digestibility coefficient and optimum WCM inclusion rates for practical diets of broilers.
- The nutritional assessment and valuation of mechanically pressed WCM indicate the highest market return in dairy rations. Industry stakeholders should consider collaborating to co-fund safety trials in dairy with low-fat solvent-extracted WCM to develop this market opportunity.
- As more feeding research is completed, additional analysis will be needed to determine the fair market price of solvent-extracted WCM relative to alternative feed ingredients.
- Minimizing or eliminating anti-nutritional attributes, such as glucosinolates, through processing, treatments, and crop breeding could accelerate the adoption of WCM into animal diets.
- More insight is needed to better understand the full scope and timeline of how quickly scaling could occur for other market opportunities, such as biofuels, which can drive WCM supplies for use in animal diets.

WCM can be incorporated into animal diets at varying levels and price points, but industry collaboration is needed to advance key work areas and outputs to improve industry knowledge and accelerate WCM's market adoption. Aligning around the best commercialization pathways to minimize resource needs, leverage various funding sources, and accelerate overall regulatory acceptance and optimization efforts are key areas for deeper investment and coordination.

REFERENCES

AAFCO. (2025). Official Feed Terms, Common or Unusual Ingredient Names and Ingredient Definitions. In AAFCO, & E. Bubb (Ed.), *AAFCO Official Publication* (pp. 341- 547). Champaign, IL: Association of American Feed Control Officials. Retrieved from Association of American Feed Control Officials: https://www.aafco.org/wp-content/uploads/2026/01/2025_ OP_Chapter_6_enc.pdf

Alltech. (2025, April 30). *Global feed production rebounds in 2024*. Retrieved from Feedstuffs: https://www.feedstuffs.com/agribusiness-news/global-feed-production-rebounds-in-2024

Arbor. (2025, May 25). *What is a CO_2 Equivalent (CO_2e)?* Retrieved from Arbor: https://www.arbor.eco/blog/what-is-a-co2-equivalent-co2e-carbon-101

Aziza, A., Quezada, N., & Cherian, G. (2010). Antioxidative effect of dietary Camelina meal in fresh, stored, or cooked broiler chicken meat. *Poultry Science*, *89*(12), 2711-2718. doi: https://doi.org/10.3382/ps.2009-00548

Berti, M. T., Morocho-Lema, M., Anderson, J. V., & Lizarazo-Torres, C. (2025). Nitrogen rates affect seed yield and carbon intensity in spring and winter camelina. *Industrial Crops and Products*, *233*. doi: https://doi.org/10.1016/j.indcrop.2025.121473

FAO. (2012). *World agriculture towards 2030/2050: the 2012 revision.* Rome: Food and Agriculture Organization of the United Nations. Retrieved from https://www.fao.org/4/ap106e/ap106e.pdf

FAO. (2025). *Meat Market Review: Emerging trends and outlook in 2025.* Rome: Food and Agriculture Organization of the United Nations. Retrieved from https://openknowledge.fao.org/server/api/core/bitstreams/1014ce90-efe7-40ac-b4bb-408adbdf1111/content

Global Clean Energy. (2023, June 6). *Purpose Grown Energy Crop: Camelina sativa.* Retrieved 2025, from https://www. energy.gov/sites/default/files/2023-06/beto-01-energy-crops-saf-d2-3x5-june-2023-bernstein.pdf

IFEEDER. (2025). *Animal Feed Consumption Report*. Retrieved from https://www.ifeeder.org/news/releases/ifeeder-releases-new-animal-feed-consumption-data/

IFIF. (2025). *International Feed Inudstry Federation Annual Report 2024/25.* Luxembourg: IFIF. Retrieved from https://ifif. org/about/annual-report/

Jia, M., Lei, J., Dong, Y., Guo, Y., & Zhang, B. (2024, December 5). The Interactive Effects of Nutrient Density and Breed on Growth Performance and Gut Microbiota in Broilers. *Animals*, *14*(23), p. 3528. doi: https://doi.org/10.3390/ani14233528

Menegat, M., Goodband, R., DeRouchey, J., Tokach, M., Woodworth, J., & Dritz, S. (2019). *Kansas State University Swine Nutrition Guide: Protein Sources for Swine Diets.* Manhattan, KS: Kansas State University. Retrieved from https://www.asi.k-state.edu/extension/swine/swinenutritionguide/pdf/KSU%20Protein%20Sources%20for%20Swine%20Diets%20fact%20sheet.pdf

Milford, B., Le Mouël, C., Bodirski, B., & Rolinski, S. (2019). Drivers of meat consumption. *Appetite*, *141*, 104313. doi: https://doi.org/10.1016/j.appet.2019.06.005

National Institute of Food and Agriculture. (2025). *Economics of Specialty Crop Production and Distribution.* USDA Research, Education, and Economics Information System. Retrieved from https://portal.nifa.usda.gov/web/crisprojectpages/1024582-the-economics-of-specialty-crop-production-and-distribution.html

OECD/FAO. (2025). *OECD-FAO Agricultural Outlook 2025-2034.* Paris and Rome: OECD and FAO. Retrieved from https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/07/oecd-fao-agricultural-outlook-2025-2034_3eb15914/601276cd-en.pdf

Won, C. (2025, June 12). *New Animal Food Ingredient Review Process Touts "Twice as Fast" Scientific Evaluation.* Retrieved from AVMA News: https://www.avma.org/news/new-animal-food-ingredient-review-process-touts-twice-fast-scientific-evaluation

World Bank. (2025, July 11). *World Population Day: trends and demographic changes.* Retrieved from World Bank Data Blog: https://blogs.worldbank.org/en/opendata/world-population-day--trends-and-demographic-changes

Yalçın, S., Ramay, M., Yalçınkaya, H., Kardoğan, Ö., Erkurt, A., Kılınç, B., . . . Kocadaş, E. (2025). *Evaluation of high levels of solventextracted Camelina sativa meal in diets on performance, blood indices, cecal microorganisms, and nutrient digestibility in broilers.* Tropical Animal Health and Production, 57(2), 100. doi: https://link.springer.com/article/10.1007/s11250-025-04339-1

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