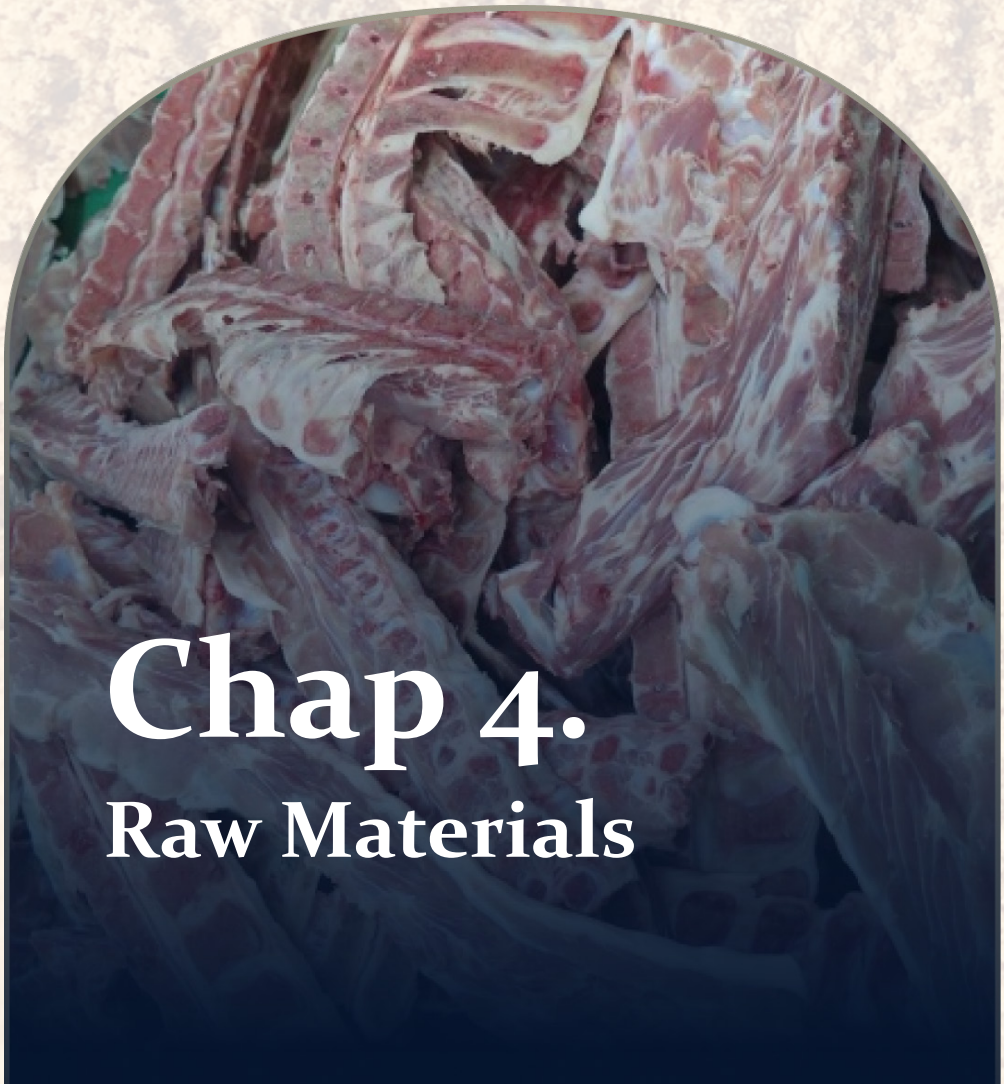


Chap 4.
Raw Materials

Introducing
Chapter 4

The rendering industry is responsible for collecting and processing animal by-products generated from various sources such as slaughter facilities, meat-processing plants, and butcher shops. These by-products consist of inedible or non-utilized tissues from livestock and poultry species, including cattle, swine, poultry, and fish, that are not used for human consumption.

WHAT YOU WILL DISCOVER IN THIS CHAPTER:

1. Origin of Rendering Raw Materials: You will identify which animal parts (from cattle, swine, poultry, and fish) are directed to the animal recycling stream from slaughterhouses, meat-packing plants, butcher shops, and other collection points.
2. Yield by Species: You will analyze the percentage of total live weight from each species that can be recovered and converted into rendered products, and how these yields vary by species.
3. Critical Collection Factors: You will explore the key operational and sanitary elements that impact the efficiency and safety of raw material collection, including:
    - Decomposition and spoilage timelines
    - Transportation and storage conditions
    - Biosecurity risks and cross-contamination prevention

To fully understand the spectrum of raw materials in the rendering industry, it is essential to distinguish between two primary operational models: **integrated rendering plants (packer renderers)** and **independent rendering plants (independent renderers).**

Integrated renderers operate as part of a vertically integrated meat-processing business, receiving raw material directly from their own slaughter and fabrication operations. This vertical alignment provides a controlled, continuous, and internal supply chain, integrating most stages of the rendering value chain.

Key Characteristics:

- Located within or adjacent to a slaughterhouse or meat-processing facility
- Processes exclusively (or primarily) by-products generated in-house
- Steady and predictable raw-material flow
- Minimal variation in raw-material quality due to controlled sourcing
- Rendering operations synchronized with slaughter schedules
- Focus on internal efficiency, cost control, and sanitary compliance

Advantages:

- Higher raw-material freshness (less degradation/spoilage)
- Reduced collection and transportation requirements
- Lower operating costs due to vertical integration

Limitations:

- Limited flexibility to receive third-party materials
- Processing capacity tied to the meat operation's slaughter volume
- Operational capacity is directly dependent on the facility's internal slaughter schedule and throughput

In contrast, **independent renderers** specialize solely in the collection, transport, and processing of animal by-products sourced from multiple external suppliers. These plants serve as essential regional circular-economy and biosecurity hubs, recovering materials from sources such as slaughterhouses, deboning plants, butcher shops, supermarkets, and, in the case of used cooking oils (UCO), restaurants and food-service operations.

Typical Raw-Material Sources:

- Small- and medium-sized slaughterhouses
- Meat-processing and deboning facilities
- Supermarkets and retail meat counters
- Restaurants and food-service operations (for UCO)

Key Characteristics:

- Strong logistics capability (fleet, routing, containers, collection systems)
- Receives material from diverse origins and quality levels
- Higher variability in composition and raw-material characteristics
- Focus on collection service, operational efficiency, and value maximization

Advantages:

- Larger scale and supplier diversification
- Ability to grow volume through collection contracts
- Operational flexibility for multiple raw-material streams and formulations

Limitations:

- Strong dependency on logistics and transport quality
- Greater fluctuation in raw-material freshness and quality
- Requires strict traceability, sanitation, and biosecurity protocols

Is one model better? The answer is **no**. Final product quality does not depend on the rendering model itself, but on technical management, raw-material freshness and sanitary handling, logistics control, processing practices, biosecurity measures, and operational standards applied before, during, and after processing.

Both models are complementary and strategic to ensure efficient animal-by-product utilization, sustainability of the agri-food system, and compliance with global sanitary and biosecurity regulations.

COMPARATIVE TABLE: PACKER RENDERER VS. INDEPENDENT RENDERER

Aspect	Packer Renderer (Integrated)	Independent Renderer
Location	On-site/adjacent to slaughter or meat plant	Stand-alone facility
Raw-material flow	Internal, stable, controlled	Multi-supplier, variable
Logistics	Minimal, internal	Extensive logistics & collection
Raw-material freshness	Very high	Variable, route-dependent
Variability in composition	Low	High
Scale	Limited by associated slaughter facility	Regional or national
Business model	Internal by-product valorization	Collection service + value recovery
Flexibility	Low	High
Dependency	Own slaughter volume	Supplier contracts & collection network
Primary focus	Internal efficiency & cost control	Raw-material capture, logistics, quality, market optimization
Regulatory & biosecurity demand	High	Very high; multi-stream management

TECHNICAL AND OPERATIONAL FACTORS IN RAW MATERIAL COLLECTION

The collection and handling of raw materials for rendering involve a series of technical challenges and critical considerations to ensure process efficiency and minimize environmental and sanitary impacts. Key factors include the rapid spoilage rate of animal by-products (which demands fast processing), proper collection and transport procedures from slaughter facilities, odor control during storage and processing, management of wastewater and effluents, and compliance with sanitary and regulatory standards. Each of these factors is described below:

• Decomposition Rate and Processing Speed

Raw animal tissues are highly perishable and begin to break down within hours after slaughter due to microbial activity. This significantly limits the allowable time window for safe collection and processing. If not handled promptly, pathogenic bacteria can proliferate, strong odors can develop, and the quality of the recoverable fat and protein declines (due to rancidity and protein denaturation). In warm climates, decomposition is accelerated, with visible spoilage sometimes occurring in less than 24 hours.

For this reason, rendering plants typically operate on daily cycles, processing all collected raw material within the same day. Many regional regulations require that raw material be processed within **24–48 hours** of generation. Large slaughter facilities may use chilled holding rooms to temporarily store by-products; however, refrigeration is often impractical for viscera and offal due to cost, so frequent collection is preferred. High-volume plants may be serviced daily or multiple times per day.

Upon arrival at the rendering facility, best practice is immediate or near-immediate processing. Continuous rendering systems allow material to be fed directly into cookers as it arrives, avoiding extended storage.

Ultimately, minimizing time between slaughter and rendering is essential for both sanitary control and finished-product quality: **fresher material produces cleaner-colored tallow and higher-value protein meals, while degraded raw material yields darker fats and lower-palatability meals.**

• Collection and Transportation Methods

Raw material collection at slaughter plants is a critical component of rendering logistics. Modern facilities dedicate a non-edible by-products area where offal, fat trimmings, heads, and other tissues are placed immediately after slaughter. Dedicated containers or sealed hoppers are commonly used, sometimes equipped with lids. Larger plants may grind by-products onsite to improve handling efficiency. Rendering companies dispatch specialized trucks on programmed routes to collect these materials. Trucks are usually enclosed to prevent leakage and contain odors; some may be refrigerated, though sealed steel bodies are more common. To prevent cross-contamination, by-product areas are physically separated from edible product zones, and personnel follow hygiene protocols when transitioning between areas.

Speed is key, raw material must be transported promptly to the nearest rendering plant. In regions with high livestock and meat-processing density, rendering plants are strategically located to minimize transit time. In more dispersed areas, intermediate collection points may be used; occasionally, additives are added to slow decomposition, although this is less common due to cost.

Beyond slaughter facilities, independent renderers typically manage broad collection networks, including butcher shops, supermarkets, and restaurants. This requires specialized equipment, such as **tankers for used cooking oil (UCO)** and small urban collection vehicles. Effective reverse-logistics systems, like those implemented in Brazil, where more than **85% of animal by-products are recovered**, are key to maximizing material capture.

Ultimately, collection systems are tailored to material type (e.g., containers for solids, tanks for blood) and designed to ensure **safe, fast, and sanitary transport.**

• Odor Control and Environmental Management

Odor is one of the most visible operational challenges in rendering. The decomposition of animal tissues releases highly volatile compounds (amines, hydrogen sulfide, rancid fatty acids) with intense odors. Effective odor-control strategies are essential both during transport and at the plant.
Collection trucks typically use sealed bodies with gaskets and filtered vents to minimize emission. Some operators apply deodorizing agents or enzymatic treatments to containers.
At the plant, the cooking process generates odorous vapors. **Modern rendering facilities employ advanced air-treatment systems**, including:

- **Chemical scrubbers** (e.g., hypochlorite, permanganate), often achieving >85% odor reduction
- **Biofilters** packed with organic media colonized by odor-metabolizing microbes
- **Thermal oxidizers** in sensitive areas, incinerating gases to eliminate virtually all odor emissions

Environmental controls extend to spill prevention and facility sanitation. Raw material unloading areas include **impermeable flooring and drainage** connected to treatment systems. Trucks and containers are washed after unloading, and wastewater is properly managed. Pest-control practices (fly prevention, rodent traps, daily cleaning) are mandatory.
Odor-impact studies and environmental permits are often required for new rendering facilities. In short, **robust odor-control and environmental systems are critical for public acceptance and sustainable operation.**

• Wastewater and Effluent Management

Rendering operations generate significant wastewater due to both **moisture released from cooked raw material** and process-area cleaning. Efficient treatment systems are essential.
During cooking, moisture evaporates and later condenses into **stick water,** a nutrient-rich effluent containing dissolved proteins and minerals. Some plants recover and concentrate stick water to produce **protein concentrates** or incorporate it into blood or meat-and-bone meal production. Excess liquid must be treated before discharge. Typical effluent-treatment systems include:

- Dissolved-air flotation units (DAF) for grease removal
- Anaerobic/aerobic digestion to reduce organic load
- Lagoons or filtration systems for final polishing

Rendering wastewater is high in **nitrogen and phosphorus**, so untreated discharge can cause eutrophication. Accordingly, strict biochemical oxygen demand (BOD/COD) standards apply in many regions.

Cleaning water from truck bays and process floors also enters treatment systems. Water reuse practices, such as recycling condensate for non-critical washing, support resource efficiency. Modern plants favor **dry-rendering systems** to minimize water generation.
Some semi-solid by-products (e.g., rumen contents) are diverted to composting or biodigesters to avoid excess liquid waste.

Ultimately, effective wastewater and effluent controls are essential to **environmental compliance and sustainable rendering operations.**

SOURCES OF RAW MATERIALS FOR RENDERING

Raw-material streams for the rendering industry are classified based on their origin:

1. Slaughterhouses Abattoirs

Slaughter facilities represent the primary source of fresh raw material for the rendering industry, generating non-edible by-products such as offal, bones, heads, feet, blood, rumen and intestinal contents, fat and tissue trimmings, and, in the case of poultry, feathers. These materials are produced continuously during harvest operations, requiring highly efficient collection systems, typically daily or per-shift, to preserve quality and prevent microbiological deterioration.

Facilities maintain clearly segregated edible and inedible product zones in compliance with food-safety and sanitary regulations for the meat supply chain.

2. Meat and Poultry Processing Plants

Meat-processing and poultry-processing plants are key contributors of rendering raw materials, producing by-products from deboning, fabrication, and further-processing operations. Typical materials include meat-and-bone trimmings, soft and hard fats, residual emulsions from sausage and processed-meat lines, and feathers and viscera in poultry operations.

Because many facilities are located near urban distribution centers, subproduct volumes are high, and collection must occur frequently to prevent spoilage, maintain sanitary conditions, and preserve raw-material quality.

3. Seafood Industry

The seafood industry contributes fish-based raw materials from filleting plants, canning facilities, and port-based processing operations. Typical by-products include heads, frames, skins, viscera, muscle scraps, and effluent sediment from cleaning and evisceration.

Due to their high perishability and sensitivity to enzymatic and microbial breakdown, these materials require **immediate refrigeration, freezing, or acidification** to maintain quality and ensure suitability for rendering. Proper handling enables efficient valorization of marine biomass within a circular bioeconomy framework.

4. Retail and Food-Service Sector

Retail and food-service channels provide significant raw-material volumes from supermarkets, restaurants, hotels, and industrial kitchens. Collected materials include meat trimmings, expired or off-rotation products, prep scraps, and used cooking oil (UCO).

Given their predominantly urban location and continuous generation, these sources require tightly managed, frequent pickup programs to ensure adequate segregation, hygienic handling, and timely removal, preserving value and preventing sanitary risks.

COLLECTION METHODS

Pickup Modalities

Method	Characteristics	Advantages	Challenges
Scheduled daily collection	Fixed routing	Highest freshness	Higher logistics cost
On-demand pickup	Customer triggers service	Flexibility	Delay risk / quality loss
Transfer stations	Local aggregation + outbound hauling	Reduces long-haul trips	May require cold chain

Equipment Used for Raw-Material

For Solid By-Products

- Direct loading into sealed rendering trucks
- Metal hoppers with controlled drainage at source
- Sanitary plastic totes or bins
- On-site grinders and compactors

For Blood

- Stainless-steel receiving tanks
- Dedicated sanitary tanker trucks
- Anti-foam pumping and vacuum systems

For UCO

- Sealed HDPE drums (20–200 L)
- Stationary storage tanks
- Plastic or metal oil collection containers

CRITICAL FACTORS AT COLLECTION POINTS

Factor	Importance
Species segregation (ruminants, swine, poultry, fish)	Prevents cross-contamination
Maximum holding times	Fresher raw material = higher finished-product quality
Temperature control	Ideal <10°C for fresh raw materials
Cleaning & separation of wet/dry areas	Controls odors, pests, pathogens
Regulatory compliance	U.S.: FDA / EU: Category 1,2 & 3
Traceability	Records for origin, handling, transport, and destination
Biological-risk segregation	SRM in ruminants, disease-risk materials

BOVINE-DERIVED RAW MATERIALS

In cattle, approximately **half of the live weight** becomes non-edible by-products that enter the rendering stream. On average, **40–50% of the live weight** of a slaughtered bovine is converted into raw materials for rendering. The **carcass yield** (edible meat and offals intended for human consumption) generally represents **50–55%** of the live weight, while the remainder (~45%) consists of by-products such as hide, offal, bones, blood, inedible fat, rumen content, and other tissues.

The **bovine hide** accounts for about **7% of live weight** and is one of the most valuable by-products; however, it is primarily destined for the **leather industry** rather than rendering. **Bones** represent roughly **15% of the beef carcass weight** (equivalent to ~8–10% of live weight) and, along with connective tissue trimmings and cartilage, are typically rendered to produce **meat-and-bone meal (MBM).**

Blood constitutes approximately **3–4% of live weight** and can be collected separately for the production of **blood meal.** Additional organs and viscera, including lungs, gastrointestinal tract and its contents, head, hooves, and digestive organs, form the remainder of the by-products. Many of these tissues are **not consumed by humans** in most markets and therefore serve as raw inputs for rendering.
The percentage of the animal that does not enter human-food channels depends on **dietary habits, cultural and religious practices, and the extent to which specific by-products are utilized for other industries** such as pharmaceuticals, pet food, collagen/gelatin, and leather manufacturing.

BOVINE RAW-MATERIAL YIELDS IN RENDERING

In the rendering industry, **yields** represent the percentage of finished products, primarily **rendered fat (tallow)** and **protein meals**, that can be obtained from each type of bovine by-product. These values are essential for evaluating processing efficiency, planning production, estimating operating costs, and determining the economic value of each raw-material stream. Bovine raw materials encompass a wide range of tissues including viscera, blood, bones, fat trimmings, hides, and heads, each with different compositions of moisture, protein, fat, and minerals. Accordingly, yields can vary significantly depending on the tissue type, material quality, freshness, prior handling, and the processing technology used at the rendering facility.

The following table presents typical yield ranges for bovine by-products used in rendering, illustrating their conversion potential and relative contribution to the production of **tallow** and **animal protein meals.**

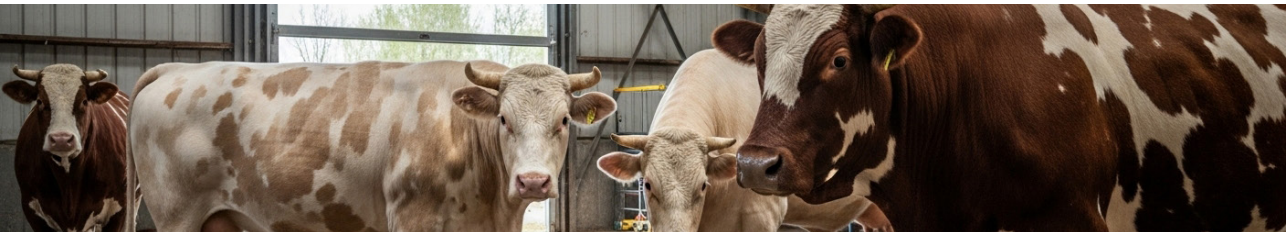
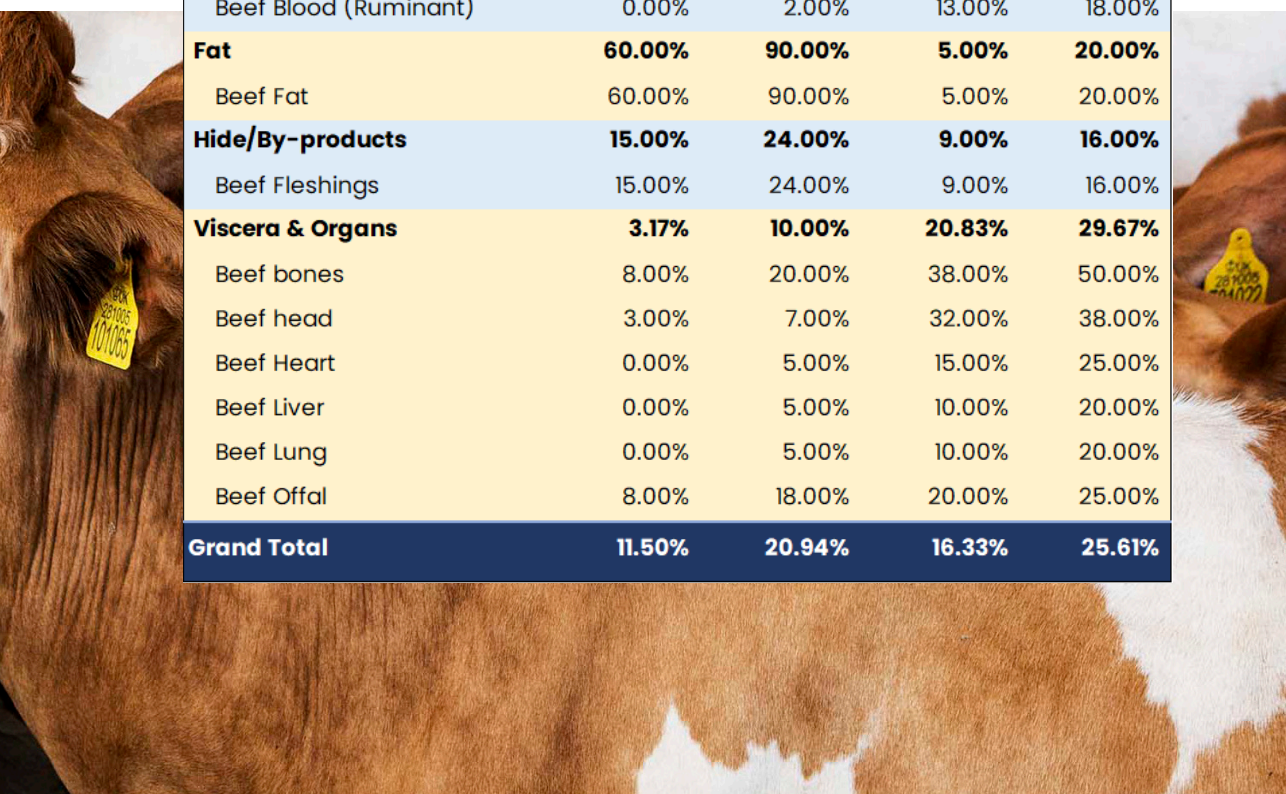


TABLE OF ESTIMATED YIELDS FROM BOVINE RAW MATERIALS

	Fat Min	Fat Max	Meal Min	Meal Max
Beef	**12.56%**	**22.33%**	**15.78%**	**25.44%**
Blood	**0.00%**	**2.00%**	**12.00%**	**18.00%**
Beef Blood (Ruminant)	0.00%	2.00%	12.00%	18.00%
Fat	**60.00%**	**90.00%**	**3.00%**	**15.00%**
Beef Fat	60.00%	90.00%	3.00%	15.00%
Hide/By-products	**15.00%**	**24.00%**	**9.00%**	**16.00%**
Beef Fleshings	15.00%	24.00%	9.00%	16.00%
Viscera & Organs	**6.33%**	**14.17%**	**19.67%**	**30.00%**
Beef bones	8.00%	20.00%	38.00%	50.00%
Beef head	5.00%	10.00%	30.00%	35.00%
Beef Heart	0.00%	5.00%	15.00%	25.00%
Beef Liver	0.00%	5.00%	10.00%	20.00%
Beef Lung	0.00%	5.00%	10.00%	20.00%
Beef Offal	25.00%	40.00%	15.00%	30.00%
Dairy	**10.44%**	**19.56%**	**16.89%**	**25.78%**
Blood	**0.00%**	**2.00%**	**13.00%**	**18.00%**
Beef Blood (Ruminant)	0.00%	2.00%	13.00%	18.00%
Fat	**60.00%**	**90.00%**	**5.00%**	**20.00%**
Beef Fat	60.00%	90.00%	5.00%	20.00%
Hide/By-products	**15.00%**	**24.00%**	**9.00%**	**16.00%**
Beef Fleshings	15.00%	24.00%	9.00%	16.00%
Viscera & Organs	**3.17%**	**10.00%**	**20.83%**	**29.67%**
Beef bones	8.00%	20.00%	38.00%	50.00%
Beef head	3.00%	7.00%	32.00%	38.00%
Beef Heart	0.00%	5.00%	15.00%	25.00%
Beef Liver	0.00%	5.00%	10.00%	20.00%
Beef Lung	0.00%	5.00%	10.00%	20.00%
Beef Offal	8.00%	18.00%	20.00%	25.00%
Grand Total	**11.50%**	**20.94%**	**16.33%**	**25.61%**



POULTRY-DERIVED RAW MATERIALS

In the poultry industry, broiler chickens typically achieve a **carcass yield of approximately 70%** of live weight (bone-in edible meat). However, a substantial portion of the bird is **not consumed by humans** and is diverted into the animal-by-products recycling stream. It is estimated that **30–40% of the live weight** of a broiler consists of non-edible by-products destined for rendering.

Key poultry by-products include:

- **Feathers** (~5–7% of live weight, depending on genetics and production system)
- **Blood** (~4% of live weight)
- **Heads and feet** (not commonly consumed in Western markets, though feet are widely consumed in Asia, Latin America, and Africa)
- **Non-edible viscera and internal organs** (intestinal tract, lungs, etc.)
- **Intestinal contents and other condemned offal**

Feathers represent a distinct raw-material stream and are typically processed separately through **hydrolysis** to produce **feather meal**, a high-protein ingredient rich in keratin.
Overall, approximately **37% of the broiler live weight** is not utilized for human consumption and is recycled via rendering or hydrolysis (including feathers, non-edible viscera, blood, and associated tissues). Thus, only about **63% of the bird**, primarily muscle and select edible giblets, is directed to the human-food chain, while the remainder is valorized through rendering. The processing of poultry by-products yields **poultry fat (schmaltz / poultry oil) and poultry by-product meal**, widely used in **pet food, aquaculture feed, poultry diets, and other animal nutrition markets.**

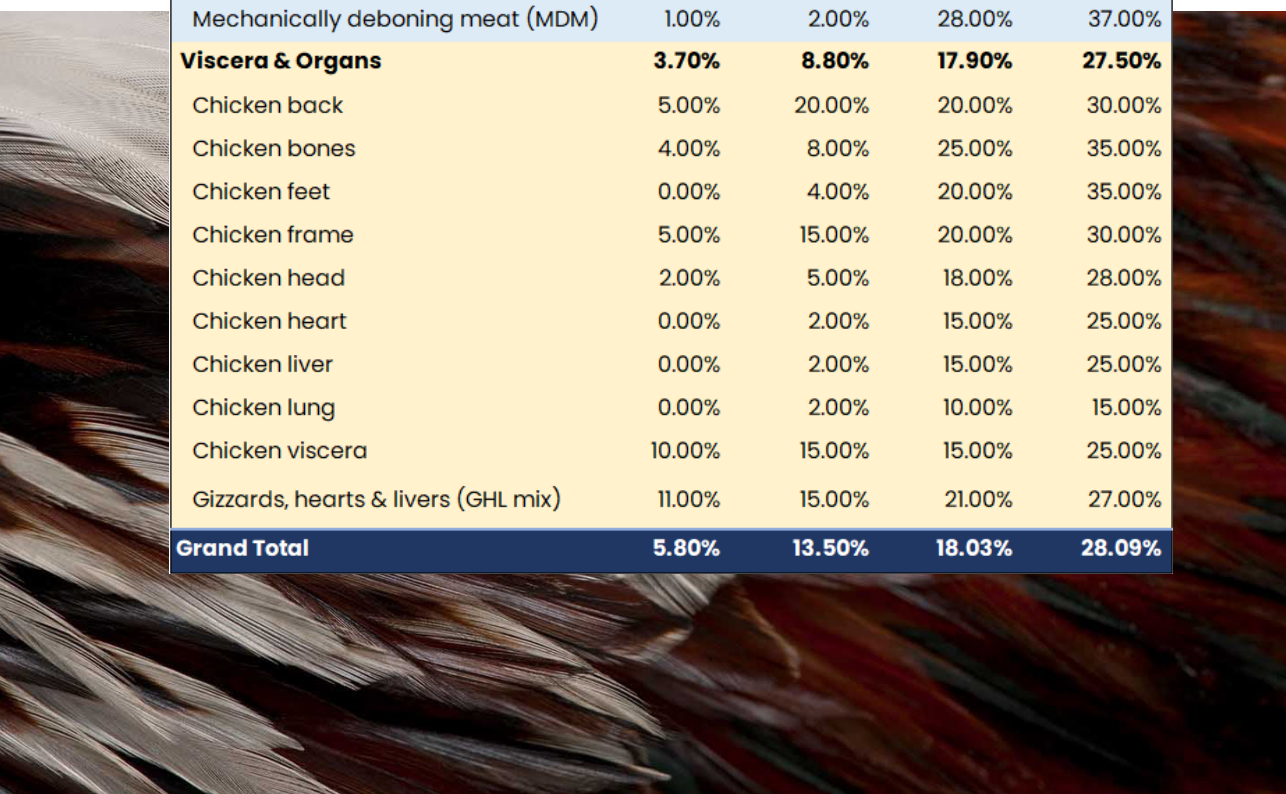
POULTRY RAW-MATERIAL YIELDS IN RENDERING

Analyzing poultry raw-material yields allows processors to estimate the proportions of each fraction available for rendering, optimize operational planning, evaluate collection efficiency, and forecast final production of meals, fats, and other rendered derivatives.

These values are indicative and may vary depending on species, genetics, production system, slaughter yields, processing technology, raw-material condition, and sanitary handling practices.

TABLE OF ESTIMATED YIELDS FROM POULTRY RAW MATERIALS

	Fat Min	Fat Max	Meal Min	Meal Max
Broiler	**5.80%**	**13.50%**	**18.03%**	**28.09%**
Blood	**0.00%**	**2.00%**	**10.00%**	**19.00%**
Chicken blood	0.00%	2.00%	10.00%	19.00%
Dead Stock	**11.00%**	**13.00%**	**21.00%**	**24.00%**
Chicken mortality	11.00%	13.00%	21.00%	24.00%
Fat	**35.00%**	**79.50%**	**10.00%**	**20.00%**
Chicken fat/Cutting	35.00%	79.50%	10.00%	20.00%
Feathers	**0.00%**	**0.00%**	**25.00%**	**50.00%**
Chicken feathers	0.00%	0.00%	25.00%	50.00%
Hides and skins	**15.00%**	**47.00%**	**11.00%**	**25.00%**
Chicken skin	15.00%	47.00%	11.00%	25.00%
Meat Cuts	**4.23%**	**9.60%**	**19.15%**	**27.95%**
Chicken leg	5.00%	10.00%	18.00%	30.00%
Chicken meat trim	1.90%	3.40%	23.60%	26.80%
Chicken wings	5.00%	10.00%	15.00%	25.00%
Chicken wings tip	5.00%	15.00%	20.00%	30.00%
Mechanically Separated	**1.00%**	**2.00%**	**28.00%**	**37.00%**
Mechanically deboning meat (MDM)	1.00%	2.00%	28.00%	37.00%
Viscera & Organs	**3.70%**	**8.80%**	**17.90%**	**27.50%**
Chicken back	5.00%	20.00%	20.00%	30.00%
Chicken bones	4.00%	8.00%	25.00%	35.00%
Chicken feet	0.00%	4.00%	20.00%	35.00%
Chicken frame	5.00%	15.00%	20.00%	30.00%
Chicken head	2.00%	5.00%	18.00%	28.00%
Chicken heart	0.00%	2.00%	15.00%	25.00%
Chicken liver	0.00%	2.00%	15.00%	25.00%
Chicken lung	0.00%	2.00%	10.00%	15.00%
Chicken viscera	10.00%	15.00%	15.00%	25.00%
Gizzards, hearts & livers (GHL mix)	11.00%	15.00%	21.00%	27.00%
Grand Total	**5.80%**	**13.50%**	**18.03%**	**28.09%**



PORCINE-DERIVED RAW MATERIALS

In swine, a high proportion of the animal is utilized for human consumption, with **carcass yields typically ranging from 70–75% of live weight**. However, a substantial fraction of the animal does not enter the human-food supply chain. On average, **40–45% of the live weight** of a hog consists of by-products that are diverted to rendering or other non-edible streams. Some studies indicate that, when including edible offals in regions where they are consumed and accounting for gastrointestinal content, the non-meat fraction of a pig can reach values close to **~80% of live weight**. This larger estimate captures both edible by-products used in traditional foods and materials not directed to human consumption.

Key porcine by-products used as raw material for rendering include:

- **Blood** (~3% of live weight)
- **Bones** (~10% of live weight, as bones represent ~11% of the carcass)
- **Digestive tract and contents**
- **Lungs and other non-edible viscera**
- **Head,** in markets where it is not consumed
- **Inedible fat trimmings**

Swine skin represents approximately **3–8% of live weight** (average ~5%). Depending on market preferences, pork skin may be utilized for human food applications (e.g., pork rinds, edible skin products). However, surplus or non-grade skin can be recycled into **rendered fat and gelatin-type derivatives.** Overall, approximately **44% of the pig live weight** is considered raw material for rendering or other by-product utilization pathways rather than direct human consumption.

PORCINE RAW-MATERIAL YIELDS IN RENDERING

Understanding the typical yields associated with each category of porcine raw material is essential for plant-capacity planning, production forecasting, operating-cost evaluation, and identifying market opportunities. Yield performance can vary depending on carcass type, deboning level, pre-harvest handling, raw-material quality, and the processing technologies employed at the rendering plant.

The following analysis provides a general reference framework commonly used in the industry to support technical and commercial decision-making.

TABLE OF ESTIMATED YIELDS FROM SWINE RAW MATERIALS

	Fat Min	Fat Max	Meal Min	Meal Max
Blood	**9.35%**	**19.05%**	**16.95%**	**22.60%**
Blood stick	18.70%	33.10%	18.90%	25.20%
Pork Blood	0.00%	5.00%	15.00%	20.00%
Dead Stock	**11.00%**	**13.00%**	**21.00%**	**24.00%**
Dead hog on farm	11.00%	13.00%	21.00%	24.00%
Fat	**57.67%**	**77.67%**	**7.33%**	**17.00%**
Cutting fat	56.00%	69.00%	11.00%	17.00%
Cutting fat with skin	42.00%	74.00%	8.00%	26.00%
Leaf lard fat	75.00%	90.00%	3.00%	8.00%
Hair	**0.00%**	**0.00%**	**20.00%**	**35.00%**
Hog hair	0.00%	0.00%	20.00%	35.00%
Hides and skins	**26.60%**	**42.50%**	**23.30%**	**34.75%**
Pork dried skin	26.60%	42.50%	23.30%	34.75%
Mechanically Separated	**7.90%**	**8.60%**	**41.00%**	**46.00%**
Mechanically deboning meat (MDM)	7.90%	8.60%	41.00%	46.00%
Mucosa	**10.70%**	**15.41%**	**17.00%**	**21.00%**
Small intestine/Mucosa	10.70%	15.41%	17.00%	21.00%
Viscera & Organs	**10.77%**	**17.46%**	**24.69%**	**33.46%**
Ear	1.00%	4.00%	15.00%	30.00%
Pig tail	6.00%	28.00%	28.00%	46.00%
Pork Bones	10.00%	20.00%	34.00%	40.00%
Pork crackling	48.00%	60.00%	41.00%	52.00%
Pork Heart	0.00%	5.00%	15.00%	25.00%
Pork Hock/feet	5.00%	10.00%	22.00%	30.00%
Pork liver	0.00%	5.00%	15.00%	25.00%
Pork lung	0.00%	5.00%	10.00%	20.00%
Pork Neck/Backbone	10.00%	15.00%	36.00%	42.00%
Pork Offal	5.00%	10.00%	20.00%	30.00%
Skull	6.00%	8.00%	38.00%	42.00%
Trimming	47.00%	50.00%	17.00%	18.00%
Whole head (pork)	2.00%	7.00%	30.00%	35.00%
Grand Total	**16.87%**	**25.11%**	**21.70%**	**30.08%**

FISH AND SEAFOOD BY-PRODUCTS

In the fishing and seafood-processing industries, a substantial portion of the biomass becomes raw material for rendering-type processes, primarily **fishmeal and fish oil production**. Most fish species yield relatively low fillet percentages; depending on species and processing method, only **~30–50% of live weight** is converted into edible fillets or human-consumption products, leaving **50–70%** as by-products. On average, approximately **57% of the live weight** of commonly processed fish consists of non-edible parts.

Fish by-products typically include:

- **Heads**
- **Frames and bones**
- **Viscera and stomach contents**
- **Scales**
- **Skin (for species where skin is not consumed)**
- **Trimmings and muscle scraps from filleting**

During fillet production, large volumes of carcasses and trimmings are generated. These materials are rich in **high-quality proteins and omega-3 fatty acids**, and are therefore recycled through cooking, pressing, and drying to produce **fishmeal** (from the solid protein fraction) and **fish oil** (from extracted lipids). Although this process is commonly carried out in **specialized fishmeal plants**, it is functionally analogous to terrestrial rendering. Due to the extremely rapid spoilage rate of fish, **acid silage or controlled fermentation** is often used as a temporary preservation method before processing, particularly in remote or coastal sites.
In summary, **more than half of the harvested fish biomass** becomes a valuable raw material for circular-economy processing, and its proper utilization is critical to prevent environmental contamination in coastal regions.

FISH RAW-MATERIAL YIELDS IN RENDERING

The following values represent industry-reference ranges used in the fish-rendering and fishmeal sector to estimate expected yields of **fishmeal** and **fish oil** based on the type and quality of raw material. Actual percentages may vary depending on species, seasonality, freshness, fishing or aquaculture conditions, and processing technologies applied at the plant.

TABLE OF ESTIMATED YIELDS FROM FISH RAW MATERIALS

	Fat Min	Fat Max	Meal Min	Meal Max
Fish	**4.29%**	**8.29%**	**18.29%**	**23.00%**
Hides and skins	**2.00%**	**5.00%**	**30.00%**	**35.00%**
Fish skin	2.00%	5.00%	30.00%	35.00%
Meat Cuts	**6.00%**	**10.00%**	**18.00%**	**22.00%**
Filleting Trimmings	6.00%	10.00%	18.00%	22.00%
Viscera & Organs	**5.00%**	**9.75%**	**18.25%**	**23.00%**
Whole Fish	6.00%	12.00%	18.00%	22.00%
Fish Head	3.00%	6.00%	20.00%	25.00%
Viscera / Offal	10.00%	18.00%	10.00%	15.00%
Bones / Frames	1.00%	3.00%	25.00%	30.00%
Sludge	**2.00%**	**4.00%**	**7.00%**	**12.00%**
Plant Sediments / Sludge	2.00%	4.00%	7.00%	12.00%
Grand Total	**4.29%**	**8.29%**	**18.29%**	**23.00%**

UCO – USED COOKING OIL

Used cooking oil (UCO) is a valuable raw material for the rendering and renewable-fuel industries. It is primarily collected from restaurants, industrial frying operations, supermarkets, food-service facilities, and, in some countries, directly from households through advanced urban recovery systems. Proper segregation, storage, and logistics are essential to prevent contamination and degradation, ensuring high-quality oil for industrial valorization within circular-economy frameworks.

Unlike traditional animal-based rendering inputs, UCO is a **fat-dominant raw material,** allowing for **high yields of refined oil** suitable for energy and oleochemical applications.

PROCESS FLOW — UCO TREATMENT FOR FAT RECOVERY

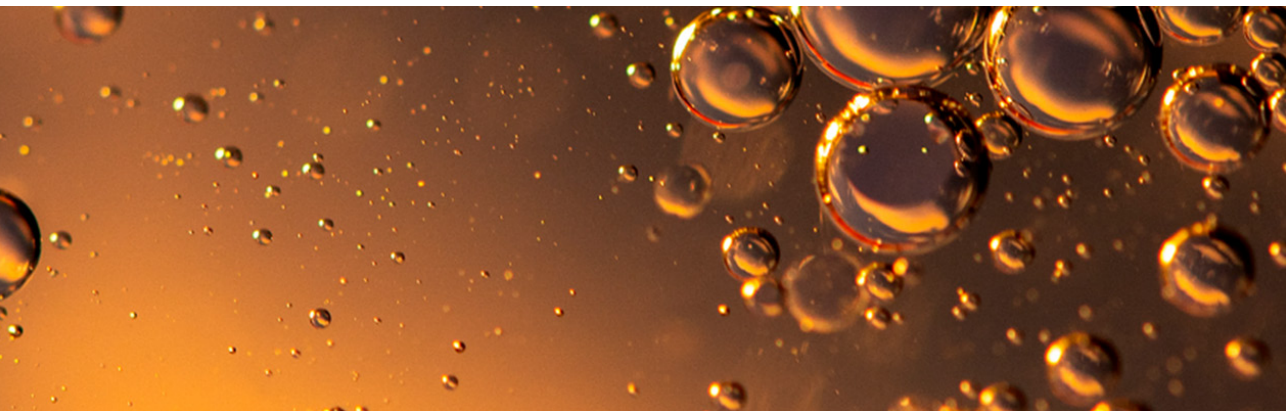
Stage	Description	Technical Objective	Output
Collection & Receiving	UCO collected from restaurants, food industries, kitchens	Ensure traceability; assess quality (MIU, FFA)	Quality classification & processing route
Pre-Storage & Initial Settling	Conical tanks / bottom purge	Separate water & heavy solids	Initial contaminant removal
Primary Filtration	Screen / mesh filters	Remove food particles & coarse solids	Reduced solids load
Heating (60–90°C)	Thermal conditioning	Reduce viscosity & enhance separation	Fluid material for efficient processing
Secondary Decantation	Clarifying tanks	Additional gravitational separation	Removal of free water & fine solids
Option 1 — Decanter Centrifuge	Mechanical separation of solids/emulsions	Reduce high MIU → pre-purification	Semi-clean oil + solids cake
Option 2 — High-Speed Polisher	High-speed separator	Final polishing	Oil with MIU < 0.5%
Degumming / Neutralization (optional)	Remove gums, FFAs, polymers	Meet HVO/SAF & oleochemical specs	Reduced phospholipids & resin compounds
Thermal Drying	Vacuum or controlled heat	Reduce moisture	Oil with <0.3% moisture
Homogenization / Final Tank	Blending & stabilization	Consistent quality & specs	Stabilized, dispatch-ready oil
Storage & Dispatch	Heated tanks & traceability	Maintain quality & flow	Certified lots for biodiesel/HVO/SAF

The final yield depends on the efficiency of the separation process, the quality of the collected UCO, and the level of purification required for downstream applications, ranging from biodiesel and HVO/SAF production to industrial and oleochemical uses. The percentages presented below represent industry-reference values used to estimate the typical conversion of UCO into usable oil and residual fractions.

TYPICAL YIELD OF PROCESSED UCO

Fraction	% Range	Description
Recovered fat / clean oil	**85–95%**	Suitable for biodiesel, HVO/SAF, soaps & oleochemicals
Moisture & solids	**2–10%**	Water, food particles, carbonized residues
Gums / impurities (FFAs, polymers)	**1–5%**	Phospholipids, thermal resins, oxidative polymers
Operational losses	**1–2%**	Mechanical losses in pumps, piping, filters

INDUSTRY AVERAGE: ≈ 90% CLEAN OIL RECOVERY



YIELD VARIATION BY UCO QUALITY

UCO Source	Fat Yield	Notes
Premium restaurant UCO	**92–95%**	Better handling, lower degradation
Industrial frying operations	**88–92%**	Higher polymer content, higher FFA
Mixed urban UCO	**85–90%**	High variability, moisture presence
Contaminated UCO	**<85%**	Requires intensive pre-treatment

INDUSTRY EVOLUTION & STRATEGIC IMPORTANCE

UCO processing has evolved from basic oil reclamation to **advanced refining and purification**, driven by global demand for **renewable fuels and bio-based materials**. Modern facilities may incorporate:

- **Three-phase centrifugation systems**
- **Vacuum drying and thermal conditioning**
- **Inline MIU and FFA monitoring**
- **Traceability and certification platforms**

As specifications for **HVO (Hydrotreated Vegetable Oil)** and **SAF (Sustainable Aviation Fuel)** become increasingly stringent, UCO has emerged as a **strategic feedstock** in the energy transition. Process innovation and waste-to-value pathways allow UCO to deliver high-value outputs, reduce reliance on fossil resources, and strengthen circular-economy models across the food and energy systems.