Carcass Disposal: A Comprehensive Review

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Chapter

4

Rendering

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Abbreviations & Definitions

Though most of the terms related directly and indirectly to carcass rendering have been defined to some extent in the text, for convenience the following glossary of technical terms is provided. Definitions were adopted from Franco and Swanson (1996), Pocket Information Manual (2003), Morehead and Morehead (1995), and Merriam-Webster's Dictionary (2003).

AAFRD: Alberta Agriculture, Food and Rural Development.

Animal fat: An aggregate term generally understood to be fat from mammals.

Anvils: Raised rectangular solid sheet teeth in some of the reducing size equipment.

APHIS: Animal and Plant Health Inspection Service

AUSVETPLAN: Australian Veterinary Emergency Plan, Agricultural and Resource Management Council of Australia and New Zealand.

BOD (biochemical oxygen demand): The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. Normally five days at 20°C unless otherwise stated. A standard test used is assessing the biodegradable organic matter in municipal wastewater.

BSE: bovine spongiform encephalopathy

Byproducts: All discarded material from animals or poultry and other sources that are processed in a rendering plant.

Composting: A natural biological decomposition process that takes place in the presence of oxygen (air).

Carcass meal: Proteinaceous solids.

Centrifuge: Machine used radiating force to separate materials of different densities.

COD (chemical oxygen demand): A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specified test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand.

Clostridium perfringens: An indicator microorganism, which shows the sterilizing effect of rendering procedures.

Cooker: Horizontal, steam-jacketed cylinder equipped with a mechanical agitator. Raw material is heated to certain conditions and according to a repetitive cycle.

Continuous cooker: heating equipment used in rendering process, where the raw material through the system is flowing in an essentially constant manner and without cessation or interruption.

Cracklings: Solid protein material discharged from screw press of rendering process and after removal of liquid fat.

Crusher: Machine containing blades or knives that grind raw material to uniform size.

D Value: The time in minutes required to destroy 90 percent (or a one-log cycle) of a population of cells at a given reference temperature.

Digestibility: The Percentage of feeding stuff taken into the digestive tract that is absorbed into the body.

Dry matter: The portion of a substance that is not comprised of water. The dry matter content (%) is equal to 100% minus the moisture content (%)

Edible rendering: Fats and proteins produced for human consumption which is under the inspection and processing standards established by the US Department of Agriculture, Food and Safety Inspection Service (USDA/FSIS).

Edible tallow: Exclusively beef, this product is rendered from fat trimmings and bones taken from further processing at a slaughterhouse. Because of the associated processing and the limits of raw material, the product of light color and low moisture, insolubles, unsaponifiables, and free fatty acids. The tallow may be further refined, polished, and deodorized to become a cooking fat. The pet food industry generally uses the crude product not shipped under seal. This often is referred to as technical tallow.

END: exotic Newcastle disease

EPAA: Environment Protection Authority of Australia

FDA: US Food and Drug Administration

FMD (foot and mouth disease): A highly infectious viral infection of cattle, pigs, sheep, goats, buffalo and artiodactyls wildlife spies characterized by fever, vesicles (blisters) in the mouth and on the muzzle, teats, and/or feet; and death in young animals. Affected animals may become completely incapacitated or be unable to eat/drink due to pain associated with the vesicles.

FFA: free fatty acids

Grax: Suspended solid proteins.

Greaves: A high-protein solid which is left following the extraction of tallow from animal by-products during the rendering process with further processing this becomes MBM.

HACCP: hazard analysis critical control point

Hasher: A chopper of materials (a French word).

HTR: high temperature rendering

Ileal: The last division of the small intestine extending between the jejunum and large intestine.

Independent rendering plant: Obtains its byproduct material from a variety of sources and especially dead animals which are off-site or separate from the plant facility.

Inedible products: Fats and proteins produced from dead animals for feeding the animals with certain specifications and for other non-edible uses.

Integrated or dependent rendering plant: Operates in conjunction with a meat slaughterhouse, or poultry processor whose byproduct materials are processed on-site.

KOFO: Kodfodfabrikken Ostjyden

Lard or edible grease: Fat which is obtained from the pork tissue by the rendering process and its production is very similar to tallow.

LTR: low temperature rendering

MBM (meat and bone meal): Meat and bone meal is prepared from the rendering of dead animals or wastes materials associated with slaughtering operations (carcass trimmings, condemned carcasses, condemned livers, inedible offal (lungs) and bones). It is basically dry rendered protein product from mammal tissues with more than 4.4Percent phosphorus.

NCSART: North Carolina State Animal Recovery Team

Offal: All material from the animal's body cavity processed in a rendering plant.

Percolating pan: A tank with a perforated screen through which the liquid fat drains freely and separates from the tankage.

Post-rendering process: Screening the protein and fat materials, sequential centrifugations for separation of fat and water, drying and milling of protein materials.

Pre-rendering process: Size reduction and conveying.

Rendering process: A process of using high temperature and pressure to convert whole animal and poultry carcasses or their by-products with no or very low value to safe, nutritional, and economically valuable products. It is a combination of mixing, cooking, pressurizing, fat melting, water evaporation, microbial and enzyme inactivation.

***Salmonella*:** Human pathogen that causes gastro-intestinal problems.

SBO: specified bovine offal

SCI: Sparks Companies, Inc.

Screw press: Machine used to separate fat from tankage continuously by applying the required pressure with a rotating screw.

Scrubber: Pollution control device for containing air exhausted from rendering plant with a water solution containing deodorizing chemicals for odor removal.

Sewage: Refuse liquids or waste matter carried off by sewers.

Sterilization: Sterilization is based on a statistical probability that the number of viable microorganisms will remain below an specified level after heating process (particularly temperature, time and pressure) and is dependent upon the overall heat transfer coefficient (conductive and convective) of cooking materials, which can determine the lethal effect of the heat.

Stick liquor or stick water: The viscous liquid left in the rendering tank after cooking process.

Tallow: The white nearly tasteless solid rendered fat of cattle and sheep which is used chiefly in soap, candles, and lubricants.

Tankage: Cooked material remaining after the liquid fat is drained and separated.

TDH: Texas Department of Health

Tricanter: A vessel used to separate three phases of small solid protein particle, water and fat solutions.

TSE: transmissible spongiform encephalopathy

UKDEFRA: United Kingdom Department for Environment, Food and Rural Affairs

US: United States

USDA: US Department of Agriculture

USEPA: US Environmental Protection Agency

Wet rendering: A method of batch rendering in which the raw material is subjected to a temperature of 140°C under high pressure generated either by injecting steam into the cooker, or by allowing the steam from moisture in the raw material to build up.

Yellow grease A or B; no 1, no 3 tallow: These result from the poorer pork and beef sources of raw material. Free fatty acid range up to 35%, and color can be as high as 37 FAC. (FAC is the abbreviation of the Fat Analysis Committee of the AOCS.) Often referred to as feed fats, they come from spent frying oils and animal fats. They may be animal or vegetable. A sample of fat is filtered then compared with standard color slides mounted on a circular aperture. FAC color standard runs from 1-45 using odd numbers divided into five series for grading:

1-9 = Light colored fats 11,11A, 11B, 11C =Very yellow fats,

13-19 = Dark, reddish fats. 21-29= Greenish fats 31-45= Very dark fats

The different series are somewhat independent so there is no orderly increase in the color from the lowest to the highest numbers, i.e., fats graded 21-29 may actually be lighter than those graded 13-19. The FAC method is used when fats are too dark or green to be read by the lovibond method.

Z value: The temperature increase required to reduce the thermal death time by a factor of 10 (or a one-log cycle

Section 1 – Key Content

This chapter provides a discussion of various aspects of carcass rendering, including effective parameters, raw materials, heat-energy, specifications, machinery, necessary equipment, cost analysis, and environmental impacts. This information has been adopted from Pelz (1980), Thiemann and Willinger (1980), Bisping et al. (1981), Hansen and Olgaard (1984), Clottey (1985), Machin et al. (1986), Kumar (1989), Ristic et al. (1993), Kaarstad (1995), Expert Group on Animal Feedingstuffs (1992), Prokop (1996), Haas et al. (1998), Turnbull (1998), United Kingdom Department for Environment, Food and Rural Affairs or UKDEFRA (2000), Mona Environmental Ltd. (2000), Ockerman and Hansen (2000), Texas Department of Health or TDH (2000), Food and Drug Administration or FDA (2001), Romans et al. (2001), Alberta Agriculture, Food and Rural Development or AAFRD (2002), Arnold (2002), Atlas-Stord (2003), Dormont (2002), Environment Protection Authority of Australia or EPAA (2002), UKDEFRA (2002), US Environmental Protection Agency or USEPA (2002), Giles (2002), Ravindran et al. (2002), Sander et al. (2002), Sparks Companies, Inc., or SCI (2002), Hamilton (2003), Kaye (2003), Pocket Information Manual (2003), Morley (2003), Pearl (2003), Provo City Corporation (2003), Scan American Corporation (2003), and The Dupps Company (2003).

1.1 – Definition and Principles

Rendering of animal mortalities involves conversion of carcasses into three end products—namely, carcass meal (proteinaceous solids), melted fat or tallow, and water—using mechanical processes (e.g., grinding, mixing, pressing, decanting and separating), thermal processes (e.g., cooking, evaporating, and drying), and sometimes chemical processes (e.g., solvent extraction). The main carcass rendering processes include size reduction followed by cooking and separation of fat, water, and protein materials using techniques such as screening, pressing, sequential centrifugation, solvent extraction, and drying. Resulting carcass meal can sometimes be used as an animal feed ingredient. If prohibited for animal feed use, or if produced from keratin materials of carcasses such as hooves and horns, the product will be classified as inedible and can be used as a fertilizer. Tallow can be used in livestock feed, production of fatty acids, or can be manufactured into soaps.

1.2 – Livestock Mortality and Biosecurity

Livestock mortality is a tremendous source of organic matter. A typical fresh carcass contains approximately 32% dry matter, of which 52% is protein, 41% is fat, and 6% is ash. Rendering offers several benefits to food animal and poultry production operations, including providing a source of protein for use in animal feed, and providing a hygienic means of disposing of fallen and condemned animals. The end products of rendering have economic value and can be stored for long periods of time. Using proper processing conditions, final products will be free of pathogenic bacteria and unpleasant odors.

In an outbreak of disease such as foot and mouth disease, transport and travel restrictions may make it impossible for rendering plants to obtain material from traditional sources within a quarantine area. Additionally, animals killed as a result of a natural disaster, such as a hurricane, might not be accessible before they decompose to the point that they can not be transported to a rendering facility and have to be disposed of on-site.

To overcome the impacts of catastrophic animal losses on public safety and the environment, some independent rendering plants should be sustainable and designated for rendering only species of animals which have the potential to produce end products contaminated with resistant prions believed to be responsible for transmissible spongiform encephalopathy (TSE) diseases, such as bovine spongiform encephalopathy (BSE; also known as mad cow disease), and the products from these facilities should be used only for amending agricultural soils (meat and bone meal or MBM) or as burning fuels (tallow).

1.3 – Capacity, Design, and Construction

While independent rendering plants in the United States (US) have an annual input capacity of about 20 billion pounds (10 million tons), the total weight of dead livestock in 2002 was less than 50% of this number (about 4.3 million tons). In order to justify costs and be economically feasible, a rendering plant must process at least 50-65 metric tons/day (60-70 tons/day), assuming 20 working hours per day. In the event of large-scale mortalities, rendering facilities may not be able to process all the animal mortalities, especially if disposal must be completed within 1-2 days. Providing facilities for temporary cold storage of carcasses, and increasing the capacities of small rendering plants are alternatives that should be studied in advance.

Rendering facilities should be constructed according to the minimum requirements of Health and Safety Code, §§144.051-144.055 of the Texas Department of Health (TDH) (2000). More clearly, construction must be appropriate for sanitary operations and environmental conditions; prevent the spread of disease-producing organisms, infectious or noxious materials and development of a malodorous condition or a nuisance; and provide sufficient space for placement of equipment, storage of carcasses, auxiliary materials, and finished products.

Plant structures and equipment should be designed and built in a manner that allows adequate cleaning, sanitation, and maintenance. Adulteration of raw materials should be prevented by proper equipment design, use of appropriate construction materials, and efficient processing operations. Appropriate odor control systems, including condensers, odor scrubbers, afterburners, and biofilters, should be employed.

1.4 – Handling and Storage

Animal mortalities should be collected and transferred in a hygienically safe manner according to the rules and regulations of TDH (2000). Because raw materials in an advanced stage of decay result in poor-quality end products, carcasses should be processed as soon as possible; if storage prior to rendering is necessary, carcasses should be refrigerated or otherwise preserved to retard decay. The cooking step of the rendering process kills most bacteria, but does not eliminate endotoxins produced by some bacteria during the decay of carcass tissue. These toxins can cause disease, and pet food manufacturers do not test their products for endotoxins.

1.5 – Processing and Management

The American rendering industry uses mainly continuous rendering processes, and continually attempts to improve the quality of final rendering products and to develop new markets. Further, the first reduced-temperature system, and later more advanced continuous systems, were designed and used in the US before their introduction into Europe. The maximum temperatures used in these processes varied between 124 and 154°C (255 to 309°F). The industry put forth considerable effort to preserve the nutritional quality of finished products by reducing the cooking temperatures used in rendering processes.

Batch cookers are not recommended for carcass rendering as they release odor and produce fat particles which tend to become airborne and are deposited on equipment and building surfaces within the plant. The contents and biological activities of lysine, methionine, and cystine (nutritional values) of meat meals produced by the conventional batch dry rendering method are lower than that of meat meals obtained by the semi-continuous wet rendering method because of protein degradation.

In dry high temperature rendering (HTR) processes, cookers operate at 120°C (250°F) and 2.8 bar for 45 min, or at 135°C (275°F) and 2 bar for 30 min, until the moisture content falls below 10%. While there is no free water in this method, the resulting meal is deep-fried in hot fat.

Low temperature rendering (LTR) operates in the temperature range of 70-100°C (158-212°F) with and without direct heating. While this process produces higher chemical oxygen demand (COD) loadings in wastewater, it has lower air pollutants (gases and odors), ash content in final meal, and an easier phase separation than HTR. The fat contents of meals from LTR processes are about 3-8%, and those from HTR processes are about 10-16%.

If LTR is selected to have less odors and obtain the final products with better color quality, nearly all tallow and more than 60% of the water from the minced raw materials should be recovered from a process at 95°C (203°F) for 3-7 minutes and by means of a pressing or centrifuging processes at (50-60°C or 122-140°F) just above the melting point of the animal fat. The resultant solids should be sterilized and dried at temperatures ranging from 120 to 130°C (248 to 266°F).

LTR systems that incorporate both wet and dry rendering systems appear to be the method of choice. This process prevents amino acid destruction, maintains biological activities of lysine, methionine, and cystine in the protein component of the final meal, produces good-quality MBM (high content of amino acids, high digestibility, low amount of ash and 3-8% fat), and generates tallow with good color.

Contamination of finished products is undesirable. Salmonellae can be frequently isolated from samples of carcass-meal taken from rendering plants; Bisping et al. (1981) found salmonellae in 21.3% of carcass-meal samples. Despite the fact that salmonellae from rendered animal protein meals may not cause diseases in livestock/poultry and humans, it will provide much more confidence for the users if they are completely free of any salmonellae.

Carcass meal and MBM are the same as long as phosphorus content exceeds 4.4% and protein content is below 55%. MBM is an excellent source of calcium (7-10%), phosphorus (4.5-6%), and other minerals (K, Mg, Na, etc., ranges from 28-36%). As are other animal products, MBM is a good source of vitamin B-12 and has a good amino acid profile with high digestibility (81-87%).

1.6 – Cleaning and Sanitation

Discrete "clean" and "dirty" areas of a rendering plant are maintained and strictly separated. "Dirty" areas must be suitably prepared for disinfection of all equipment including transport vehicles, as well as collection and disposal of wastewater. Processing equipment is sanitized with live steam or suitable chemicals (such as perchloroethylene) that produce hygienically unobjectionable animal meal and fat. The sanitary condition of carcasses and resulting products is facilitated by an enclosed flow from receiving through packaging.

Effective disinfection processes are verified by the presence of only small numbers of gram-positive bacteria (like aerobic bacilli) within the facility, and by the absence of *Clostridium perfringens* spores in waste effluent.

Condenser units, which use cold water to liquefy all condensable materials (mainly steam and water-soluble odorous chemical compounds), are used to reduce the strongest odors which arise from cooking and, to some extent, drying processes. The cooling water removes up to 90% of odors, and recovers heat energy from the cooking steam thus reducing the temperature of the non-condensable substances to around 35-40°C (95-104°F). Scrubber units for chemical absorption of non-condensable odorous gases (using hypochlorite, multi-stage acid and alkali units) and chlorination may be employed. Remaining odorous gases can be transferred to a biofilter bed constructed of materials such as concrete, blockwork, and earth, and layered with products such as compost, rice hulls, coarse gravel, sand, pinebark, and woodchips. Microorganisms in the bed break down organic and inorganic odors through aerobic microbial activity under damp conditions. Modern biofilter units (such as Monafil) provide odor removal efficiency of more than 95% for hydrogen sulfide (H_2S) and 100% for ammonium hydroxide (NH_4OH). Odor control equipment may incorporate monitoring devices and recorders to control key parameters.

All runoff from the rendering facility should be collected, directed away from production facilities, and finally directed to sanitary sewer systems or wastewater treatment plants.

1.7 – Energy Savings

Semi-continuous processes, incorporating both wet and dry rendering, use 40% less steam compared with dry rendering alone. Energy consumption in rendering plants can be reduced by concentrating the waste stream and recovering the soluble and insoluble materials as valuable products. Clean fuels, free of heavy metals and toxic wastes, should be used for all boilers, steam raising plants, and afterburners.

Energy for separation of nearly all fat and more than 60% of the water from carcasses can be conserved by means of a pressing process at low temperature (50-60°C or 122-140°F, just above the melting point of animal fat). This process reduces energy consumption from 75 kg oil/metric ton of raw material in the traditional rendering process, to an expected figure of approximately 35 kg oil/metric ton raw material, saving 60-70% of the energy without changing generating and heating equipment (e.g., boiler and cooker equipment).

The animal fat (tallow) produced by mortality rendering can be used as an alternative burner fuel. A mixture of chicken fat and beef tallow was blended with No. 2 fuel oil in a ratio of 33% chicken fat/beef tallow and 77% No. 2 fuel oil. The energy content of unblended animal biofuels was very consistent among the sources and averaged about 39,600 KJ/kg (16,900 Btu/lb). Blended fuels averaged nearly 43,250 KJ/kg (18,450 Btu/lb), and all were within 95% of the heating value of No. 2 fuel oil alone.

1.8 – Cost and Marketing

Over the last decade, the number of "independent" rendering plants has decreased, with an increasing trend towards "integrated" or "dependent" rendering plants (i.e., those that operate in conjunction with meat or poultry processing facilities). Out of 250 rendering plants operating in the US, only 150 are independent. While in 1995, production of MBM was roughly evenly split between integrated (livestock packer/renderers) and independent renderers, recent expert reports show that in the present situation, integrated operations produce at least 60% of all MBM, with independents accounting for the remaining 40% or less.

Current renderers' fees are estimated at $8.25 per head (average for both cattle and calves) if the final MBM product is used as an animal feed ingredient. If the use of MBM as a feed ingredient is prohibited (due to concerns regarding possible BSE contamination), it could increase renderers' collection fees to an average of over $24 per bovine.

According to the Sparks Companies, Inc. (SCI) (2002), independent renderers produced more than 433 million pounds of MBM from livestock mortalities, or approximately 6.5% of the 6.65 billion pounds of total MBM produced annually in the US (this total amount is in addition to the quantities of fats, tallow, and grease used in various feed and industrial sectors). The raw materials for these products comprised about 50% of all livestock mortalities.

Carcass meals are sold as open commodities in the market and can generate a competition with other sources of animal feed, thereby helping to stabilize animal feed prices. The percentage of feed mills using MBM declined from 75% in 1999 to 40% in 2002, and the market price for MBM dropped from about $300/metric ton in 1997 to almost $180/metric ton in 2003. The total quantity of MBM exported by the US increased from 400,000 metric tons in 1999 to about 600,000 metric tons in 2002 (Hamilton, 2003).

The quality of the final MBM produced from carcasses has a considerable effect on its international marketability. Besides BSE, *Salmonella* contamination may result in banned products. While export of MBM from some other countries to Japan has been significantly reduced in recent years because of potential for these contaminants, some countries like New Zealand made considerable progress in this trade. According to Arnold (2002), New Zealand MBM exports to Japan have attracted a premium payment over Australian product of between $15-$30/ton. Japanese buyers and end-users have come to accept MBM from New Zealand as being extremely low in *Salmonella* contamination and have accordingly paid a premium for this type of product. According to Arnold (2002), New Zealand exported 34,284 tons of MBM to Japan during 2000, representing 18.5% of the market share. During the first nine months of 2001, New Zealand exports to Japan had increased to 32.6% of the market share. In contrast, US MBM products represented 1.8% of the market share in 2000, and 3.2% of the market share during the first nine months of 2001.

1.9 – Disease Agent Considerations

The proper operation of rendering processes leads to production of safe and valuable end products. The heat treatment of rendering processes significantly increases the storage time of finished products by killing microorganisms present in the raw material, and removing moisture needed for microbial activity. Rendering outputs, such as carcass meal, should be free of pathogenic bacteria as the processing conditions are adequate to eliminate most bacterial pathogens. However, recontamination following processing can occur.

The emergence of BSE has been largely attributed to cattle being fed formulations that contained prion-infected MBM. As Dormont (2002) explained, TSE agents (also called prions) are generally regarded as being responsible for various fatal neurodegenerative diseases, including Creutzfeldt-Jakob disease in humans and BSE in cattle. According to UKDEFRA (2000), epidemiological work carried out in 1988 revealed that compounds of animal feeds containing infective MBM were the primary mechanism by which BSE was spread throughout the UK. Thus the rendering industry played a central role in the BSE story. Experts subsequently concluded that changes to rendering processes in the early 1980s might have led to the emergence of the disease.

Various policy decisions have been implemented to attempt to control the spread of BSE in the cattle population. Many countries have established rules and regulation for imported MBM. The recently identified cases of BSE in Japan have resulted in a temporary ban being imposed on the use of all MBM as an animal protein source (Arnold, 2002). FDA (2001) implemented a final rule that prohibits the use of most mammalian protein in feeds for ruminant animals. These limitations dramatically changed the logistical as well as the economical preconditions of the rendering industry.

According to UKDEFRA (2000), in 1994 the Spongiform Encephalopathy Advisory Committee stated that the minimum conditions necessary to inactivate the most heat-resistant forms of the scrapie agent were to autoclave at 136-138°C (277-280°F) at a pressure of ~2 bar (29.4 lb/in^2) for 18 minutes. The Committee noted that the BSE agent responded like scrapie in this respect. Ristic et al. (2001) reported that mad cow disease was due to prions which are more resistant than bacteria, and that the BSE epidemic may have been sparked by use of MBM produced from dead sheep, and processing of inedible by-products of slaughtered sheep by inadequate technological processes.

Section 2 – Background

The livestock and poultry industry has historically been one of the largest agricultural businesses in the United States (US). According to the US Department of Agriculture (USDA, 2003), from the nationwide 9.2 million dairy cows in 2002, nearly 170 billion pounds of milk was produced. SCI (2002) indicated that the market for US meat and meat-based products requires the annual slaughter of roughly 139 million head of cattle, calves, sheep, hogs and other livestock, as well as 36 billion pounds of poultry (broiler chickens, layer chickens and turkeys). Every year, millions of animals, representing billions of pounds of mortality, perish due to typical production death losses. For example, the average death rate of dairy cows is about 5% nationwide (Gerloff, 2003).

2.1 – History of Animal Mortality from Disease and Disasters

According to the USDA Economics and Statistics Systems (2002), more than 439 million poultry (excluding commercial broilers) were raised for commercial sale in the United States in 2002. Out of this production, about 52 million birds (almost 12% of the total production) died of various causes before they were marketable. SCI (2002) reported that ruminants (cattle, sheep, lamb, and goats) combine to account for about 22%, and swine 78%, of all mammalian livestock that die prior to slaughter each year. However, because they are considerably larger and heavier, cattle account for about 67% by weight of the total death loss each year.

Infectious and non-infectious diseases worldwide cause heavy losses of animal populations every year. Some of the worst catastrophic mortality losses resulting from various diseases in different countries during the last 10 years are summarized below.

- In 1993, an outbreak of Newcastle disease occurred on a Venezuela farm having nearly 100,000 chickens (Pakissan.com, 2001).
- In 1997 and in 2001, foot and mouth disease (FMD) outbreaks in Taiwan generated millions of dead swine, sheep, and cattle carcasses to be disposed of in a biosecure and time-sensitive manner (Wilson & Tsuzynski, 1997).
- In 1998, animal diseases took a heavy toll. Newcastle disease damaged three poultry farms in New South Wales (Province of Australia), and FMD damaged pig farms in Central Asia, Africa, South America, China, and Middle Eastern countries like Israel. In another case, Rift Valley fever led to the loss of 70% of the sheep and goat populations, and 20-30% of the cattle and camel populations in East and West Africa. During the same year, African swine fever broke out in Madagascar leading to the death of more than 107,000 pigs (Pakissan.com, 2001).
- In 2001, an outbreak of FMD in the United Kingdom resulted in the slaughter and disposal of over 6 million animals, including cattle, sheep, pigs, and goats (UKDEFRA, 2002). Approximately 4 million of these animals were culled for welfare reasons rather than for disease control purposes.
- An exotic Newcastle disease (END) outbreak in 2003 in Southern California resulted in the depopulation of nearly 4.5 million birds and is another example of a disease outbreak in poultry operations (Florida Department of Agriculture and Consumer Services, 2003).

Natural disasters have the potential to cause catastrophic animal mortalities that are just as devastating as infectious diseases. Mortality due to natural disasters can be attributed to a wide variety of events, such as floods, storms, lightning, heat extremes, fires, droughts, and earthquakes. Heat extremes, especially in unusually hot summers, have significant impact on increasing animal mortality. The following natural disasters caused massive animal mortalities.

- Floods that occurred in Texas in 1998 resulted in livestock losses estimated to be approximately $11 million over 20 counties (Ellis, 2001).
- In 1999 Hurricane Floyd in North Carolina resulted in estimated losses of livestock and poultry valued at approximately $13 million (North Carolina State Animal Recovery Team, NCSART, 2001). Losses included over 2 million chickens, 750,000 turkeys, 28,000 hogs, and over 1,100 cattle.
- During a period of intense heat in July 1995 in Iowa and Nebraska, the mortality of feedlot cattle increased tremendously. A total of 10,000 feedlot cattle perished, 3,750 within a single day. The estimated losses to livestock and poultry producers in central Iowa, respectively, were $28 million and $25 million (USDA, 2002).
- In 1997 the North Dakota Department of Agriculture disposed of approximately 11 million pounds of animals that perished during an April blizzard. More than 950 carcasses were removed from waterways, and a total of 13,700 carcasses were buried (Friez, D.C., 1997).

In each catastrophe, animal mortalities caused considerable economic loss to producers. In addition to economic consequences, catastrophic mortality losses may potentially impact public health or the environment.

2.2 – Historical Use of Rendering

The rendering process uses the dead cattle and other farm animal carcasses or their waste by-products. This process involves series of actions including crushing the raw material followed by direct or indirect heating, evaporation of the moisture and separation of the fat from the high-protein solids, pressing the greaves to remove the water, centrifugation of aqueous solution to remove the fat and protein materials, sometimes solvent extraction of protein parts to remove more tallow, drying the protein materials, and grinding them into meat and bone meal (MBM).

The production of tallow for candles and soap has occurred for centuries, demonstrating that the rendering process is not a new industry. However, it was only at the beginning of the 20th century that the conversion of animal slaughtering by-products to MBM for animal feed became important. It can be concluded that the rendering system emerged firstly for animal byproducts and secondly for carcass conversion.

In the 1980s, both tallow and MBM had good commercial values. It was the tallow which was the primary product of rendering. According to the UK Department for Environment, Food and Rural Affiars (UKDEFRA) (2000), the production and use of MBM steadily increased throughout the first half of the century and when national self-sufficiency became an important issue in the UK during the Second World War, regulations actually prescribed its use in animal feed. The production of MBM and tallow continued to increase after the war. UKDEFRA (2000) reported in 1985, roughly half of approximately 1.3 million tonnes or so of raw material processed annually was being dealt with in the 10% of plants that had a normal weekly capacity in excess of 1,000 tonnes. The capacity of the new, larger continuous rendering plants exceeded local supplies of raw materials. They had to look further a field, thus competing with other less efficient renderers, not only for customers, but also for this raw material. The number of rendering plants fell from about 120 in the 1960s, to around 100 in 1979 and roughly 70 in 1986. Many farms were closed, merged, or were taken over during these years. The concentration of the industry continued with further mergers. By 1991, the share of a single firm named PDM in the market had grown to 55% in Great Britain and 60% in England and Wales.

The UKDEFRA (2000) recognized that animal waste collection and rendering "constituted a vital public service as well as commercial activity," but made some recommendations intended to remedy the effect on competition of these firms' pricing policies. Further, carcass rendering offers several benefits to food animal production operations, including providing a feed source for livestock, and protecting herds from diseases resulting from fallen and condemned animals. Though this method of carcass disposal is environmentally sound and the recovered protein meal and fats can be used in animal and other industries, due to the resistance of the causative agent of bovine spongiform encephalopathy (BSE) (also known as mad cow disease) to rendering conditions, and the consequent potential health effects of feeding infective protein meal to susceptible animals, the demand for products from rendered animal carcasses has declined substantially.

2.3 – Objectives

The purpose of this report is to discuss various aspects of rendering as a mortality disposal option. This work is intended to provide information to those with planning and decision making responsibility to determine whether rendering is suitable to the circumstances at hand, and if so, to choose the most appropriate rendering process.

Section 3 – Principles of Operation

This section provides a discussion of various aspects of the rendering process as a carcass disposal mechanism.

3.1 – General Carcass Rendering Process

Definition

Rendering has historically been defined as separation of fat from animal tissues by the application of heat. Romans et al. (2001) indicated that rendering involves the heating or cooking of raw materials (with complex or simple mixtures of protein, minerals, and fatty substances) to liquefy fats and break down membranes or other structures that may hold fat. According to Kumar (1989), the goals of carcass rendering are elimination of water, separation of fat from other materials (mainly protein substances), sterilization of the final products, and production of MBM from a variety of condemned, fallen, culled, and experimental animals. Prokop (1996), UKDEFRA (2000), and Romans et al. (2001) defined rendering as a process of using high temperature and pressure to convert whole animal and poultry carcasses or their by-products with no or very low value to safe, nutritional, and economically valuable products. In fact, the highly perishable protein and fat materials comprising carcasses become a major problem and a liability if they are not converted, stabilized, or somehow processed during 24 hours following death.

Basic rendering processes

Generally rendering process is accomplished by receiving raw materials followed by removing undesirable parts, cutting, mixing, sometimes preheating, cooking, and separating fat and protein materials. The concentrated protein is then dried and ground. Additionally, refining of gases, odors, and wastewater (generated by cooking process) is necessary. Rendering processes may be categorized as either “edible” or “inedible.”

In “edible” rendering processes, carcass by-products such as fat trimmings are ground into small pieces, melted and disintegrated by cooking processes to release moisture and “edible” tallow or fat. The three end product portions (proteinaceous solids, melted fat, and water) are separated from each other by screening and sequential centrifugations. The proteinaceous solids are dried and may subsequently be used as an animal feed, water is discharged as sludge, and the edible fat is pumped to storage for refining. Figure 1 in Appendix A shows the flow diagram of fat materials in edible rendering.

Plants that employ “inedible” rendering processes convert the protein, fat, and keratin (hoof and horn) materials found in carcasses into tallow, carcass meal (used in livestock feed, soap, production of fatty acids, etc), and fertilizer, respectively. As was true for the edible process, raw materials in the first stage of an inedible process are dehydrated and cooked, and then the fat and protein substances are separated. The pre-cooking processes mainly include removal of skin and paunch and thorough washing of the entire carcass. The hide is not usually removed from hogs and small animals, but the hair of such animals is generally removed before washing and cleaning. The carcasses are crushed and transported to a weighing bin and then passed through metal and non-metal detectors. These devices in turn sort out nearly all of the magnetic and non-magnetic metal materials (tags, hardware, and boluses). Metals that may be associated with the carcasses are removed by strong magnets attached to conveyors.

The use of carcasses in advanced stages of decomposition is undesirable because hide removal and carcass cleaning is very difficult, and the fat and protein resulting from such carcasses is generally of low quality. In the event of a disaster situation, decayed carcasses without entrails along with dumped paunches should be segregated and processed separately.

Although edible and inedible rendering processes are generally similar, they differ in their raw materials, end products, and sometimes equipment. UKDEFRA (2002) stated that in batch rendering of inedible foodstuffs, multiple cookers are used. In inedible rendering systems the final solids, called "cracklings," are ground to produce protein meal. The fat is centrifuged or filtered to remove any remaining protein solids and is then stored in a tank.

According to the Expert Group on Animal Feedingstuffs (1992), the average particle size of material entering the cookers is 40 mm, the average cooking time is about 3 1/2 hours, and the maximum temperatures range from 120-135°C (248-275°F) under atmospheric pressure. This group also stated that some plants cook the materials under higher pressure and temperature (2 bar and 141°C [286°F]), but for a shorter time (e.g., 35 min). In some plants the load is discharged once the maximum temperature is reached; in others there may be a holding time of up to 20 minutes. On discharge, the free run fat is drained off and the residual "greaves" (a high-protein solid which is left from the cooking materials) are removed for pressing and/or centrifugation to extract more fat. Finally, the dried greaves are subsequently ground to produce MBM, or sold as greaves to other renderers for further processing. High-intensity odor emissions result from heated materials on the "percolating pan," and the screw press is either air-cooled in finned tube systems or water-cooled in shelled tube systems.

The resulting greaves and tallow products of rendering systems are impure and require further purification and refining processes. The tallow may contain water, and the greaves contain fat and water. To separate fat and water from greaves, solvent extraction and drying of solid proteins are used. According to UKDEFRA (2000), from the 1950s until the 1970s the preferred method of extracting tallow from greaves was solvent extraction. This extracted more tallow than other processes, so the resulting MBM contained less fat. During this time, the extra cost of solvent extraction was justified by the fact that the animal feed industry desired MBM with fat content of only 1 to 5%, and because tallow fetched a much higher price than MBM. However, this process subsequently fell out of favor for the following reasons (Arnold, 2002):

- The energy crisis in the 1970s dramatically raised the price of solvents;
- The price of tallow fell relative to MBM in the late 1970s, reducing the profit in producing more tallow and less MBM;
- Animal feed manufacturers began to produce higher-fat feeds (about 10 to 12% fat), and therefore no longer required the low-fat MBM produced by solvent extraction but preferred higher-fat MBM instead; and
- The use of solvents entailed an ongoing risk of fire and explosion.

Alternatives to refining by solvent extraction include a variety of methods, all of which are based on increasing the difference in specific gravity between the fat and suspended water and protein materials. Techniques to increase or pronounce the density differences between fat, protein materials, and water include the use of steam-jacketed, conical fat refining vessels along with adding brine solution and centrifugation. The fat and protein mixture is indirectly heated and boiled in a steam-jacketed vessel for about 15 minutes, and then pumped to another vessel. During the settling process, the heavy portion of the mixture (water and coagulated protein) settles to the bottom of the fat portion in the vessel. The proteinaceous matter and water are removed through a draw-off valve.

The fat obtained from the above process still contains impurities, primarily suspended proteinaceous substances. To separate these materials, Kumar (1989) recommended spraying saturated brine (around 20-25% salt content at the rate of 10% v/v of fat) on the fat surface and boiling the fat solution for 10 minutes. The main advantage of adding salt (brine) is the resulting breakdown of the water/fat emulsion with a corresponding increase in the difference in specific gravity between the fat and suspended matter. In this process most of the coagulated protein, along with the brine, will settle to the bottom, while clear fat floats to the top. The suspended matter is then easily removed through a draw-off valve. The remaining water and proteinaceous substances can be separated from the fat solution by high speed centrifugation and deodorization processes.

Factors affecting carcass rendering processes

Prokop (1996) stated that factors such as time, temperature, particle size, liquid level, and speed of the rotor in cylindrical tanks (defined as revolutions per minute or RPM) directly impact the quality and quantity of finished rendered products. Factors such as electrical loads in amperes for certain equipment, control valve settings, and equipment on/off status are considered indirect parameters. In modern rendering operations, computerized systems monitor and provide instantaneous indications of all of the above.

In order to separate carcass fat from the heavier materials (water and protein), it is necessary to use appropriate combinations of temperature, time, and air pressure, along with proper mixing of crushed raw materials. Proper temperature during the rendering process will increase the density differences between the heavy and light materials. After removing all the materials from the cooking vessel, the wet meat/bone material is dried, milled, and bagged. The cooking water contains some dissolved protein and fat, both of which are removed separately. The protein is added to the meat/bone meal before drying and the fat is directed to tallow stock.

Time and temperature

The time required to complete the rendering process depends greatly on the temperature and air pressure inside the system. As the air pressure and temperature increase, the time to complete the rendering process decreases. For example, the same material that that requires a process time of about 3.5 hours at 125°C (257°F) may only require 35 minutes under pressure (2 bar) at 141°C (286°F) (Expert Group on Animal Feedingstuffs, 1992, Annex 2.4). Furthermore, cooking time and temperature in turn depend on the type of rendering system used (wet or dry, batch or continuous), and on the particle size and chemical composition of raw materials. For instance, UKDEFRA (2000) reported that if the product was high in fat and low in moisture (as edible fat is), tallow in the material would melt out of the solid at around 45-50°C (113-122°F). Once the material reached 100°C (212°F), moisture would be driven off and the solid residue would cook very quickly, virtually frying in the hot tallow. On the other hand, some carcass by-product materials such as offal, which are higher in moisture and lower in fat, would take much longer to render at a higher temperature. As a matter of practicality, most renderers chose maximum temperatures below 140°C (284°F) and adjust processing times. At these temperatures vitamins and trace elements in the solids are not greatly affected, but solids are sufficiently processed to facilitate grinding. Renderers of low-quality material can afford to use higher temperatures.

Air pressure

Air pressure inside the rendering system has an important impact on the quality of outgoing products. According to Taylor (2000), conventional rendering processes do not inactivate prion proteins; but it can reduce their infectivity. He stated that complete inactivation will be achieved, when materials are cooked at 132°C (270°F) at approximately 3 bar (45 psi) for 4.5 hours. Shirley and Parsons (2000) studied the effects of rendering pressures of 0, 2, and 4 bar (0, 30 and 60 psi) on amino acid digestibility in MBM, and on the deactivation of the BSE agent within MBM. They concluded that increasing pressure during the rendering process, even for short time periods (i.e., 20 min), reduced the content of cysteine and lysine in MBM, and the true digestibility of these two amino acids (AA) was also significantly decreased. The digestibility of cysteine was observed to be 65, 50, and 15% at 0, 2, and 4 bar, respectively; the digestibility of lysine was observed to be 76, 68, and 41% at 0, 2, and 4 bar, respectively. While increasing rendering pressure and temperature in the cooking process reduces the potential BSE infectivity of MBM, it likely also decreases the nutritional value of MBM. Therefore, further research is warranted to identify new processing methods (such as applying high pressure without increasing temperature) that effectively eliminate prion infectivity while minimizing detrimental impacts on nutritional quality.

Clottey (1985) indicated that lowering the pressure at the end of the heating time, and simultaneously allowing the tank to cool for 40 to 45 min, will help to gravitate the heavier material to the bottom. Water will be collected above this in a middle layer, while fat rises to the top.

3.2 – Rendering System Options

This section discusses and compares various types of rendering systems.

Rendering systems

In spite of the variation in investment and energy costs, different rendering systems work well for small (poultry), medium (swine, sheep, calves), and large sized (cattle and horse) mortalities. This section outlines the four major rendering options (wet, dry, batch, and continuous) as well as recent combination techniques called wet pressing.

Wet rendering

In wet rendering systems, moisture is added to the raw materials during the cooking process. According to Kumar (1989), wet rendering is a process in which the raw material and added water are subjected to direct high steam pressure in a wet rendering vessel. A wet rendering process may be carried out in batch or continuous formats, and in horizontal or vertical vessels. Kumar (1989) stated that a cylindrical vessel with a semi-circular bottom fitted with a draw off valve can be used. In this system, a perforated metal plate is fitted at the junction of the bottom and sidewall of the vessel. This prevents solids from blocking the run-off valve. The vessel is also fitted with a manhole at the top for loading the offal or processed animal parts, and with a discharge door at the sidewall for removing the cooked materials. Two or three draw off cocks are also provided at the sidewall for removal of fat. The vessel has other fittings, such as a pressure gauge, steam supply valve, steam release valve, etc. Wet rendering vessels are available in capacities of 0.45-0.90 metric ton (0.5-1 ton). The manufacturers also indicate the maximum steam pressure with which the equipment may be safely and efficiently operated.

Clottey (1985) recommended a vertical or oblong-shaped cylinder with a cone-shaped base built of heavy steel and fitted with a steam-charging mechanism to provide high temperatures for cooking. Initially, the wet rendering tank is filled with water to about one-third of its capacity. The relatively heavier materials, like bones, feet, and heads, are put in next, with reduced sizes at the bottom of the tank. Softer organs, such as those of the viscera and carcass trimmings, are layered next. Finally, fat is placed on the top, allowing a headspace for the boiling action. In practice, the fill does not exceed three-quarters of the cylinder's volume. With the tank closed, steam is charged through the bottom directly into the tank. Clottey (1985) observed that this process was conducted at a pressure of about 2.72 bar (40 lb/in^2), a temperature of 135°C (275°F), and time of up to 5 hours. Under these conditions, the process was capable of breaking up and softening the tissues, releasing fat, and, importantly, destroying harmful microorganisms.

Injection of live (pressurized) steam into the raw material increases the rate of temperature increase inside the enclosed tank, and speeds up the process. However, it also causes overheating of nutrient materials. Romans et al. (2001) stated that accumulated water in this system, which needs extra energy to evaporate, may have unfavorable effects, such as the remaining material having a consistency similar to molasses. This phenomenon is called "stick" or "stick liquor." This liquid is mixed with the tankage (precipitated solids) and dried. Clottey (1985) indicated that each batch should be analyzed to determine the nutrient composition, especially phosphorus and protein content, which are important criteria for grading and marketing. Horn and hoof tissues are prepared similarly to MBM, but this is done separately because they are inedible and intended to be used as fertilizers.

Although wet rendering can produce good-quality tallow, this system is no longer used because of its high energy consumption, loss of meal (up to 25% in wastewater), and adverse effects on fat quality (Ockerman & Hansen, 2000). It is also a labor-intensive process.

Dry rendering

Whereas the wet rendering method uses direct pressurized steam to cook carcasses along with grinding in large closed tanks, the relatively "newer" method of dry rendering cooks ground carcasses indirectly in their own fat while contained in a horizontal, steam-jacketed cylindrical vessel equipped with an agitator. In both methods, the final temperature of the cooker (120-135°C [250-275°F]) destroys harmful pathogens and produces usable end products such as meat, feather, bone, and blood meal that can be used in animal feeds (Franco & Swanson, 1996, and EPAA, 2002). Dry rendering can be accomplished in batch, semi continuous, and continuous systems.

In dry rendering systems, heat generated by steam condensation is applied to the jacket and agitator blades to ensure uniform heat distribution and shorten the time necessary for cooking the carcass materials. According to Kumar (1989), during the cooking time (which ranges from 45 minutes to 1.5

hours), the jacket pressure is normally maintained around 4.2 bar (60 lb/in^2), and the internal shell pressure around 2.8 bar (40 lb/in^2).

The indirect heat of the dry system converts the moisture in carcasses to steam; the resulting steam pressure inside the vessel, combined with continuous agitation, break down fat cells and disintegrate the material. The cooker is brought to a desirable steam pressure at which it is maintained for a period of time.

Through a sampling valve, cooked material is monitored periodically to determine when the cooking process is complete. The slight grittiness and fibrous nature of the cracklings provide indications of the progress of the cooking process (e.g., disappearance of fiber indicates over-cooking) (Kumar, 1989).

After cooking, steam generated inside the cooker is removed through a steam release valve (adjusted at specific pressure). Since there is no discharge of liquid stick in a dry rendering process, the remaining cooked product is dried inside the vessel, contributing to the higher yield of meat meal observed for dry rendering as compared to wet rendering processes.

Batch rendering

Both dry and wet rendering systems may be used in a batch configuration. The dry process will be considered first. In England about 20% of the available raw materials were consumed in batch rendering systems (Expert Group on Animal Feedingstuffs, 1992). According to Prokop (1996), UKDEFRA (2000), and EPAA (2002), "batch cookers" consist of large, horizontal, steam-jacketed, cylindrical vessels equipped with agitators or revolving beater shafts, which facilitate further break down of fatty tissues. In the first stage, the raw material from the receiving bin is conveyed to a crusher or similar device to reduce its size to pieces of 25-50 mm (1-2 in) for efficient cooking. Cookers are heated at normal atmospheric pressure to around 100°C (212°F) until the moisture is driven off through vents in the form of steam and the temperature rises to 121-135°C (250-275°F) depending on the type of raw materials. This high temperature breaks the cell structure of the residue and releases the fat as tallow. In terms of loading, some plants discharge raw materials to the batch cooker when the batch maximum temperature is reached; others utilize a holding time of up to 30 minutes. After the heating process, which normally takes up 2-3 hours, the tallow is decanted off and the solids are emptied from the cooker.

The cooked material is discharged into a separate container or a percolator drain pan, which allows the free-run fat to drain away from the protein solids (known as tankage or cracklings). Prokop (1996) and the US Environmental Protection Agency (USEPA) (2002) stated that the resulting insoluble protein (solid content), containing about 25% fat, is conveyed to a screw press and releases approximately 15% more fat, resulting in a final residual fat content of 10%. Figure 1 in Appendix B shows the material flow for a dry process in a batch configuration.

Another method of batch rendering is "wet rendering," in which the raw material is subjected to a temperature of 140°C under high pressure generated either by injecting steam into the cooker, or by allowing the steam from moisture in the raw material to build up. UKDEFRA (2000) reported that renderers often choose to first raise the temperature to the maximum and hold it for a while, and then slowly release the pressure, sending the temperature back to around 100°C (212°F). The extruded tallow can then be removed and purified by gravity or centrifugation to remove any water and particulate matter. The moist solids are then dried at this temperature for three to four hours. As an alternative, some renderers simply cook the raw material at an increasing temperature for two to three hours before reaching the maximum temperature, whereupon the material is removed (either immediately or after a specified holding time).

Protein solids containing residual fat are then conveyed to the pressers for additional separation of fat. Prokop (1996) stated that it is usual to screen and grind the protein material with a hammer mill to produce protein meal that passes through a number 12-mesh screen. The fine solid particles, which are discharged from the screw press along with fat, are usually removed either by centrifugation or filtration.

Water vapor is released by vacuum via an exhausted air vent. The USEPA (2002) reported that vapor emissions from the cooker pass through a condenser where the water vapor is condensed. Non-condensable compounds are emitted as volatile organic compounds.

Continuous rendering

Although a variety of rendering options have been designed and operated (from the early 1960s, by Baker Commodities in Los Angeles), most of them have a "continuous cooker" and use heating, separation, and cooling processes on a continuous flow basis. EPAA (2002) explained that in this system, all the rendering processes are done simultaneously and consecutively. Most continuous rendering systems require little to no manual operation, and, assuming a constant supply of raw material, finished products will be generated at a constant rate. In this system, more automated control is exercised over the crushing of big particles, uniform mixing of raw material, and the maintenance of required time and temperatures of the cooking processes. Batch and continuous rendering systems use indirect steam in jacketed vessels. Generally, continuous ones are equipped with automatic controls for both time and temperature. Continuous systems also generally offer greater flexibility, allowing a wider range of time and temperature combinations for cooking raw materials (UKDEFRA, 2000). Figure 2 in Appendix B shows that the flow diagram of a continuous dry rendering system is similar to batch rendering, but materials are added and product is removed in a continuous manner.

Press dewatering and wet pressing methods

Although under similar conditions, dry rendering systems use less energy than wet rendering systems, the energy conservation issue has forced renderers to seek new rendering processes that are even more energy efficient. A variety of methods have been suggested that use less heat while at the same time producing tallow and MBM of higher quality and quantity. In the press dewatering method suggested by Rendertech Limited (2002) the main processes are similar to continuous low temperature rendering (LTR) systems in that raw materials are heated until all the carcass fat is melted. After pressurizing the mixture with a double screw press, the solid protein and liquid portions are separated. The fat layer is removed by disc centrifuge, and the remaining liquid portion is evaporated. To produce the MBM, the thick liquid from the dehydrator is added to the solid protein left over on the press and the mixture is dried and sterilized.

Another method of conserving heat energy is the wet pressing method. In 1986, Kodfodfabrikken Ostjyden (KOFO) summarized the process, stating that offal and condemned animals are pre-broken (max. size 70 mm), transported to a weighing bin, and screened by metal and non-metal detectors, as well as a heavy duty electro magnet assembly specially designed and mounted on the entrance of the bin conveyor, to remove both magnetic and non-magnetic metal materials.

The raw material, free of metal, is hashed or chopped to a size of less than 19 mm and indirectly preheated with hot water to 60°C (140°F) in a coagulator. After passing a strainer screw with adjustable sized holes, it is condensed in a twin-screw press. This process divides the raw materials into two portions, a solid phase (press cake) containing 40-50% water and 4-7% crude fat on a dry matter basis, and a liquid phase containing fat, water, and some solids. The liquid phase is heated to 100°C (212°F) with live steam and passed through a 3-phase decanter (tricanter), which separates it into fat, stick water (the viscous liquid), and grax (suspended solid proteins).

The grax is returned to the coagulator, the fat is sent for refining and sterilization, and the stick water (containing 8% dry matter and 0.6% crude fat) is pumped into the 3-stage waste heat evaporator for concentration. This concentrate, containing 35% dry matter (with 8-9% fat in dry matter), is mixed into the press cake, which is dried in a plate contact drier indirectly heated by live steam. The meal leaves the drier at no less than 110°C (230°F) at which temperature sterilization is accomplished. The meal has a moisture content of 5-7% and a fat content of 7-8%. It is transported to milling by means of a pneumatic transport system. The drier gasses pass a scrubber where the particulates are removed from the vapors and a small proportion of the vapors are condensed. The scrubber liquid heats water (90°C [194°F]) for the coagulator via a heat exchanger. Figure 3 in Appendix B shows clearly the flow diagram for a wet pressing system and highlights the main differences as compared to the batch and continuous rendering systems.

Because lower temperatures are used in the dewatering and wet pressing methods, they are sometimes called LTR methods.

Comparison of different rendering processes

As mentioned earlier, the conditions of each system have a considerable effect on the materials and energy requirements and also on the properties of the final product.

Batch versus continuous systems

Batch and continuous rendering systems each have advantages and disadvantages. A batch rendering system cooks, pressurizes, and sterilizes in the same vessel, and separate cookers can be set aside for different materials (e.g., edible tallow, margarine tallow, and inedible tallow). Ockerman and Hansen (2000) stated the following major disadvantages of batch systems:

- Tallow is darker compared to that from LTR methods (dewatering and wet pressing).
- The high cooking and pressing temperature produces fines which pass into tallow and are lost in the effluent from the tallow-polishing centrifuges.
- Carcass material (especially viscera) must be cut and washed otherwise it generates a loss of fat and protein and adds water to the raw material.
- Since batch rendering processes are not contained in enclosed vessels, there is increased potential for re-contaminated of cooked products, and plant sanitation is more difficult.
- It is difficult to control the end point of the cooking process.
- There is a high consumption of steam if vent steam is not recovered as hot water.
- Finally, it is a labor-intensive process.

Continuous systems (single cooker) have the following advantages (Prokop, 1996) and disadvantages (Ockerman & Hansen, 2000).

Continuous system – advantages

- Continuous systems consist of a single cooker, whereas batch systems consist of multiple cookers (2 to 5 units).
- Continuous systems usually have a higher capacity than batch cooker systems.
- Continuous systems occupy considerably less space than batch cooker systems of equivalent capacity, thus saving construction costs.
- Single-cooker units are inherently more efficient than multiple-cooker units in terms of steam consumption. Thus, continuous systems achieve a significant savings in fuel usage by the boilers. Likewise, less electric power is consumed for agitation in the single continuous cooker units.
- They are labor-efficient.
- Continuous systems are more conducive to computerized control via centers located inside environmentally controlled rooms. Such control centers feature process control panels, which provide a schematic flow diagram of the entire process; indicator lights show whether individual equipment components are on or off. Process microcomputers control all start/stop operations in an interlocking sequence, adjust the speeds of the key equipment parts, and control various process elements to optimize plant operation.

Continuous system —disadvantages

- Continuous systems require greater initial capital investment.
- They cannot sterilize the product nor hydrolyze hair and wool by adding pressure along the cooking process.

These differences in rendering performance result in considerable differences in final products. Ristic et al. (1993) compared a conventional batch dry rendering method using screw press defatting to a semi-continuous wet rendering method using centrifugal defatting for processing inedible raw material (76.5% soft offal, 15% industrial bones, and 8.5% swine cadavers). He observed that the amount of amino acid destruction was higher, and biological activities of lysine, methionine, and cystine in the protein component of the final meal were lower with the conventional batch dry rendering method than with the semi-continuous wet rendering method. Thus, semi-continuous processes incorporating both wet and dry methods have been invented.

Although semi continuous rendering systems have high capital and repairs costs, they have been recommended by Ockerman and Hansen (2000) due to the following advantages:

- They produce tallow and meal of high quality.
- The meal fat is about 8%.
- Approximately 40% less steam is used compared with dry rendering.
- The process can be automated.

Low versus high temperature rendering

Cooking temperature (in batch or continuous systems) makes detectable and noticeable changes in the final rendering products. Taylor (1995) indicated that LTR, especially with direct heating (wet rendering), resulted in higher chemical oxygen demand (COD) loadings in wastewater, but lower odor production, when compared to high temperature rendering (HTR).

In traditional high-temperature dry rendering processes, water boils rapidly and evaporates after the raw material temperature in the cooker reaches 100°C (212°F). When the temperature rises to 110-130°C (230-266°F), there is no free water and the meal is deep-fried in hot fat. Due to the fact that the cooker contents (batch or continuous) are subjected to temperatures above 100°C (212°F) for relatively long periods, Ockerman and Hansen (2000) emphasized using only washed raw material for rendering to remove paunch contents and other "dirt." Otherwise, dirt color from the raw material becomes "fixed" in the tallow, and the tallow will be downgraded.

Since phase separation is carried out easily in LTR (70-100°C [158-212°F]), there is no need to wash raw materials because the color of paunch contents and other dirt do not become fixed in the tallow. As mentioned earlier, final meal products resulting from well-controlled LTR systems and post rendering processes will have low fat and moisture contents. Ockerman and Hansen (2000) reported the fat content of meals in HTR (usually batch dry-rendering) to be about 10-16%, and those of LTR to be about 3-8%.

3.3 – Design Parameters and Capacity of Carcass Rendering

As with any other industry, the concept of processing design in carcass rendering is to have suitable capacity and even flow of inputs and outputs while maintaining optimum quality. Proper design will lead to appropriate capacity, adjustable and meaningful production costs, and straightforward management and operation of the system. However, undersized or oversized capacities (due to improper design) may result in products that do not meet the required microbiological, nutritional, and physical characteristics. Improper design of machinery, process conditions, and plant layout may cause inadequate heating, incomplete destruction of pathogenic bacteria, overheating of raw materials, destruction of nutritional material, insufficient removal of unpleasant gases and odors, and finally production of wastewater with high biochemical oxygen demand (BOD), which may introduce environmental contamination. This section discusses effective design parameters, operating capacity, and their relation to different rendering systems.

Design parameters

Bone particle sizes and overall raw material throughput rate have substantial effects on the rendering process and inactivation of pathogens, particularly heat resistant microorganisms. Furthermore, the flow rate of material is affected by the dimensions and mixer revolutions of cookers. Manufacturing companies design various forms of milling, cooking, and drying machinery to meet the time and temperature requirements for sterilization, while at the same time preserving the nutritional quality of the final products.

It should be noted that most rendering methods, including wet, dry, high temperature, and low temperature (dewatering and wet pressing), can be designed and manufactured in a continuous manner. UKDEFRA (2000) explained that in a continuous rendering system, the workings of the heating stage varied according to plant design. Following are types of continuous cooking process, most of which were named after their first introducers.

- **Stork-Duke.** This system of rendering works on the principle of deep fat frying. Heat is applied indirectly via a steam jacket and a steam-heated tube rotor. The particle size of the raw material entering the cooker is 2.5-5.0 cm (1-2 in) and is held for at least 30 minutes at high temperatures ranging from 135 to 145°C (275 to 293°F). The protein material is then processed before being ground into MBM. Some sources indicate that 65 minutes is needed for the materials to pass from one end of the cooker to the other, however an accurate estimate it is difficult to determine because the residence time depends on the rate at which new material is fed into the system.

- **Stord Bartz.** Raw materials (particle size 2-5 cm or 0.8-2 in) are heated by a steam-heated disc rotor, which occupies the length of the rendering vessel. The average maximum temperature achieved is approximately 125°C (257°F) with an average residence time of between 22 and 35 minutes. Pressing and grinding of the end product (MBM) is similar to the procedure used in the Stork-Duke system. Most Stord Bartz driers operate in the range of 125 to 145°C (257 to 293°F), although some operate at 80°C (176°F).

- **Anderson Carver-Greenfield Finely.** Raw material (minced to less than 10 mm or 0.4 in) is first mixed with recycled, heated tallow to form a slurry. The mixture is then pumped through a system of tubular heat exchangers with vapor chambers under partial vacuum before being centrifuged and pressed into MBM. The described heat treatment involves a maximum process temperature of 125°C (257°F) with an average residence time of between 20 and 25 minutes.

- **Protec and Stord Bartz De-watering Process.** In this low temperature system, raw material is initially minced to a particle size of 10 mm (0.4 in) before being heated to 95°C (203°F) for 3-7 minutes. The liquid phases (fat and water) are removed by centrifuging or light pressing and further separated to recover the tallow. The resultant solids are dried at temperatures ranging from 120 to 130°C (248 to 266°F). An alternative process used at one facility employing a Protec low-temperature rendering system involves placing the residue inside a rotating barrel for about 25 minutes while treating with forced air that enters at 700-800°C (1292-1472°F) and exits at about 110°C (230°F). However, the actual temperature of the material inside the rotating barrel is unknown.

- **Dupps Continuous Rendering System or Equacooker.** This system is designed to operate in a manner similar to a batch cooker. While the layout, heating system, rotating shaft, material agitation, and conveying systems are similar to other continuous systems, the primary difference lies in an adjustable variable-speed drive of the feed screw. The discharge rate for the Equacooker is controlled by the speed or rotation of the control wheel. It employs buckets, similar to those used in a bucket elevator, to pick up the cooked material from the Equacooker and discharge it to the drainer.

According to UKDEFRA (2000), the American rendering industry uses mainly continuous rendering processes. The US rendering industry, as a net exporter of tallow and MBM, is continually attempting to improve the quality of final rendering products and to develop new markets. The first reduced temperature system (from Carver-Greenfield), and, later, more advanced continuous systems, were designed and used in the US before their introduction into Europe. The maximum temperatures used in these processes varied between 124 and 154°C (255 to 309°F). In the years leading up to 1986, the rendering industry put forth considerable efforts to preserve the nutritional quality of finished products by reducing the cooking temperatures used in rendering processes.

Drying systems

Recently The Dupps Company (2003) introduced the Quad-pass (dual-zone) drier (also called a four-pass rotary drier). Figure 1 in Appendix C provides a comparison of this new system with traditional three-pass drum driers. In traditional three-pass driers, material usually begins drying at high air velocity, with air velocity decreasing at each subsequent stage, ultimately slowing such that the material falls out. In this system particles are prone to accumulation, over-drying, volatilization, pyrolysis, and clogging. The manufacturer indicates that in the new four-pass rotary drier, the velocity of particles is slowest at the entrance of the drier and gets progressively faster in subsequent stages. This design allows moisture to be removed from each particle at its individual drying rate without overheating or volatilizing, regardless of particle size or moisture content.

Morley (2003) designed an airless drying system, which uses superheated steam at temperatures up to 450℃ (841℉) to dry protein materials at atmospheric pressure. This design, which produces a faster drying rate than conventional air or contact driers, utilizes two separate closed loops of gas combustion and drying. The separation between the two loops occurs via a high efficiency heat exchanger. Figure 2 in Appendix C shows the combustion loop that produces heat energy from a two-megawatt gas burner, which heats up one side of the heat exchanger. The combustion loop recycles a high percentage of heat in order to maximize operating efficiencies. The drying loop re-circulates the superheated steam via a 37-kilowatt (kW) process fan. Superheated steam is conveyed via 700-milimeter ducting through a dust cyclone, process fan, and heat exchanger before entering a cascading rotary drying vessel measuring some 14.5 meters in length and 1.8 meters in diameter. Results of experimentation with this new system suggest that superheated steam dries at a faster rate while using less raw energy at temperatures above 210℃ (410℉).

A central process logic controller (PLC) controls the devices of the two loops, including burner settings, fan speeds, combustion air, and exhausting air. The speed-controlled fan presents cooled steam from the preceding pass at 140℃ (284℉) to the heat exchanger where it is reheated to a maximum of 450℃ (840℉). From there it is introduced to a rotary cascading drum along with the moist material to be dried. To control the system, at any one time a dozen sensors monitor flows and temperatures and make subtle setting changes to the burner outlet, process fan speed, and feed augers to ensure that only the needed amount of heat energy is delivered to the drying vessel. Morley (2003) reported the following advantages for this new drier:

- The process does not require any form of biofiltration or odor control. Nitrogen oxide levels are markedly reduced.
- The system is constructed entirely of food-grade stainless steel, including all ducting, fans, cyclones, and valves, ensuring that the airless drier is easily cleaned.
- More steam leaves the drier on each pass than enters it due to the process of evaporating moisture during each pass. This is bled off before the heat exchanger and is presented to a condenser unit where the waste heat is converted into hot water that is reused within the plant.
- The overall efficiency of the drying loop reaches 85%, which contributes to impressive fuel conservation.
- The system allows for full recording, trending, and reporting of quality control information, and provides documentation that sterilization criteria have been reached.
- The design parameters suggest a 20% energy savings can be achieved, however, in reality a savings of approximately 35% is achievable based on similar throughputs of the conventional drying method. This is expected to increase with further refinements, including the utilization of waste heat from the combustion loop exhaust.
- Due to less contact of air with the materials being dried, the nutritional values of the resulting MBM are correspondingly higher than materials dried with conventional driers.

Many efforts have been directed at recovering heat energy in rendering systems. Atlas-Stord (2003) designed a new system of recovering waste heat from the dewatering process called the "Waste Heat Dewatering System." Figure 3 in Appendix C shows the flow process of this patented system. In this system, a twin screw press splits the preheated raw material into a solid and a liquid phase, with the liquid phase containing mainly water. Fat is concentrated in the waste heat evaporator, utilizing the energy content of the vapors from the continuous cooker. The pre-concentrated press water and the solids from the twin screw press are dried in the continuous dry rendering cooker. The final de-fatting of the solids takes place in the high pressure press. The authors indicate that a 50-60% reduction in steam/fuel demand compared with conventional batch systems can be achieved, and increases of up to 70% in capacity compared to existing continuous cooker/drier rendering plants may be realized.

Odor reduction

Considerable progress has been achieved in manufacturing very high efficiency odor neutralizing units. For example, Mona Environmental Ltd. (2000) built a biofilter pilot plant next to a rendering plant in Brittany, France to absorb and digest emissions produced by the cooking process. This plant had inlet concentrations of 400 mg H_2S/m^3 and 50 mg NH_4OH/m^3, and outlet concentrations of 20 mg H_2S/m^3 and 0 mg NH_4OH/m^3 (emission unit is defined by mg of odors such as H_2S and NH_4OH in 1 m^3 of gases leaving the cooking tank). In other words, the odor removal efficiency was 95% for H_2S and 100% for NH_4OH. Subsequently, a full scale system was installed to treat the total airflow of 60,000 m^3/hr, in which a removal efficiency of >99.5% was achieved for H_2S and 100% for NH_4OH.

Rendering capacity

Generally speaking, in most parts of Europe, as well as in the US, there is a trend towards fewer rendering plants of larger capacity. But recently, larger rendering capacities have resulted from the need for new technologies to meet environmental requirements. According to Asaj (1980), in Croatia the capacity of rendering plants was very low, with the average volume of material processed annually in the 7 existing plants estimated at roughly 57,000 tons. Due to expansion of the cattle-industry, two additional rendering plants were constructed to achieve a capacity of 100 metric tons (220,000 lb) per day. UKDEFRA (2000) reported that in 1991 in Holland, one company was processing all raw materials, mostly in two rendering plants. In Belgium, one plant processed 95% of raw material. In Denmark, there were four renderers, but one processed more than 80% of the raw material in four plants. On the other hand, in Germany, where federal authorities were directly or indirectly responsible for disposal of animal waste, there were about 42 public and private plants in operation. In Italy in 1995, there were 74 renderers (including those associated with slaughterhouses). They indicated that most European renderers transitioned from batch processes to continuous processing in order to meet pressure for hygienic products, decrease energy consumption, lower labor costs, and minimize environmental impacts. UKDEFRA (2000) reported that rendering in Northern European Countries (e.g., Austria, Denmark, Germany, Holland, Sweden, and Switzerland) required high-pressure cooking, and the new European Community (EC) regulations led to the installation of 200 high-pressure systems throughout the European Union (EU).

The US situation is different from that in Europe. In the past, most operations were "independent" rendering plants (which obtain their raw materials mainly from dead animals and are off-site or separate from the plant facility). However, over the years there has been an increasing trend towards "integrated" or "dependent" rendering plants (which operate in conjunction with meat and poultry processors). Of the estimated 250 plants operating in the US, approximately 150 are independent and approximately 100 are integrated facilities (UKDEFRA, 2000). Whereas in 1995, production of MBM was roughly evenly split between livestock packer/renderers and independents, recent expert reports show that in the present situation, the packer/renderers produce at least 60% of all MBM, with independents accounting for the remaining 40% or less (Giles, 2002).

In spite of the fact that the meal production of independent renderers has declined in recent years, they have a very good capacity to process dead animals. A UKDEFRA (2002) report indicates that the entire US rendering industry in 2002 produced about seven million tons of rendered products (MBM, lard, and tallow). According to SCI (2002), independent renderers produced more than 433 million pounds of MBM from livestock mortalities, or approximately 6.5% of the 6.65 billion pounds of total mammalian-based MBM produced annually in the US (this total amount is in addition to the quantities of fats, tallow, and grease used in various feed and industrial sectors). The livestock mortalities used for this product (433 million lbs) represent about 50% of all livestock mortalities.

As there is no published data on the rendering capacities of "integrated" rendering plants in the US, based on the above-mentioned data related to the year of 2002, the following calculation shows that independent renderers have enough potential to absorb and render all livestock mortalities.

- (100 dependent renderers)(2C) + (150 independent renderers)(C) = 7,000,000 tons (total production). To ensure a conservative estimate of the capacity (C) of independent renderers, the capacity of dependent renderers was assumed to be about two times that of independent renderers.
- Based on the above-mentioned equation, C (production capacity of each independent renderer) = 20,000 tons, and their total production capacity = (150 plants)(20,000 tons/plant) = 3,000,000 tons.
- The total production capacity of a rendering plant is approximately 30% of their input capacity, and based on this fact the independent rendering plants in the US have an input capacity of about 10,000,000 tons.
- Since the 433 million lbs of produced MBM were about 10% of the livestock mortalities as the raw materials, the total livestock mortalities were about 4.33 billion lbs, or 50% of the total mortalities in that year. Thus, the total weight of dead livestock was about 8.660 billion lbs (4.33 million tons).
- Comparison of the capacity of independent rendering plants and the total weight of dead livestock clearly shows that the independent plants have a good potential to convert all the farm animal mortalities into carcass meal and tallow.

Others (namely, Hamilton [2003]) report that the US rendering industry generates about 52 billion pounds (26 million tons) of rendered products annually. Of the raw materials used in this production, 40% is represented by animal mortalities made up of approximately 4 million cattle, 18 million pigs, and 100 million poultry. Keener et al. (2000) classified carcasses into four different weight groups of small (less than 23 kg [50 lb]; i.e., poultry), medium (23-114 kg [50-250 lb], or average of 70 kg [154 lb]; i.e. swine), large (114-227 kg [250-500 lb], or average of 170 kg [374 lb]) and very large or heavy carcasses (225- 500 kg [500-1100 lb], or an average of 362 kg [800 lb]). Using average weights of 600 lbs for cattle, 300 lbs for swine, and 4 lbs for poultry, the overall estimated weight of on-farm animal deaths will be as follows:

4×10^6 cattle x 600 lbs/cattle = 2.4 billion lbs

18×10^6 pigs x 300 lbs/pig = 5.4 billion lbs

100×10^6 poultry x 4 lbs/poultry = 400 million lbs

Total weight of dead livestock = 8.2 billion lbs (4.1 million tons)

This number is very close to the weight of dead farm animals calculated by MBM production in independent rendering plants. Figure 4 in Appendix C provides an overview of the relationship between the total animal mortalities and MBM production in 2002. The actual weight of mortalities used by renderers in 2002 was about 3.3 billion lbs. This number was about 40-50% of the total weight of dead carcasses or 8.3 billion lbs.

3.4 – Raw Materials, Energy, and Equipment Requirements

The microbiological, chemical, and physical characteristics of carcasses are important factors for making high quality rendered products. Some preparation processes, such as size reduction, pre-heating, and conveying, are essential for marketable rendering products.

Raw materials

Carcasses are composed of four broad components including water, fat, protein, and minerals. The European Commission (2003) reported that water, a major component of the live weight of the animal, varies between 70-80%, and for carcass byproducts is about 65%. Livestock mortality is a tremendous source of organic matter. A typical fresh carcass contains 32% dry matter, of which 52% is protein, 41% is fat, and 6% is ash. The carcasses of different animal species have slightly different compositions (see Table 1 in Appendix D). Fat content is quite different as well; the fat content of cattle and calves is about 10-12%, that of sheep is about 22%, and that of hogs is about 30%. These compositional differences result in different species having different optimal processing conditions. For example, under equal conditions, the wastewater generated by rendering hog carcasses may require more separation to remove all the fat as compared to wastewater generated by rendering cattle carcasses.

"Integrated" plants are generally located in conjunction with a slaughter operation and typically process only one type of raw material. Although the composition of raw material used in this type of operation is not completely homogeneous, it is somewhat consistent and raw materials are relatively fresh, therefore simplifying control of the processing conditions. In this system, the final human-grade, edible oil products known as tallow, lard, or edible grease are derived from the fatty tissues of cows and pigs.

Conversely, "independent" operations often process farm animal mortalities and a variety of other "raw by-products" that are not suitable for edible rendering. These raw materials are less homogeneous and therefore require more frequent changes in operating conditions within the system. Furthermore, these raw materials may harbor a potential public health hazard, and should preferably be sterilized before rendering. In addition to carcasses, the following could be used as raw materials for independent renderers, however the use of finished inedible products may be restricted in some circumstances (i.e., may not be used in some types of animal feed, etc.; Oosterom, 1985):

- Placenta
- Offal from hatcheries
- Inedible offal from slaughterhouses and poultry processing plants
- Intestinal contents, such as rumen ingesta
- Trimmings, fleshing, floor sweepings, sieve remains, and fat from wastewater produced in slaughterhouses and meat industries
- Sludge from slaughterhouse wastewater treatment plants
- Condemned fish and fish offal
- Leftover foods from restaurants, food industries, catering establishments, etc.
- Cadavers of pets, strays, and sport animals
- Cadavers of laboratory animals after completion of experiments
- Animals slaughtered for partial use: fur animals, sharks, shrimp, lobsters, frogs, crocodiles, etc.
- Remains from leather industries
- Remains of animal materials sent for examination to veterinary institutes, food laboratories, etc.

In July 1997 the US Food and Drug Administration (FDA) established a rule to prevent transmission of transmissible spongiform encephalopathy (TSE) agents in ruminant animals. According to FDA (2001), feeding ruminants with the meat meal resulted from rendering certain species of animals (mainly cattle, goats, sheep and farm-raised deer or elk) was prohibited. No restriction has been made on feeding ruminant animals with MBM produced by rendering non-ruminants such as poultry. The prions of TSEs are responsible for many fatal neurodegenerative diseases in humans and animals.

In addition to the 1997 ruminant-to-ruminant feed ban, other protective measures have been taken. These have included a ban on importation of ruminants and ruminant products from countries with BSE and measures to exclude potentially infective material from the human food supply. With the December 2003 discovery of BSE in Washington state, additional safeguards and surveillance activities are being implemented.

The European Commission (2003) defined the term MBM as a meal produced from red meat animals, but excludes meal produced from poultry. According to the Animal By-Products Regulations of Northern Ireland (2003), "MBM" or "mammalian MBM" refers to mammalian protein derived from the whole or part of any dead mammal by rendering (with the heat treatment at least 140°C for 30 minutes at 3 bar pressure) and "protein" means any proteinaceous material which is derived from a carcass (but does not include: milk or any milk product; dicalcium bone phosphate; dried plasma or any other blood product; gelatin; or amino acids produced from hides and skins). MBM in the US is defined as a multiple source of protein derived from the processing of animal carcasses (Zamzow, 2003). This material can include animals that are deceased from disease and even pet animals that have been euthanized. The material processed by carcass renderers may consist of the parts of permitted animals that are unsuitable for people to eat as a food, such as:

- offal that did not have a more valuable use, such as the bladder, diaphragm, udder, intestines, kidneys, spleen, blood, stomach, heart, liver, and lungs, which were only occasionally used for other purposes;
- the head, hooves, bones, and tails;
- edible fat; and
- waste from knacker's yards (entities who collect dead or diseased animals from farms in order to salvage any products of value and dispose of the remains, usually to a renderer), and from other animal by-product trades such as hunt kennels, maggot bait farms, tripe dressers, and tanners.

These materials could be subjected to further rapid deterioration or otherwise be contaminated by microbiological organisms, including those which may be pathogenic to humans. In order to protect human and animal health, as well as the environment, these materials should be properly collected and decontaminated as soon as possible after they become available. Decontamination of animal materials could be achieved by various means. For example, for destruction of anthrax spores, Turnbull (1998) recommended using formaldehyde, glutaraldehyde (at pH 8.0-8.5), hydrogen peroxide, and peracetic acid (for raw materials without blood such as hooves and bones). Although irradiation with gamma rays, use of particle bombardment, or fumigation with a gaseous disinfectant such as ethylene oxide has been recommended for decontamination of certain animal by-products (Turnbull, 1998), further research is needed to see the applicability of these methods for decontamination of animal mortalities.

Although the rendering process is capable of converting carcasses or their parts to dry meal, the quality of the carcass will affect the final product in terms of protein content and total bacterial counts. Clottey (1985) emphasized that only condemned material and parts of freshly dead animals can be included, but not material that is putrefied or in an advanced state of decomposition.

Storage of carcasses

When the quantity of carcasses received exceeds the processing capacity of a rendering plant, it is necessary to store the carcasses as a surplus of raw material. According to AAFRD (2002), carcasses requiring storage for more than 48 hours after death may be stored in one of the following ways:

- In an enclosed structure under refrigerated conditions (0-5°C or 32-41°F).
- Outside during winter months when the ambient temperatures is low enough to maintain the carcasses in a frozen state.
- In a freezer unit.

Some animal production operations use special low temperature storage bins, to refrigerate or freeze carcasses until they can be taken to a rendering facility. Using cold storage for carcasses not only reduces chemical and microbial activities and their associated odors, it also keeps them out of sight and prevents scavenging. Carcass storage areas should be located in areas that will minimize the spread of disease. It has been recommended separate entrances be provided to feedlots to prevent rendering trucks from entering the main feedlot areas.

Carcass storage areas and the surrounding vicinity should be thoroughly cleaned before and after use, and wastewater should be prevented from entering streams or other surface waters.

Electrical and heat energy

The most limiting factor in carcass rendering processes is the energy required for releasing fat, evaporating water, and more importantly, complete sterilization of raw materials. Due to the mixture of fat and water in the rendering process, the heat transfer coefficient varies, and therefore the required heat energy varies as well. According to Herbert and Norgate (1971), the heat transfer coefficients of rendering systems decline rapidly from 170 to 70 Btu/ft^{2}hF^o. They explained that as water is evaporated during the rendering process, a phase inversion occurs from a tallow-in-water dispersion initially present in the cooker, to a water-in-tallow dispersion. A minimum value is reached when all water droplets have disappeared and remaining water is present only as "bound water" in the protein particles. This idea became a base for transitioning from HTR to LTR systems, especially in batch rendering configurations which have high energy consumption and do not allow for secondary use of the energy in the exhaust steam from cookers.

KOFO (1986) outlined a concept of "wet pressing" based on the discovery that it is possible to separate nearly all fat, and more than 60% of the water, from the solids of raw materials by pressing at low temperature (50-60°C or 122-140°F, just above the melting point of the animal fat). This process optimized the energy necessary for sterilization and removal of water, thus reducing the energy consumption from 75 kg oil/metric ton raw materials in the traditional process, to approximately 35 kg oil/metric ton of raw material in the new process. As a further advantage, no organic solvents are needed for the process. Furthermore, as compared to HTR systems this system produces protein meal and tallow with higher quality and quantity. Energy consumption measurements demonstrated the following:

- 33.2 kg fuel oil used/metric ton of offal, corresponded to the use of 60.1 kg oil/metric ton of evaporated water.
- 69.1 kWh of energy/metric ton of offal, or 125 kWh/metric ton of evaporated water.

Fernando (1984) compared LTR and HTR systems and concluded that LTR systems required around 0.5 kg (1 lb) of steam per kg of raw material, whereas HTR systems required around 1.0 kg (2.2 lb) of steam per kg of raw material. That is, under equal conditions the consumption of steam in HTR is twice that of LTR systems.

Processing equipment

The machinery and equipment required depends on the specific rendering option, the input capacity, the degree of automation, and the extent of end product refining and storage. In batch systems, only minimal equipment is required (sometimes only one vessel). Flow (addition and removal) of materials is static. In a continuous system, materials flow in a steady stream, therefore pre- and post-rendering equipment is needed in addition to the main rendering unit.

Although traditional batch systems include a vessel in which most of the rendering process occurs, dry and continuous carcass rendering systems require auxiliary equipment, such as a pre-breaker, hasher and washer, metal detector, screw conveyor, fat refining system, and centrifugal extractor. Usually this equipment is installed along with the rendering cooker mainly for pre-rendering and post-rendering processes. Although optional for animal by-products (like offal), use of such pre-rendering equipment is necessary for rendering whole carcasses because of the size and nature of the materials.

In order to minimize processing time and allow use of the lowest possible sterilization temperature, carcass materials are crushed and mixed using equipment such as crushers, mixers, mills, screeners, decanter centrifuges, and millers. Of the equipment used on a continuous basis, size reducers, cookers, presses, evaporators, and centrifuges are notable. Surge bins, along with variable-speed drives between different units of operation, provide a relatively even flow and control of material through the system. Figure 1 in Appendix D provides a schematic diagram of the machinery and equipment used, along with material flow, in a continuous dry rendering process. More detailed information about the most common equipment used for different rendering processes follows.

Pre-rendering equipment

Before heat treatment, carcasses have to be broken down in a closed system into pieces not larger than 10 cm^3. This is accomplished using a "crusher" or pre-breaker to reduce carcasses into pieces of uniform size prior to passing through size reduction equipment and subsequently entering a continuous pre-heater or cooker/drier. A pre-breaker contains "anvils" in place of knives. In order to break large materials and move them through the bars, the anvils rotate between parallel bars at the bottom of the honor or pre-beaker. The capacity of size reducing equipment must be adequate to maintain a steady throughput of pre-ground material through the rendering plant.

Further size reduction is accomplished with rotating hammer devices called "hammer mills" or simply "grinders with rotating knives" that operate by impacting and pinching actions to force crushed materials through a retaining screen. As the rotor turns, hammer-heads swing and beat/drive the materials into a breaker plate and through a retention screen. Depending on the nature of raw materials, cutters or bars may be used instead of hammers.

Other pre-rendering equipment that may be used include hasher and washer units (hasher represents a French word for equipment that chops materials such as meat and potatoes into small pieces), metal detectors, and screw conveyors. The combined hasher and washer chops and washes carcass material, and, in some cases, soft tissue such as stomachs and intestines. A metal sorter detects and removes metal from crushed raw materials; ear tags, magnets, consumed metals, and other metal pieces are fairly common in livestock carcasses. Finally, a screw conveyor transports crushed raw material to the pre-cooker or cooker.

Cooking equipment

An integral part of any continuous rendering system (wet or dry) is the cooker, comprised of sections of pre-heater and heater. Cookers are constructed in a cylindrical form through which ground carcass material is conveyed by means of a rotor or agitator in the form of screw conveyer. For efficient heat energy use and transfer, most cylinders and agitators are steam heated. Various steam jacket designs have been used; for cylinders of considerable length the steam jacket can be divided into sections. Each section is equipped with devices for individual condensate discharge to regulate the steam supply and thus maintain the proper temperature for each section.

Various names such as "renderer," "rendering vessel," "rendering melter," or "rendering cooker" are given to the principal piece of equipment used in the rendering process. According to Kumar (1989), the conventional cooker is a horizontal steam jacketed vessel made up of two concentric cylindrical shells of milled steel (covered with end plates) and fitted with an agitator. The mixer is made of a shaft and attached solid or hollow blades. Along the horizontal central axis of the vessel, the shaft passes through the two end plates and is supported by heavy-duty bearings on either side. The blades are designed to continuously scrape the inner surface of the cooker, thus preventing scorching and overcooking. A manhole at the top of the cooker is used for maintenance and repairs. The vessel is equipped with an entrance gate for crushed raw material. Valve and discharge gates are fitted at one of the end plates. A suitable gear drive box and motor for the agitation are mounted on the other end plate of the vessel. Depending on the required rendering capacity, dry rendering cookers are manufactured in various sizes, but most are generally manufactured to withstand a working steam pressure of 7 bars or 100 psi (Kumar, 1989). In dry rendering systems (batch or continuous), steam is the main heating source which is entered in jacket layers, while in wet rendering water in form of steam or normal liquid is injected directly into the raw materials. Several factors, such as loading rate, temperature, pressure, and quantity of steam used, control the average cooking temperature and retention time of the materials inside the rendering tank.

Electrical instruments such as starters and reversing switches, as well as fittings such as pressure gauges (for the steam jacket and internal shell), safety valves, vapor line valves, steam condensate discharge valves, water jet condensers, etc. are provided at a convenient place for operation and monitoring.

Pressing units

Pressing units may be used to press the input materials going to the cooker, or the output products from the cooking process. Usually typical screw presses with one or two rotating elements operate in a continuous manner. The performance of single-screw presses is very similar to double-screw presses, with a reduction of volume as material moves down the screw (due to the change in pitch and diameter of flights).

Ockerman and Hansen (2000) reported that wet output material is fed into an inlet chute (a sloping channel) at the end of the press and fills the free space between the screw flights and the strainer plates. The materials are subjected to steadily increasing pressure that causes an efficient squeezing of the wet material. The liquid materials (mainly water and fat) escape through the perforated strainer plates around the screws and are colleted in a tray equipped with a discharge pipe. The solid or pressed, dewatered, and defatted material is discharged axially at the end of the press.

The characteristics of the material to be pressed have significant effects on the throughput and volume ratio of screw presses. Ockerman and Hansen (2000) indicated that for moist and soft materials, there is generally a quick initial compression followed by a more gradual compression rate during the subsequent pressing.

Evaporators

The liquid mixtures coming from the rendering process contain considerable water which can be removed economically using efficient evaporators. Water evaporation is an energy-intensive process; low-pressure evaporators are more efficient than open kettles or other systems operating at atmospheric pressure. At a pressure of 0.5 bar (almost 0.5 atmosphere) water boils at 81.5°C (179°F); therefore, the use of low pressure evaporators can produce "waste" vapors that can be used as a heat source for the evaporators.

Increasing the efficiency of evaporators has been accomplished in several ways. One is by using the condensed live steam leaving the jacket of a cooker/drier as a heat source to drive the evaporator. Another technique is to use multiple-effect (stage) evaporators. Ockerman and Hansen (2000) reported that addition of every stage to the evaporator will nearly double the efficiency of evaporation, meaning twice as much liquid is evaporated per quantity of live steam or waste vapor consumed in the steam jacket. In a multiple-effect evaporator system, vapor from an effect is condensed in the steam jacket of a succeeding effect.

Increasing the heat transfer surface has been successfully practiced in modern evaporators. Instead of simple jacketing of the boiling chamber, vertical tube bundles can be used with the heating medium on the outside of the tubes and the product boiling on the inside. In the heat tubing evaporators, product is either moved downward through the tubes (falling film), or upward through the tubes (rising film). By feeding the evaporator with a thin film of product and at a proper flow rate, the overall heat resistance coefficient inside the tubes is minimized. This results in high heat transfer coefficients and allows a significant amount of water to be evaporated within a relatively small area of equipment.

Solid –liquid separators

Although tallow, water, and solid protein stay at three different levels in the rendering tank, each portion has considerable impurities of the other portions. Separation is achieved using both simple and sophisticated separation tools such as decanters, strainers, and centrifuges.

Ockerman and Hansen (2000) specified three purposes of decanters for clarification of rendered products, namely (1) primary clarification of tallow, (2) dewatering of coagulated blood solids, and (3) dewatering of solids from effluent. They recommended using decanters for removal of solids from slurry containing 30-40% solids. A drum rotating at 3,000-4,000 rpm separates the liquid phase, which remains close to the axis of rotation of the machine, from the solid content or heavier phase, which goes to the outside of the rotating drum, is transported along the shell to the conical section with the aid of a screw, and is discharged.

High speed separators, based on the application of centrifugal force, effectively separate tallow, water, and solid protein. Various types of centrifugal separators, such as decanters and disc-type high-speed separators are used in the rendering industry. Cracklings from the percolator are loaded into a perforated basket covered with a filter cloth and fitted inside a centrifugal fat extractor. As Kumar (1989) indicated, the centrifugal fat extractor (an ordinary centrifuge) runs at a high speed of 600 to 1,000 rpm, and provides for passing steam through the loaded cracklings to keep the fat in a molten state. When the centrifuge is in operation, it separates fat and moisture from the cracklings by centrifugal force, and the fat is collected in a tallow sump.

Today, high-speed disc centrifuges are commonly used as they are well suited to final clarification and purification of tallow. Separation takes place in the disc stack of the centrifuge. While the lighter phase, clarified and purified tallow, is discharged axially at the top of the centrifuge, the solids part accumulates in the widest part of the bowl and is discharged intermittently by opening a discharge slit (Fenton, 1984). In a relatively new type of decanting centrifuge, a screw rotates horizontally inside a drum and in the direction of the drum but at lower RPM (revolutions per minute). The solid protein, water, and liquid fat are discharged at the front, middle, and opposite end of the centrifuge from ports located close to axis of the rotation.

Driers

The solid protein materials leaving the rendering tank are the substances that contain the most moisture. That is, dry-rendering cookers are not capable of releasing the extra water of carcass meal, and there is, therefore, a need for subsequent driers.

Different drying equipment has been used to dehydrate these wet materials. The Dupps Company (2003) built an energy-efficient Ring Drier, which recovered the heat energy of exhausting air and dried product more efficiently than in conventional driers. According to Ockerman and Hansen (2000), a major advantage of the Ring Drier was recycling of 60% of the heated air back through the drier, which helped to make drying of a high-moisture substance, such as carcass protein or blood, economically feasible.

Odor control equipment

Odor control equipment systems include condensers, scrubbers, afterburners (incinerator), and bio-filters.

Condensers

Strong odors are generated during cooking, and, to some extent, drying processes, and are carried in the steam emitted by rendering plants. Condenser units function to wash the cooking steam with cold water and then liquefy all condensable materials (mainly steam- and water-soluble odorous chemical compounds). According to Fernando (1995), this process reduces the temperature of the non-condensable substances to around 35-40°C (95-104°F) and transfers the heat. The cooling water removes up to 90% of odors and recovers heat energy from the cooking steam. Figure 2 in Appendix D provides a schematic diagram of a condenser used for hot gases and steam coming from the rendering plant.

Scrubbers

Although condensing units absorb water soluble odors, they do not absorb chemical compounds. To address this problem, two chemical scrubbing systems have been used. The venturi-type scrubber is used for facilities generating low intensity odors, and the packed-bed type scrubber with various chemicals is used for facilities generating high intensity odors. Figures 3a and 3b in Appendix D provide schematic views of these two types of scrubbers. A condenser followed by a two-stage scrubbing unit can provide up to 99% odor reduction.

Depending on the chemical composition of odors produced, different chemical solutions can be used. According to Fernando (1995), for rendering plant applications, an acid pre-wash (using dilute sulphuric acid, pH 1.6) was used in the first-stage scrubber to prevent generation of odorous chlorinated compounds from forming ammonia and amines. Then, a second-stage used strong alkaline (pH 12-13) sodium hypochlorite with considerable excess of available chlorine. Alternatively, acidic sodium hypochlorite with pH 5.0 may be used in the first stage, and sodium hydrogen sulphite and sodium hydroxide in sequential order can be used in the second stage to remove aldehydes. Table 2 in Appendix D outlines combinations of chemicals for use in scrubbers.

Afterburners

An afterburner is used to burn the gases released from the exhaust of a scrubber. Afterburning parameters include the residence time and minimum burning temperature. According to Fernando (1995), the minimum requirements for complete burning are a residence time of 0.5 seconds and a temperature of 750°C. In order to calculate the burning residence time precisely, he used a temperature controller and a temperature recorder and considered a safety factor of 50% by increasing the volume of the afterburner and ensuring that the minimum temperature was achieved. The test on the composition of the gases released from the exhaust of the afterburner showed that it was completely free of hydrogen sulphide, mercaptans, and amines. Figure 4 in Appendix D shows the effect of residence time and temperature combinations.

Since this equipment requires a high burning temperature, fuel costs would be high unless the air is preheated by the use of the final exhaust gases. Hot water may be used elsewhere to conserve energy. Figure 5 in Appendix D shows the flow of gases in an afterburner system.

Bio-filters

A bio-filter is a system that treats odorous gases (including air) underground by passing them through a bed of organic material such as woodchips, bark, peat moss, rice hulls, compost, or a combination of these. Gases are broken down to non-odorous compounds by aerobic microbial activity under damp conditions (USEPA, 2002). The substrate is filled with stone (road metal or scoria) or soil and the organic material is placed on the top of the stones. Figure 6 in Appendix D demonstrates the arrangement of a typical bio-filter.

Parameters such as humidity, oxygen content, microbial load, distribution of gases through the bed, porous structure of the bed, drainage system under the bed, and temperature of the gases entering the bed have considerable effects on the efficiency of bio-filters. Fernando (1995) explained that the rate of gas passing through the bio-filters depends on the strength of the odorants in the gas and varies between 10 to 120 $m^3/h/m^2$ of the filter area, and it can be matched for different gases (mixtures of air and odors).

Complete process system

Manufacturers typically specialize in a certain type of equipment; therefore it is generally not possible to obtain all equipment necessary for a rendering operation from one manufacturer. Subsequently, most rendering operations employ machinery from several different manufacturers. A resulting disadvantage is the difficulty in harmonizing various machinery in one specific rendering plant.

To provide examples of the technical specifications of each group of equipment, a general inquiry for the equipment necessary for a complete carcass rendering plant was sent to different manufacturers. Based on quotations received from The Dupps Company (2003) and from Scan American Corporation (2003), the name and some general specifications of equipment needed for a continuous dry rendering processing line are presented in Appendix D as Table 3 and Table 4, respectively.

3.5 – Quality and Use of End Products

The quality and quantity of rendering end-products depends on the physicochemical and microbiological properties of the raw materials, the method of rendering, the pre-rendering and post-rendering processes used, and the operating conditions maintained within the system. In this section, the applications of use for carcass rendering end products, as well as their quality criteria, are discussed.

Carcass rendering end products and their applications

During the last 20 years the end-products of the rendering process, mainly MBM and tallow, have been widely used in the manufacture of a diverse range of animal feed, chemical, and industrial products. Currently, the end products of carcass rendering are used in four major sectors of the economy. The first and most important usage of these products is as an ingredient in feed formulations for livestock, poultry, and aquaculture production. Due to the high conversion efficiency of MBM and tallow, the production efficiency of livestock and poultry increases considerably with these ingredients, thereby making meat, milk, and egg products more affordable. Similarly, using these products as ingredients in pet food formulations helps sustain the health and extend the life of companion animals. In a second sector, extracted and refined animal fats create up to 3,000 modern industrial products that contain lipids and lipid derivatives (Pocket Information Manual, 2003). Some of the major industrial and agricultural applications for rendered products include the chemical industry, metallurgy, rubber, crop protection agents, and fertilizer formulations. The manufacture of soaps and personal care products represents the third key sector. In spite of progress in identifying new materials for use in the manufacture of products for the detergent and cosmetic industries, tallow is still the basic ingredient of laundry and other soaps. The world consumption of these products continues to grow. The last key application, which has generated some industrial interests, is the production of biofuels from animal fats.

While animal fats and proteins are constantly challenged by competing commodities, they play an important role in world trade. However, the continued identification of high-value uses for animal by-products is key to the stability of animal agriculture. Following is a more detailed discussion of the specific uses of MBM and tallow products.

Carcass meal

Carcass meal and MBM are very similar, although slightly different definitions apply. According to UKDEFRA (2000), the concentrated protein remaining after fat removal from the crackling (solid protein material) is called "meat meal." If bone is included as a raw material such that the phosphorus content of the protein product exceeds 4.4%, or if the crude protein content is below 55%, the product is called "meat and bone meal" or MBM. The protein product resulting from the processing of condemned whole carcasses is known as "carcass meal." Based on these definitions, carcass meal and MBM are essentially equivalent, as long as criteria for protein and phosphorus levels are met.

MBM is a good source of amino acids and is routinely used in formulating feeds for all classes of poultry, swine, many exotic animals, some species of fish, and pet foods. The FDA (2001) implemented the requirements and guidelines for the use of MBM and tallow in animal feed and pet foods. According to the feed rule, 21 CFR 589.2000, the feeding of MBM containing ruminant proteins back to ruminants has been prohibited.

Greaves may be used in fertilizer or animal feed, or may be processed further by pressing, centrifugation, or solvent extraction to remove more tallow. The residue can be ground to produce MBM and used largely in animal feed, including pet food. Sometimes tankage may be used in animal rations. In the early months of 1980, for the first time tankage was used in animal rations and animal feed (as a protein source) and MBM was used for fertilizer (UKDEFRA, 2000).

Edible and inedible tallow

Edible tallow and lard are the rendered fats of cattle and hog byproducts, respectively. They have approximate melting points of 40°C (104°F) and are used in the manufacture of many human foods, such as edible fats, jellies, and in baking (Ockerman & Hansen, 2000).

Inedible tallow or grease is the rendered fat of dead farm animals and is used in animal feed and pet food, as well as in pharmaceuticals, cosmetics, and in a range of industrial products (Ockerman & Hansen, 2000). Tallow is classified by grade depending on the concentration of free fatty acids (FFA), color, general appearance, moisture, and dirt content.

Inedible tallow and the fat remaining in carcass meal both have a tendency to become rancid, especially when stored for long periods under warm and humid conditions. Another disadvantage of storing carcass meal in unfavorable conditions is degradation of the fat-soluble vitamins A, D, and E. Additionally, if meal containing rancid fat is used in livestock rations, it may cause digestion disorders. By adding anti-oxidants to tallow or grease at the final stage of processing, rancidity is substantially impeded. Under the Food and Drug Act, the most common permissible anti-oxidants are butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA). According to Kumar (1989), addition of these materials in quantities of 100 g/ton of fat material helps to control rancidity. Based on this formula, it can also be added to carcass meal according to its fat content.

Finding new sources of energy, especially with diminishing reservoirs of fossil fuels in different parts of the world, is of significant interest. Due to decreasing markets for some types of carcass meal and tallow products as a result of concerns over the transmission of TSE agents (such as BSE), the possible use of fat and tallow products as direct or indirect sources of energy has been evaluated, with promising results. According to Pearl (2003), the University of Georgia, Engineering Outreach Service used chicken fat, beef tallow, and grease blended with No. 2 fuel oil as complete substitutes of fuel oil in the 45,000 kg/h (100,000 lb/h) boiler that provides steam for the Athens campus. All blends consisted of 33% fat or grease and 67% No. 2 fuel oil. The energy content of unblended animal biofuels was very consistent among the sources and averaged about 39,600 KJ/kg (16,900 Btu/lb). Blended fuels averaged nearly 43,250 KJ/kg (18,450 Btu/lb), and all were within 95% of the heating value of No. 2 fuel oil alone. A project test team inspected the interior of the boiler after three weeks of biofuel combustion, and observed that the water tube exterior surface and the furnace interior were nearly as clean as after firing natural gas, and substantially cleaner than following the use of fuel oil alone. Pearl (2003) indicated that the animal rendering industry now has sufficient data demonstrating that rendered animal fats can be used as alternative burner fuel. Environmental benefits will likely contribute to the growth of this market.

Quality criteria

The quality of the end products of rendering are affected by the physical, chemical, and microbiological conditions of raw materials, plant sanitation procedures, preparation processes (such as size reduction, pre-heating and pre-pressing), cooking and dewatering processes, and finally post rendering processes.

Various criteria have been established to define the quality of MBM and tallow, and they include different physical, chemical, and microbiological criteria such as nutrient content (mainly the contents of protein, fat, phosphorus, calcium, and other minerals such as sodium and potassium), microbial load, particle size distribution, texture, color, odor, and general appearance. While these criteria show the quality of rendering products properly, the most important physicochemical and nutritional quality indicators are the color of tallow, nutritional aspects, and digestibility of MBM.

Color

UKDEFRA (2000) indicated that the single most important factor in determining tallow grade is color. Tallow color is affected by raw material characteristics, including livestock breed, age, feeding formulation, health condition, and location. A green color of rendered fat is attributed to the presence of chlorophyll in the plant origin of feeding materials. Generally tallow color changes from white to yellow. Overheating the raw materials in dry rendering will give a reddish appearance to the tallow, which may be undesirable (Ockerman & Hansen, 2000).

High rendering temperatures (above 100°C [212°F]) can transfer and fix the “dirt” color of raw materials into the tallow, resulting in the tallow being downgraded. Ockerman and Hansen (2000) emphasized using only washed raw materials for rendering to remove paunch contents and other “dirt.” In LTR (70-100°C; 158-212°F), there is no need to wash raw materials because the color of paunch contents and other dirt are not fixed in the tallow.

Tallow with good color is used for soap manufacture and for human consumption, while lower grades are used for animal feeds and fatty chemicals. Figure 1 in Appendix E shows the typical color of MBM and various tallow products.

Nutritional components

Table 1 in Appendix E shows the typical nutritional value of MBM. However, as is the case for other rendering end products such as tallow, the nutritional content of MBM is affected by the rendering method, heating process, type of cooking (direct or indirect; wet rendering or dry rendering), and by pre-rendering and post-rendering processes. The calcium/phosphorus ratio in MBM ranges from 2:1 to 2.2:1, with the actual content being about 9% calcium and 4.5% phosphorus (Table 1 Appendix E). The high phosphorus availability of MBM is one of its major nutritional advantages.

The optimum moisture content of MBM is 3-5%, with values lower than 3% indicating overcooking of MBM during the rendering process (Pocket Information Manual, 2003). However, moisture content is limited to a maximum of 10%. After centrifuging and pressing of MBM, fat content usually averages 8-12%. In addition to protein (amino acids) and phosphorus, MBM is an excellent source of calcium and some other minerals (K, Mg, Na, etc.). According to Machin et al. (1986), MBM normally has an ash content of 28 to 36%; calcium content of 7 to 10%, and phosphorus content of 4.5 to 6%. As is true for other animal-derived products, MBM is a good source of vitamin B-12 and has a good amino acid profile with a high "digestibility" (81-87%).

Fernando (1984) compared the quality and quantity of finished products from LTR and HTR systems. The experiments used raw materials composed of 60% water, 20% fat and 20% fat-free solids, a composition typical of animal carcasses. Table 2 in Appendix E summarizes the results of this study. Overall, the quantity and quality of finished products were higher with LTR than HTR systems. Furthermore, LTR systems required less capital, labor, repair, maintenance, and energy than HTR systems.

Digestibility and biological activities

Although the protein content (usually around 50%) of MBM is an important quality indicator and is the basis for selling this product as a feed ingredient, digestibility of the protein content (amino acids) is an essential factor in creating high quality feeds for poultry and swine. Apparent digestibility of amino acids, called "ileal" digestibility, is determined at the end of the small intestines (ileal refers to the ileum, the last division of the small intestine extending between the jejunum and large intestine) (Pocket Information Manual, 2003). According to this manual, MBM has a digestibility of 85% or higher. Some values of apparent ileal digestibility of rendered animal protein products are shown in Table 3 of Appendix E.

Ristic et al. (1993) employed the conventional batch dry rendering method with screw press defatting and the semi-continuous wet rendering method with centrifugal defatting for processing inedible raw material (76.5% soft offals, 15% industrial bones, and 8.5% swine cadavers). They observed that the contents and biological activities of lysine, methionine, and cystine (nutritional values) of meat meals produced by the conventional batch dry rendering method was lower than that of meat meals obtained by the semi-continuous wet rendering method.

Ash content significantly affects protein content and amino acid digestibility of the final MBM. Ravindran et al. (2002) studied the apparent ileal digestibility of amino acids in 19 MBM samples, obtained from commercial rendering plants processing 5-week-old broilers in New Zealand. They observed considerable variation among these samples in the contents of crude protein (38.5-67.2 g/100 g), ash (13.0-56.5 g/100 g), crude fat (4.3-15.3 g/100 g), and gross energy (9.4-22.3 MJ/kg). While amino acid concentrations and ileal digestibility of amino acids varied substantially, digestibility of amino acids, with the exception of aspartic acid, threonine, serine, tyrosine, histidine, and cystine, was negatively correlated with ash content (i.e., samples with higher ash levels had lower digestibility). Protein digestibility can be reduced in the final MBM if materials such as hooves, horns, hair, and raw feathers are used as raw materials (Pocket Information Manual, 2003).

3.6 – Cost Analysis of Carcass Rendering

As is the case for other carcass disposal methods, the costs of carcass rendering can be divided into operating (variable) and fixed costs of investment. Since the main investment for carcass rendering plants has been made by the industry, the main cost is variable cost. For any specific carcass rendering system, the cost should be analyzed and compared with other disposal methods. The most important factors involved in cost analysis of massive carcass rendering include collection, transportation, temporary storage fees, extra labor requirements, impact on the environment (sanitation for plant outdoor and indoor activities, odor control, and wastewater treatment), and sometimes additional facilities and equipment. These expenses primarily make the renderers' costs much higher than the cost of usual rendering.

Cost analysis

Given the fact that removing dead animals from production facilities would be the same for all disposal alternatives, usually the variable costs do not include labor or equipment for local mortality handling. However, SCI (2002) estimated the labor and equipment (rental or depreciation) costs, respectively, at $10 and $35/hour. Table 1 in Appendix F shows the cost of rendering (without collection and transportation cost of carcasses) is much less than other carcass disposal methods. The extra cost that renderers typically charge for collecting mortalities makes the operating and possible fixed costs of this system comparable with costs associated with most other methods.

Operating costs for different disposal techniques show significant variation across different mortality disposal methods. According to SCI (2000), if all mortalities were disposed of using only one method, the operating costs range from $58 million for incineration, to $194.4 million for rendering (if the resulting MBM from converting collected livestock are disposed in a landfill). This report indicated that current renderers' fees were estimated at $8.25 per head (average for both cattle and calves). However, assuming the sale of MBM produced from livestock mortalities were prohibited (due to the possible BSE contaminations), renderers' collection fees increase to an average of over $24 per bovine, an increase of almost 300% (see Table 1 in Appendix F). Although direct responsibility for the extra cost of rendering, including collection and transport of fallen animals, lies with livestock producers, this cost may eventually be incurred by society for controlling contamination sources and providing a pleasant environment.

Economic considerations

Table 2 in Appendix F shows consumption and export data for finished products produced by US rendering plants (primarily from carcasses) during 2001 and 2002. About 40% of the total MBM produced in US rendering plants was from carcasses. Close consideration of these data reveals the following points:

- Generally the conversion rate of raw material to dry meal is 3:1.
- More than 75% of the total fat produced in US rendering plants was inedible tallow and grease.
- Almost one third (33%) of the total inedible fat used for animal feed formulation was inedible tallow, increasing about 6% during the above-mentioned years.
- Export of inedible tallow increased almost 30%, suggesting good demand for inedible tallow in future years.
- Exported MBM increased 25%, which again suggests strong demand for this product in international markets.

Hamilton (2003) reported that the percentage of feed mills using meat & bone meal declined from 75% in 1999 to 40% in 2002, and the market price for MBM dropped from about $300/metric ton in 1997 to almost $180/metric ton in 2003. However, the total quantity of MBM exported by the US increased from 400,000 metric tons in 1999 to about 600,000 metric tons in 2002.

As long as the rendering industry can market valuable products from livestock mortalities (including protein based feed ingredients and various fats and greases), collection fees will likely remain relatively low. However, collection and disposal fees will be much higher if the final products can no longer be marketed. Having a commercial value for end products is crucial to the economic feasibility of carcass disposal by rendering. The US produces a little over 50% of the world's tallow and grease, and exports almost 40% of this (Giles, 2002). Additionally, more than half of the world's animal fat production (around 6.8 million tonnes) is produced in North America (Pocket Information Manual, 2003).

Rendering animal mortalities is advantageous not only to the environment, but also helps to stabilize the animal feed price in the market. Selling carcass meal on the open commodity market generates competition with other sources of animal feed, allowing animal operation units and ultimately customers to benefit by not paying higher prices for animal feed and meat products. Exporting rendered products promotes US export income and international activities. For example, the US exported 3,650 million pounds of fats and proteins to other countries during 1994, which yielded a favorable trade balance of payments of $639 million returned to the US (Prokop, 1996).

The quality of MBM produced from carcasses has a considerable effect on its international marketability. Issues related to TSE agents are of course critical, but even the presence of organisms such as *Salmonella* may limit the export potential of products to some countries. While the export of MBM from some countries to Japan has been significantly reduced in recent years because of potential for these contaminants, other countries such as New Zealand have made considerable progress in this trade. According to Arnold (2002), New Zealand MBM exports to Japan have attracted a premium payment over Australian product of $15-$30/ton. Japanese buyers and end-users have come to accept MBM from New Zealand as being extremely low in *Salmonella* contamination, and have accordingly paid a premium for this product. According to Table 3 in Appendix F, the market share percentage of MBM imported by Japan during the year 2000, compared to the first nine months of 2001, from New Zealand sources increased from 18.5% to 32.6%, and from US sources increased from 1.8% to 3.2%.

Section 4 – Disease Agent, Sterilization, and Environmental Considerations

Although rendering processes can eliminate many microorganisms from finished products, byproducts of the rendering process, such as odors, sludge, and wastewater, may present health and environmental problems if not treated properly. However, the potential for rapidly spreading diseases among livestock and people, and for contaminating the environment, arises if carcasses are not disposed of promptly and properly.

The following federal and state agencies have worked closely with the independent rendering plants and routinely inspect their facilities to provide proper collection and processing of fallen animals (Hamilton, 2003):

- Officers of the FDA inspect rendering facilities for compliance to BSE regulations.
- The USDA Animal and Plant Health Inspection Service (APHIS) inspects rendering plants for compliance to restrictions imposed by importing countries and issues export certificates for rendered products.
- State Feed Control Officials inspect and test rendered products for quality, adulteration, and compliance with feed safety policies.
- USEPA provides guidance and regulation for odor, sludge, and wastewater treatment.
- Additionally, voluntary internal control programs including good manufacturing practices (GMP) and hazard analysis critical control point (HACCP) systems are common among rendering plants.

Different parts of disease agents, their controlling methods and environmental impacts of carcass rendering process and related to topic of this section will be discussed.

4.1 – Disease Agents

Microorganisms

The proper operation of rendering processes leads to production of safe and valuable end products. The heat treatment of rendering processes significantly increases the storage time of finished products by killing microorganisms present in the raw material, and removing moisture needed for microbial activity.

Rendering outputs, such as carcass meal, should be free of pathogenic bacteria. Thiemann and Willinger (1980) reported that *Clostridium perfringens* is an indicator microorganism, which shows the sterilizing effect of rendering procedures. They reported that elimination of gram-negative bacteria and demonstration of only small numbers of gram-positive bacteria (like aerobic bacilli) in the rendering facility, and also absence of *Clostridium perfringens* spores in sewage of the contaminated side, are indicators of effective disinfection processes. Carcass meal, as well as waste products, may be contaminated with many pathogenic bacteria if inadequate processes are used. This contamination can be transferred to the environment. Bisping et al. (1981) found salmonellae in 21.3% of carcass-meal samples taken from rendering plants. He pointed out that the occurrence of salmonellae was due to recontamination after sterilization of the raw material. It should be noted that not all the *Salmonella* serovars or *Salmonella* species are pathogenic. The Pocket Information Manual (2003) reported that from 2,200 *Salmonella* serovars which may potentially produce disease, only about 10-15 serovars are routinely isolated in the majority of clinical salmonellosis in humans and livestock/poultry.

Resistant proteins (prions)

The emergence of BSE has been largely attributed to cattle being fed formulations that contained prion-infected MBM. As Dormont (2002) explained, TSE agents (also called prions), are generally regarded as being responsible for fatal neurodegenerative diseases in humans and animals. Creutzfeldt-Jakob is a disease of humans believed to be caused by prions. In animal populations, prions are thought to be responsible for scrapie in goats and sheep, BSE in cattle, feline spongiform encephalopathy, transmissible mink encephalopathy, and chronic wasting disease. According to UKDEFRA (2000), epidemiological work carried out in 1988 revealed that compounds of animal feeds containing infective MBM were the primary mechanism by which BSE was spread throughout the UK. Thus the rendering industry played a central role in the BSE story. Experts subsequently concluded that changes to rendering processes in the early 1980s might have led to the emergence of the disease.

The present epidemiological knowledge about BSE demonstrates why the BSE agent was able to survive the rendering processes that otherwise achieved microbial sterilization. For example, prion proteins are known to be quite heat resistant.

Various policy decisions have been implemented to attempt to control the spread of BSE in the cattle population. Many countries have established rules and regulation for imported MBM. The recently identified cases of BSE in Japan have resulted in a temporary ban being imposed on the use of all MBM as an animal protein source (Arnold, 2002).

Sander et al. (2002) reported that specific restrictions were placed on rendering sheep, goats, cattle, and farm-raised deer or elk in some areas of the US because of concern that TSE agents could be transmitted by the resulting meat meal. Poultry rendering is not subjected to new BSE regulations and it is a unique industrial section, which is typically supervised by specialized rendering firms. Poultry carcasses are generally not rendered with mammals, as the feathers require a higher heat process that damages other proteins.

According to UKDEFRA (2000), in 1994 the Spongiform Encephalopathy Advisory Committee stated that the minimum conditions necessary to inactivate the most heat-resistant forms of the scrapie agent were to autoclave at 136-138°C (277-280°F) at a pressure of ~2 bar (29.4 lb/in^2) for 18 minutes. The Committee noted that the BSE agent responded like scrapie in this respect. Ristic et al. (2001) reported that mad cow disease was due to prions which are more resistant than bacteria, and that the BSE epidemic may have been sparked by use of MBM produced from dead sheep, and processing of inedible by-products of slaughtered sheep by inadequate technological processes. They suggested that special attention should be paid when collecting and sorting these inedible raw materials and proposed a process, which includes high temperature, wet sterilization of chopped material (<40 mm) at 136°C (277°F) for 20 minutes at a pressure of 3.2 bar with constant control of critical control points in the process. Schreuder et al. (2001) used a pool of BSE infected brain stem material from the UK, and scrapie infected brain stem materials from Dutch sheep (as spike materials), at rendering plants with a hyperbaric system. They observed a reduction of about 2.2 log in the infectivity of BSE in the first round (with some residual infectivity detected) at a heating process of 20 minutes at 133°C (271°F), and in the second round in excess of 2.0 log (no residual infectivity detected).

According to Franco and Swanson (1996), while some European scientists believed this system inactivated the BSE agent, American scientists did not completely agree, and believed that using the specified high pressure and temperature in cooking processes would not completely inactivate the BSE agent, but simply reduce its infectivity. Heilemann (2002) reported that use of ruminant tissues with a high infectious potential with regard to BSE (specified risk material, or SRM) in the human and animal feed chains was eliminated. FDA (2001) implemented a final rule that prohibits the use of most mammalian protein in feeds for ruminant animals. These limitations dramatically changed the logistical as well as the economical preconditions of the rendering industry. He indicated that the basic treatment (pressure cooking) remained almost unchanged, but instead of physically recycling the products they are predominantly used as an energy source in industry.

4.2 – Controlling Methods

Use of raw materials with minimum microbial loads, combined with the use of GMPs, will facilitate control of disease agents. In this respect, appropriate sanitation and proper sterilization processes play a major role. Furthermore, GMPs are preventive practices that minimize product safety hazards by establishing basic controls and/or conditions favorable for producing a safe product.

Sterilization

The heat treatment of materials requires a sensitive balance. On one hand heat affects protein denaturation and/or enzyme inactivation of microorganisms, and therefore should be applied sufficiently to destroy certain pathogenic organisms. Conversely, many nutritional elements are sensitive to heating processes, and therefore heating should be minimized to limit significant effects on nutritional value or quality. The conditions necessary for sterilization depend on the total microbial load and on the heat tolerance of the target species, in addition to characteristics of the matrix being sterilized (i.e., moisture and fat content). Furthermore, there is a positive correlation between water level (related to water activity) and the efficiency of heat transfer to kill microorganisms. Other parameters, such as vessel size, particle size, and consistency of the material being processed, influence heat resistance.

Riedinger (1980) developed a mathematical model for computation of the sterilization process in rendering systems. Due to the similarity of the sterilization processes in canning and rendering, he used the F-value of the canning industry with heat resistance parameters "Z"= 10°C (50°F) and "D" = 10 sec as a guide. Based on the German Carcass Disposal Act requirements (temperature of 133°C or 271°F during 20 min after decomposition of the soft parts), Riedinger (1980) obtained a comparable sterilization time of roughly 300 min at 121°C for the test organism *Bacillus stearothermophilus* (a non-pathogenic organism that has been shown to be one of the most heat resistant strains of bacteria).

As Pearl (2001) indicated, for the raw materials used in the rendering industry the microorganisms of most concern are *Salmonella* sp., *Clostridium perfringens*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Campylobacter* sp., and *Escherichia coli*, all of which have much lower Z values than *B. stearothermophilus*, and, therefore, a 12D process should be achieved in a shorter time. D is defined as the time in minutes required to destroy 90% (or a one-log cycle) of a population of cells at a given reference temperature. Therefore, a 12D process refers to the time required to achieve a 12 log reduction of the target organism (equivalent to reducing a population of organisms from 100,000,000,000 to 1) at a given reference temperature.

The temperature in a batch dry rendering process is a critical issue in terms of microbial inactivation. Because this process is carried out at atmospheric pressure, the temperature remains at 100°C (212°F) for the majority of the rendering process. After all free water is evaporated from the whole mass, the temperature gradually rises to approximately 120°C (248°F). In spite of this high temperature, the presence of fats serves to protect microorganisms by making fat layers around the cells, thereby increasing the cells heat resistance and protecting bacterial spores against thermal inactivation (Lowry et al., 1979; Pearl, 2001). Thus, sterilization requires a high heating time or a period of heating under pressure to inactivate bacterial spores, which may survive rendering conditions. Hansen and Olgaard (1984) used a pilot cooker and measured the sterility of MBM mixed with water or fat and inoculated with *Bacillus cereus* and *Clostridium perfringens*. They concluded that when the temperature during drying reached 110-120°C, the heat resistance of spores of both strains increased drastically, whereas the moisture content decreased and the rendering materials cooked in fat only. Lowry et al. (1979) determined bacilli and clostridia populations in rendered products obtained directly from three commercial cookers to be between 10^2 and 10^4 unit/g. In subsequent studies, artificial cultures of the heat resistant microorganism *Bacillus cereus* were added to the contents of a pilot-scale rendering plant (46% beef trimmings, 18% bone, and 30% water) to give an initial spore density of approximately 10^7 spores per g and a typical rendering cycle at atmospheric pressure was applied. Results indicated a sharp decline in the rate of spore death when the moisture content fell below 10%, and little decrease in spore numbers during the final 30 min of rendering, although the temperature rose from 105 to 130°C (221 to 266°F). In the final experiment, which was repeated with initial heating of the cooker's content to 120°C or 248°F for 15 min, the products were sterile. It can be concluded that when the moisture content is low, the materials must be heated under pressure to ensure that the spores are not covered in fat layers and thereby protected against thermal deactivation.

Hansen and Olgaard (1984) determined thermal death graphs for spores of *B. cereus* and *C. perfringens* by using the heat transmission data for bones to predict the decimal reductions of spores in the center of the largest pieces present during a given rendering process. They showed that primary dehydration of the raw materials for 45 min, followed by cooking at 125°C (257°F) for 15 min and final drying, ensured destruction of these bacteria even in the center of 70 mm (2.8 in) bone particles. A reasonable reduction of heat resistant clostridia spores was made when the same process was repeated with the particle size reduced to less than 40 mm (1.6 in). Hamilton (2003) explained that temperature and particle size of the material in heating processes are two critical points of HACCP programs associated with the destruction of viral and pathogenic bacteria present in animal mortalities and byproducts.

As previously stated, all species of salmonellae are readily killed by the thermal processes used in conventional rendering. However, contamination of final products can occur during post rendering processes such as handling, storage, and transportation, just as it can with any feed ingredient. The only method available to prevent salmonellae contamination of feeds or feed ingredients during these stages is using permitted chemical treatments.

It is important to distinguish between the two important terms of "sterilization" and "prion inactivation." Both terms usually refer, in legislation and elsewhere, to hygiene procedures designed to prevent microbiologically contaminated food being consumed by humans. As an example, according to UKDEFRA (2000), sterilization of meat materials requires that carcasses are:

- treated by boiling or by steaming under pressure until every piece of meat is cooked throughout;
- dry-rendered, digested, or solvent-processed into technical tallow, greaves, glues, feeding meals, or fertilizers; or
- subjected to some other process which results in all parts of the meat no longer having the appearance of raw meat and which inactivates all vegetative forms and spore formers of human pathogenic organisms in the meat.

Using this definition, the sterilization process would clearly not meet conditions necessary to inactivate prion agents, such as those of scrapie or BSE.

Sanitation and traceability

Sanitation guidelines have a significant effect on the quality of final products. In a study of three New Zealand rendering plants, Arnold (2002) reported that these plants, which produced over 55% of the country's MBM exports to Japan, did not record one positive test from equipment or the plant environment for the presence of *Salmonella* over a three year period.

Usually the source of contamination can be traced back to one or more particular areas within a rendering plant. One of these locations is the surge bin prior to the mill (Arnold, 2002). Various cleaning and sanitizing procedures can be adopted to reduce or eliminate microbial contamination from the plant environment, including regular cleaning to remove protein build-up, improving airflow, daily dosing with powder sanitizer, and fumigation processes. Key to producing rendered products of low microbial load is routine sanitation of the equipment and maintenance tools used on the processing lines and facilities. According to Turnbull (1998), a rendering plant should be divided into "dirty" and "clean" areas, with the dirty side suitably prepared for disinfection of all processing equipment including transport vehicles, collection and autoclaving of wastewater. Both before and after the cooking process, materials are conveyed in closed systems. Turnbull (1998) emphasized that the veterinary authorities should monitor the level of hygiene maintained in the clean side of the rendering plant at least twice yearly.

Studies have shown that steam treatment is likely to become a valuable and environmentally friendly method of sanitizing working surfaces and controlling hygienic problems, with the potential to replace chemical disinfectants to some extent. Haas et al. (1998) demonstrated that a steam cleaning device with a pressure of 5 bar (73.5 lb/in^2) and a temperature of 155°C (311°F) was effective at eliminating *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans* along with viruses (ECBO- and Reo-virus) and *Ascaris suum* eggs on a variety of surfaces.

4.3 – Environmental Impacts and Preventive Treatments

Disposal of animal carcasses may generate different environmental and health hazards. Various agricultural agencies (AAFRD, 2002; Australian Veterinary Emergency Plan, Agricultural and Resource Management Council of Australia and New Zealand or AUSVETPLAN, 1996) indicated that improper carcass disposal processes might cause serious environmental and public health problems. These factors are summarized as follows:

- Odor nuisance, resulting from the anaerobic breakdown of proteins by bacteria, reduces the quality of life and decreases property values.
- Pathogens which may be present in decomposed material are capable of spreading diseases in soil, plants, and in animals and humans.
- Leaching of harmful nitrogen and sulfur compounds from carcasses to ground water.
- Attraction of insects and pests as potential vectors of harmful diseases for public health.

The most important byproducts of the carcass rendering process in terms of the potential to pollute air, ground water, and soil are odor and wastewater.

Odor

Because carcasses are typically not refrigerated for preservation prior to rendering, they begin to putrefy and give rise to a number of odorants. Due to this, rendering is often perceived by the public as an unpleasant or "smelly" industry. A significant environmental issue for the rendering industry is controlling various odors generated during pre-rendering, rendering, and post-rendering processes.

As discussed previously, in terms of odor emissions continuous systems have the advantage in that they are enclosed and therefore confine odors and fat particles within the equipment, whereas batch systems are open to the atmosphere during filling and discharge.

Only certain chemical compounds are responsible for odor constituents. The threshold levels at which humans can detect (smell) various odorants are shown in Table 1 of Appendix G (Fernando, 1995). A satisfactory odor abatement system in a rendering facility will reduce odorants to levels well below those given in this table. Fernando (1995) reported that amines, mercaptans, and sulphides are generally expected to be present in gases from rendering plants.

Regulatory authorities have specified methods for controlling odors from rendering plants. For example, the USEPA (2002) has established various regulations for different carcass rendering units. Following are recommended techniques for minimizing odor emissions.

- All emitted odors should be treated in condensing units followed by either chemical scrubbers or incinerators (afterburners) and/or biofilters for non-condensable odors.
- For chemical deodorization of rendering units, use of hypochlorite, multi-stage acid and alkali scrubbing followed by chlorination, and incineration of the final gases in boilers is recommended. Effective and reliable operation of chemical scrubbers and afterburners is essential.
- Odor control equipment should be fitted with monitoring devices and recorders to control key parameters.

- Good housekeeping is necessary to prevent odor development. Exposed raw materials will generate and develop odors.
- Procedures for monitoring odors, as well as investigating and resolving odor-related complaints, should be implemented.

As discussed earlier, condensers, scrubbers, afterburners, and bio-filters can be used in a combined system or individually to remove gaseous materials from the air emitted from rendering plants. Fernando (1995) reported that the cheapest to operate are bio-filters and scrubbers. Volatile gases can be burnt either in a boiler burner or an afterburner, both of which are equipped with heat recovery systems.

More than 20 years ago, different technologies were developed to eliminate odors that may transmit to neighbors. Pelz (1980) reported that in a European rendering plant built in Austria, carcasses, offal, and other animal materials were collected, transferred, and dumped in a hygienically safe manner into a receiving hopper and then transferred by screw conveyor to a crusher. Steam pressure pushed the material into a receptacle called "the gun," and from there it was conveyed to an extractor, which functioned as a sterilizer (30 min 134°C or 273°F), extractor, and drier. The wet extraction procedure used perchloroethylene and produced hygienically unobjectionable animal meal and fat. This method of deodorization created not only optimum working conditions in the plant, but also provided acceptable living conditions in the residential areas at a distance of some 400 m.

From the above discussion, it can be concluded that rendering processes can be carried out without being a public nuisance as long as "fresh" or "stabilized" raw materials are used and appropriate odor control devices are employed for plant emissions.

Wastewater

Historically, the main criteria for determining the acceptability of wastewater discharged from rendering facilities have been levels of BOD, suspended solids, and organic substances. However, available nutrients (nitrogen [N], phosphorus [P], and perhaps potassium [K]) within wastewater may play increasingly important roles (Taylor, 1995).

Microorganisms require ratios of carbon, nitrogen, and phosphorus (C:N:P) of approximately 100:6:1 to grow (Taylor, 1995). Bacteria in pond systems are unable to use high loadings of nitrogen and phosphorus that may be present in rendering wastewater. Treatment of wastewater to address these constituents, specifically phosphorus, is very important. Continued use of wastewater for irrigation tends to accumulate nitrogen and phosphorus in the soil. Since plants can only use a certain amount of these nutrients, USEPA now requires testing of soil to establish the nutrient status, and preparation of an annual "nutrient budget" showing the quantity of these materials that can be applied. If the available nutrients are greater than the amount required in the soil, nutrient contents should be reduced in refining treatment.

Mechanical aeration and oxidation of wastewater can reduce nitrogen, and to some extent phosphorus, contents. Addition of appropriate chemical flocculants, such as aluminum sulfate, to wastewater converts available phosphorus to insoluble phosphorus, which can be removed by settling processes. These chemical procedures will make rendering wastewater treatment more complex and more expensive.

In order to reduce the moisture content of carcasses and save energy in the cooker, receiving bins are generally perforated to allow water to drain off. While this procedure minimizes the energy required to evaporate excess water, it increases the microbial and chemical load of wastewater.

According to Fernando (1995), the quantity of wastewater produced in rendering plants is as follows:

1 ton of raw materials: 0.6-1 ton of wastewater

1 ton of raw materials: 0.5 ton evaporated water

Wastewater from draining in different sections: 0.1-0.5 ton

The volume of effluent and its organic materials vary from plant to plant depending on the raw material, washing process, rendering process, and plant management. The rendering operations are the major source of organic loading and they have the highest COD, 5-day BOD (BOD5), nitrogen, phosphorus, and sodium (Na) contents. Based on the Fernando (1995) report, following are typical ranges for each constituent:

BOD5 ....2,000-20,000 g/m^3

Suspended solids......3,000-30,000 g/m^3

Fat ....2,000-4,500 g/m^3

Protein ....1,000-15,000 g/m^3

Based on 200 metric tons of rendering effluent per day, about 6 tons per day of total solids (containing mainly protein and fat) or dried meal will be lost in the wastewater. By using different techniques such as evaporation, ultrafiltration, and combined chemical/physical treatment, most of the soluble and insoluble solid materials can be easily recovered. Fernando (1995) designed an air flotation system, which was based on mixing wastewater with a non-toxic natural coagulant combined with a polymer. The recovered sludge was thickened to 30% total solids using a decanter, mixed with decanted solids from the rendering process, and dehydrated in a drier. This technology not only increased final MBM yield, but also refined and treated the wastewater, resulting in lower concentrations of organic compounds.

O'Flynn (1999) mentioned that the discharged effluent of a rendering plant had a BOD level of 1,500-5,000 mg/l and an ammonia content of 250-750 mg/l, and that these levels should be reduced to 20 mg/l and 10 mg/l, respectively. He constructed an activated sludge plant with an anaerobic stage to provide a nitrification-denitrification process, and added chemicals to bind phosphate and allow its removal by post-precipitation.

Metzner and Temper (1990) showed that the wastewater from rendering plants can be used for anaerobic pretreatment to reduce COD levels. A fixed bed loop reactor was used to reduce the organic compounds of wastewater in a rendering plant. Since the main organic pollutants were volatile fatty acids, the treatment was carried out in a single-stage system. After 27 hours of anaerobic digestion, the COD concentration of wastewater was reduced to 75–80% of its original content of (8 kg/m^3).

In terms of plant and environmental sanitation, microbial contamination of wastewater is another important aspect to be considered. According to Zisch (1980), all wastewater from the unclean area of a carcass rendering plant should be sterilized, regardless of whether the sewage is discharged into the central purification plant. Another contamination source in animal rendering plants is sewage sludge produced at the end of the operation. Since the heating process converts soluble phosphorus to insoluble phosphorus, sludge contains most of the phosphorus. This sludge has a potential to become a source of soil and plant contamination if improperly disposed. One means of preventing such contamination, while at the same time properly utilizing nutrients, is to compost it with other carbon source materials. Paluszak et al. (2000) composted sewage sludge originating from animal rendering plants along with co-composting materials (such as wood chips, farmyard manure, and bark) soaked with a suspension of 20 ml *E. coli* (11.5 x 10^9 cfu/ml) and 20 ml group D Streptococci (7.5 x 10^9 cfu/ml) placed in the middle of each compost pile. The inactivation kinetics of the indicator organisms over a period of 24 weeks showed that the fastest reduction of the test organisms (0.3 log/week) was observed in the pile with sewage sludge and bark, in which a maximum temperature of >67°C (121°F) was recorded at the beginning of the composting process. After 13 weeks, the concentrations of D-Streptococci in all three clamps were within the international standard values for sanitized compost.

Because rendering plants are regulated by various governmental agencies and generally have good sanitation programs, the potential for spread of disease during the conversion process, and the potential for groundwater pollution from these plants, are relatively low compared to other carcass disposal methods. This is the main reason why many livestock producers and governmental agencies prefer rendering as an alternative to on-farm disposal methods.

Section 5 – Conclusions and Critical Research Needs

Since disposal of carcasses poses various biological and environmental problems, identifying and using safe and responsible methods is an important factor in maintaining the integrity of the livestock industry and producing safe animal protein, as well as maintaining a high level of public health and consumer confidence. Furthermore, selecting a proper disposal method in each situation is a must; and key factors include controlling the spread of disease and preventing environmental contamination. Following are the key conclusions of this report, and the identified critical research needs relative to rendering as an effective carcass disposal option.

5.1 – Conclusions

The most important, key items from the various sections of this report include the following:

- Renderers produce about 6.65 billion pounds of MBM. Independent renderers processed livestock mortalities and produced about 433 million pounds of MBM (around 6.5% of the total) and used raw materials representing about 50% of all livestock mortalities (SCI, 2002).
- The percentage of feed mills using meat & bone meal declined from 75% in 1999 to 40% in 2002 (Hamilton, 2003).
- The market price for MBM dropped from about $300/metric ton in 1997 to almost $180/metric ton in 2003 (Hamilton, 2003).
- The total quantity of MBM exported by the US increased from 400,000 metric tons in 1999 to about 600,000 metric tons in 2002 (Hamilton, 2003). Additionally, according to Arnold (2002), the market share percentage of MBM imported by Japan during the year 2000, compared to the first nine months of 2001, from New Zealand sources increased from 18.5% to 32.6%, and from US sources increased from 1.8% to 3.2%.
- Prions (or TSE agents) are believed to be responsible for fatal neurodegenerative diseases in humans and animals. US policies regarding TSE agents include (1) a ban on importation of ruminants and ruminant products from countries with BSE and (2) ruminant feeding restrictions to prevent the amplification and spread of the infective agent in domestic cattle (FDA, 2001).
- In order to justify costs and be economically feasible, a rendering plant must process at least 50-65 metric tons/day (60-70 tons/day), assuming 20 working hours per day.
- Most renderers (independent and dependent) use continuous dry rendering systems. Final MBM products are generally not completely free of salmonellae and have a fat content of about 12%. Generally the tallow produced by dependent renderers is lighter and has a higher grade than that produced by independent renderers.

5.2 – Critical Research Needs

Extensive research has been performed in the area of meat byproducts rendering, and a wealth of articles, books, and technical documents have been published or presented during the last 50 years. Additionally, many academic, governmental, state, and regional institutions and agencies worked and promoted this process and helped private sectors to produce various edible rendering products at the commercial level. The situation for "carcass rendering," which has stronger environmental and bio-security impacts, is quite different. Agricultural extension specialists and animal rendering scientists of academic institutions have made efforts to clarify the different aspects of this type of rendering. Although these efforts established rendering as a practical method of carcass disposal, the public health, animal health, and environmental hazards of "carcass rendering" have not been fully observed. To find adequate information, and to complete insufficient available data, intensive studies should be done on the following issues to determine scientific and practical answers for different aspects and challenges associated with carcass rendering:

- Develop robust sanitation, decontamination, and deodorization procedures for rendering operations. Biosecurity research should focus on the collection, transportation, storage, and processing of animal carcasses for rendering. Both waste products (odorous gases, sludge, and wastewater) and end products (meat-and-bone meal, tallow, and hides) should be free from pathogenic microorganisms, such as *Bacillus anthracis* and salmonellae, and harmful chemicals. Research would also focus on the possible combination of rendering with other methods of TSE inactivation.

- Consider how to improve rendering itself. In order to improve the quality of rendering products, research should focus on pre-rendering processes (e.g., carcass washing, grinding, and mixing), new rendering technologies (e.g., low-temperature rendering along with efficient wet pressing), and post-rendering processes (e.g., thermal centrifugation). By studying the physicochemical properties of carcass materials, valuable information might be gained and used to design improved rendering processes.
- Study how to improve rendering machinery and equipment to both comply with FDA requirements and produce top-quality products. The efficiency of some new equipment manufactured for different parts of animal byproduct rendering process should be studied, tested, and optimized for independent rendering plants.
- Investigate economic alternatives. The current economic value of rendered carcasses does not justify the cost of production, especially when protein product streams are unsuitable or disallowed for subsequent use in animal feed. Research should focus on (a) identifying means to reduce costs associated with rendering processes, (b) identifying new marketing and energy-use options for rendering products, and (c) identifying technologies that might be coupled with rendering to improve the utility of protein streams.
- Investigate temporary storage scenarios. In the case of high mortality losses, information will be needed regarding storage sites, time, and temperature and their appropriate relations to rendering.
- Evaluate means to treat waste products of rendering processes to reduce environmental impacts. Research should focus on advanced treatment systems for wastewater and exhaust odors to minimize any potential impacts to soil, ground water, vegetation, or air quality.
- Policy & regulatory considerations. Because biosecurity, traceability, and environmental protection methods for disposing of contaminated raw materials (or raw materials suspected of being contaminated) during an emergency are not available, uniform standards and methods for handling contaminated carcasses and animal byproducts are needed.

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Appendices

Appendix A

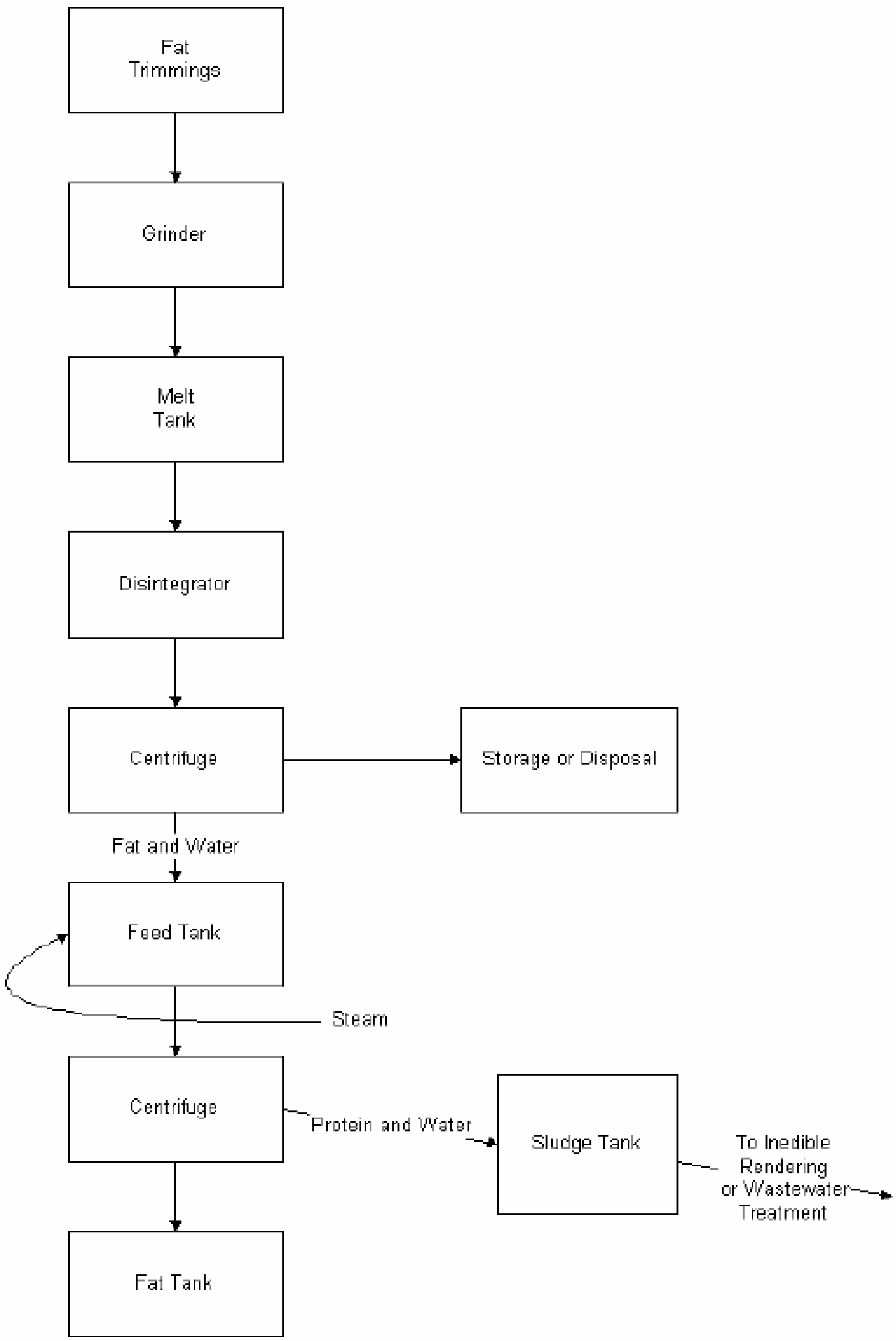

FIGURE 1. Flow diagram of an edible rendering process of fat trim.

Appendix B

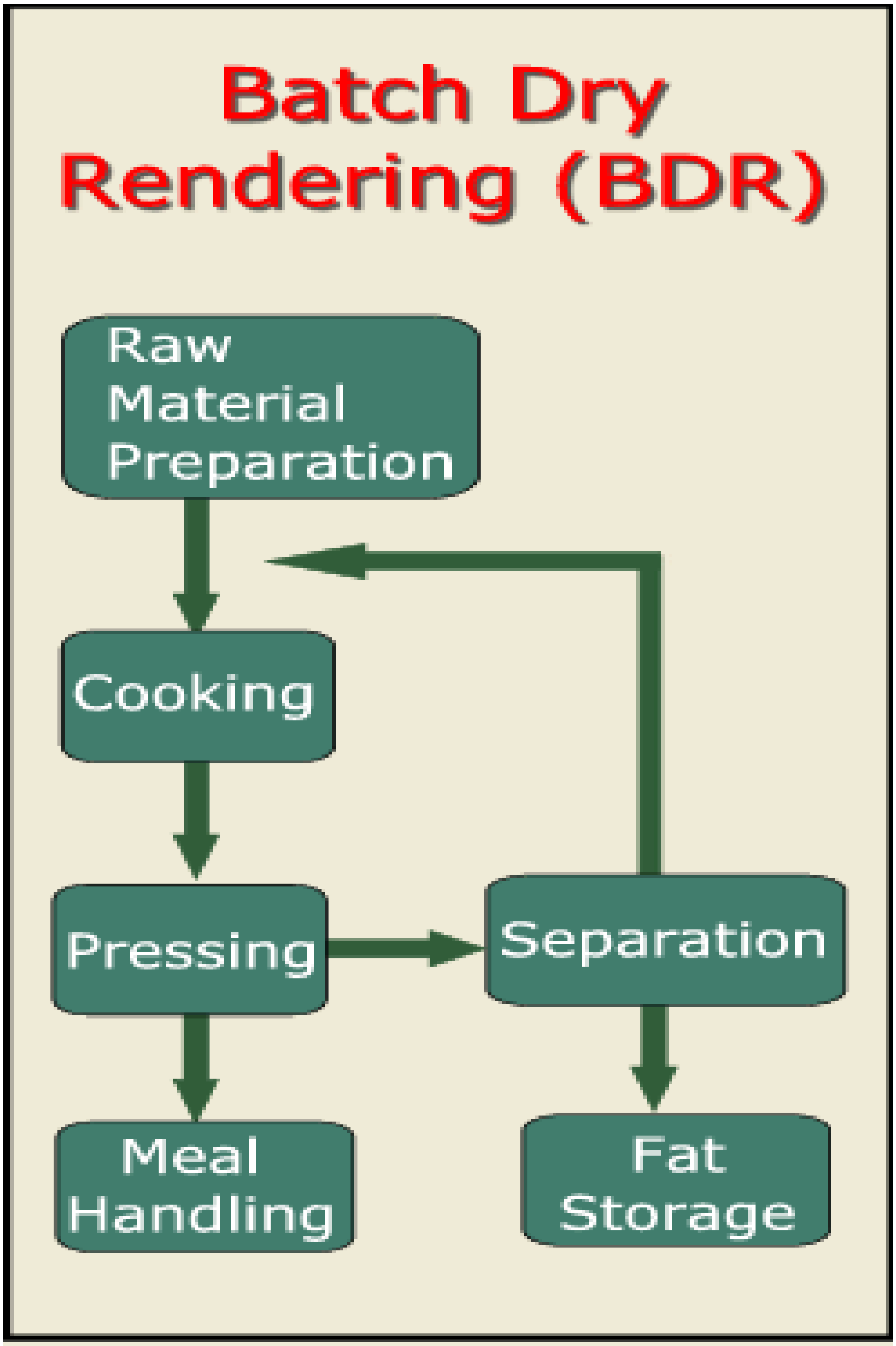

FIGURE 1. Flow diagram of batch dry rendering (Rendertech Limited, 2002).

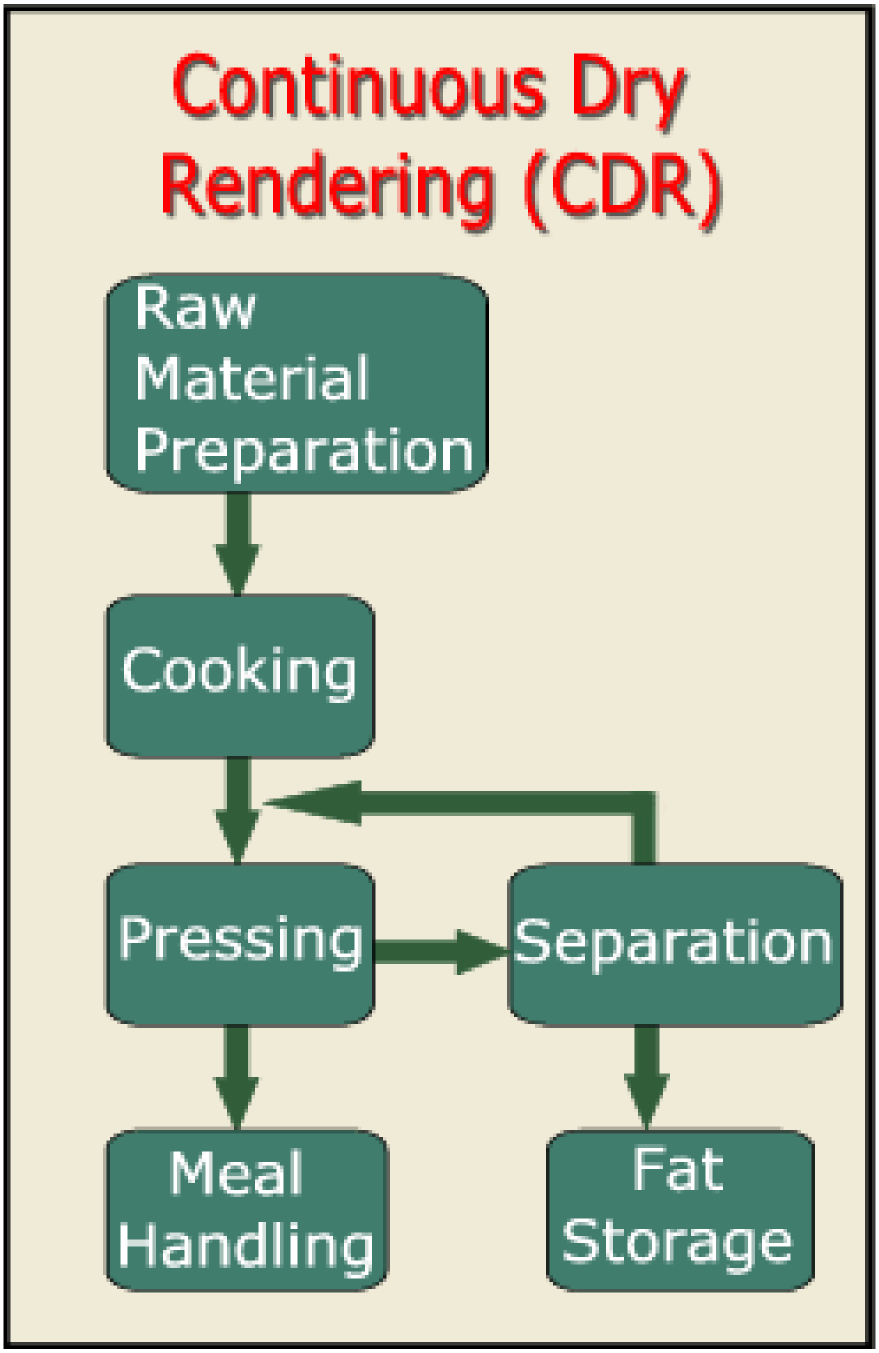

FIGURE 2. Flow diagram of continuous dry rendering (Rendertech Limited, 2002).

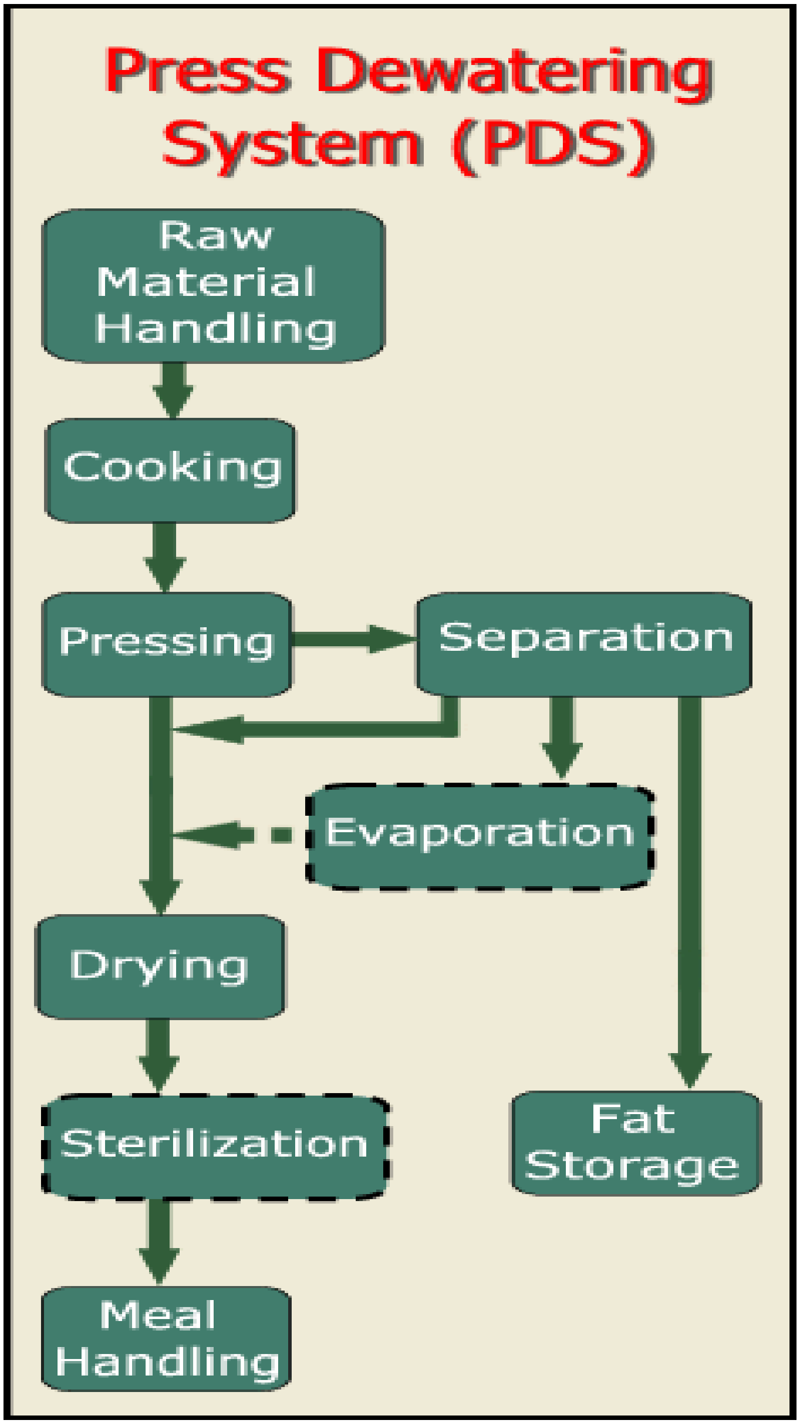

FIGURE 3. Flow diagram of press dewatering system (Rendertech Limited, 2002).

Appendix C

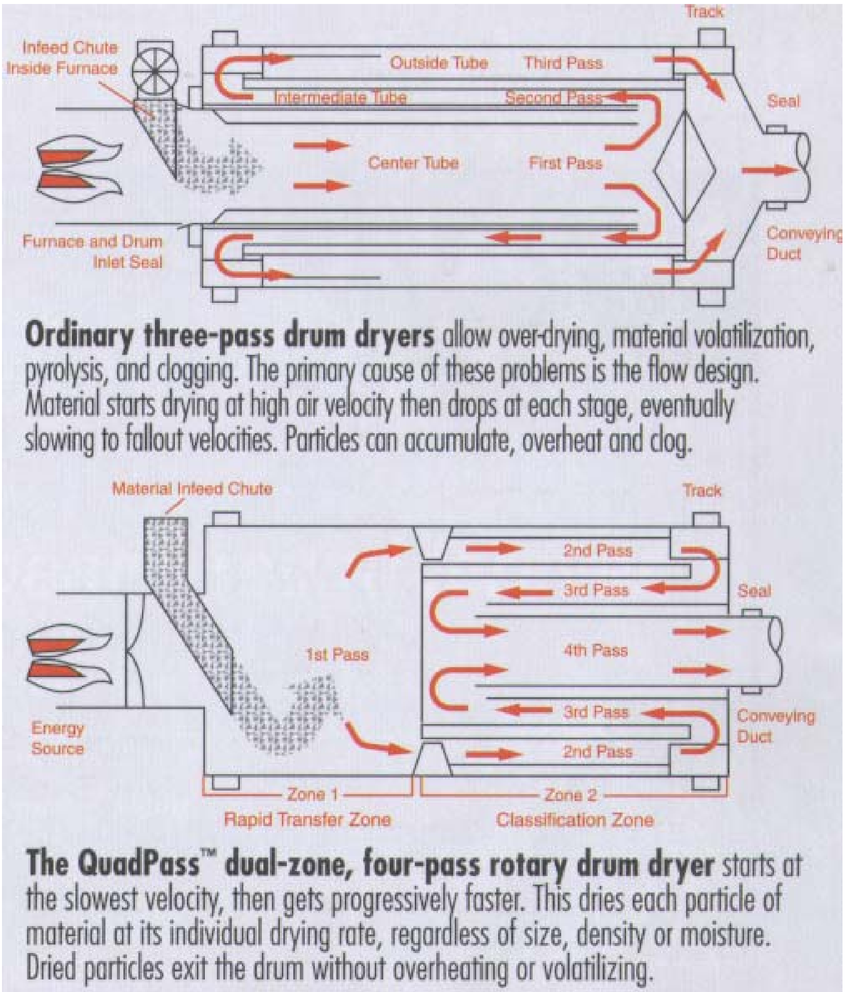

FIGURE 1. Comparison of the four-pass rotary drum drier and an ordinary three-pass drum drier used in animal rendering processes (The Dupps Company, 2003).

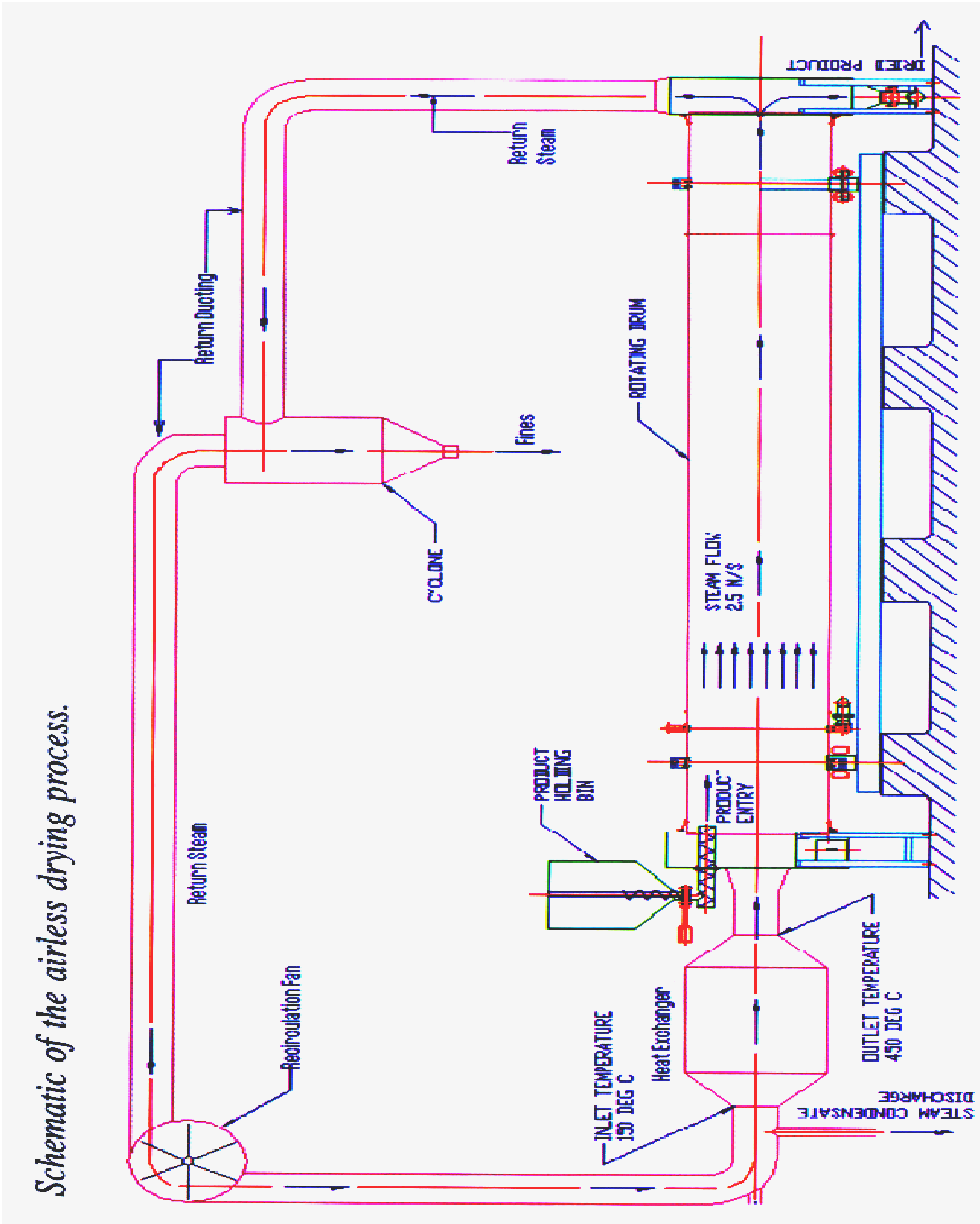

FIGURE 2. Schematic diagram of the heating and combustion loops of a new drier used for rendering processes (Morley, 2003).

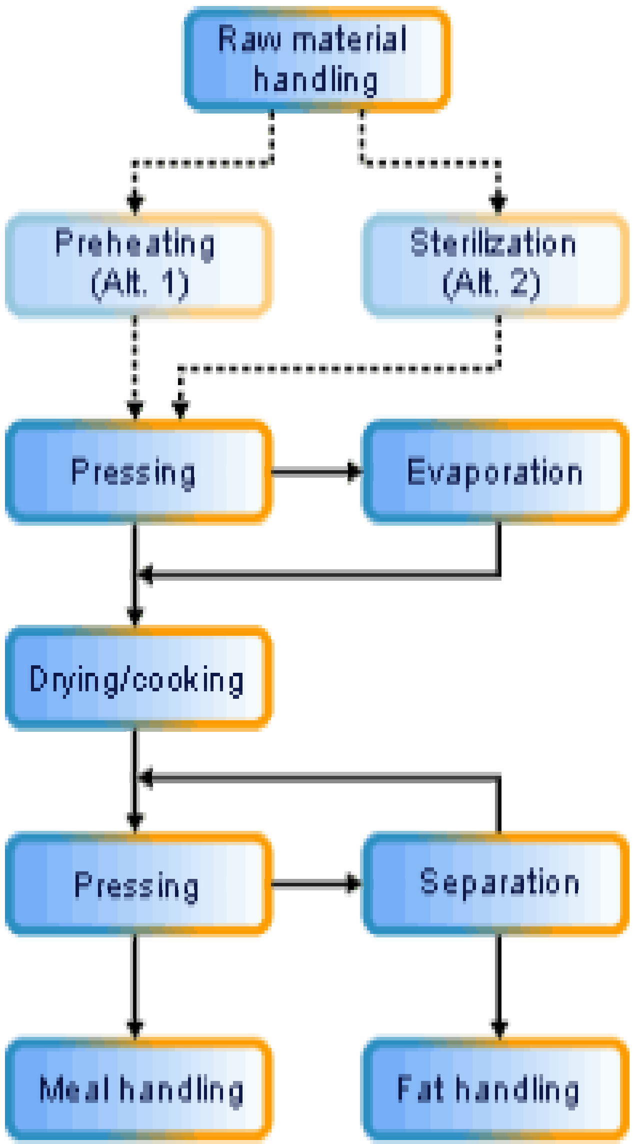

FIGURE 3. Flow process diagram of new continuous rendering systems with additional pressing and evaporation prior to the main cooking process (Atlas-Stord, 2003).

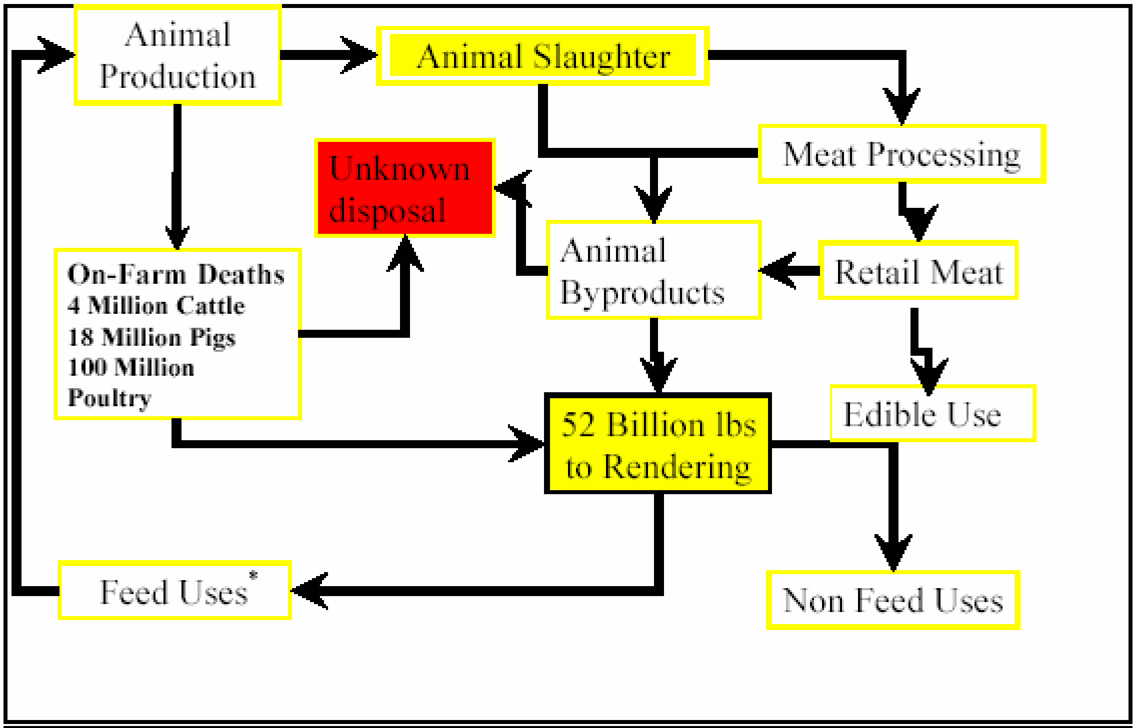

FIGURE 4. Estimated number of farm animal deaths, which provide about 40% of the raw materials needed for production of 52 billions pounds of rendering products (Hamilton, 2003).

TABLE 1. Annual animal byproducts and mortality, in 1,000 pounds (Hamilton, 2003).

Specie	Byproduct	Mortality	Total
Cattle	29,504,630	1,932,190	31,436,810
Swine	12,753,403	981,655	13,735,058
Sheep	297,213	64,106	361,319
Poultry	17,051,158	191,679	17,397,787
Total	59,606,403	3,324,570	62,930,974

Appendix D

TABLE 1. Composition of raw materials for inedible rendering (USEPA, 2002).

Source	Percent, by weight		
	Tallow/Grease	Protein Solids	Moisture
Packing house offal and bone	--	--	--
Steers	30-35	15-20	45-55
Cows	10-20	20-30	50-70
Calves	10-15	15-20	65-75
Sheep	25-30	20-25	45-55
Hogs	25-30	10-15	55-65
Poultry offal	10	25	65
Poultry feathers	None	33	67
Dead stock (whole animals)	--	--	--
Cattle	12	25	63
Calves	10	22	68
Sheep	22	25	53
Hogs	30	28	28
Butcher shop fat and bone	31	32	37
Blood	None	16-18	82-84
Restaurant grease	65	10	25

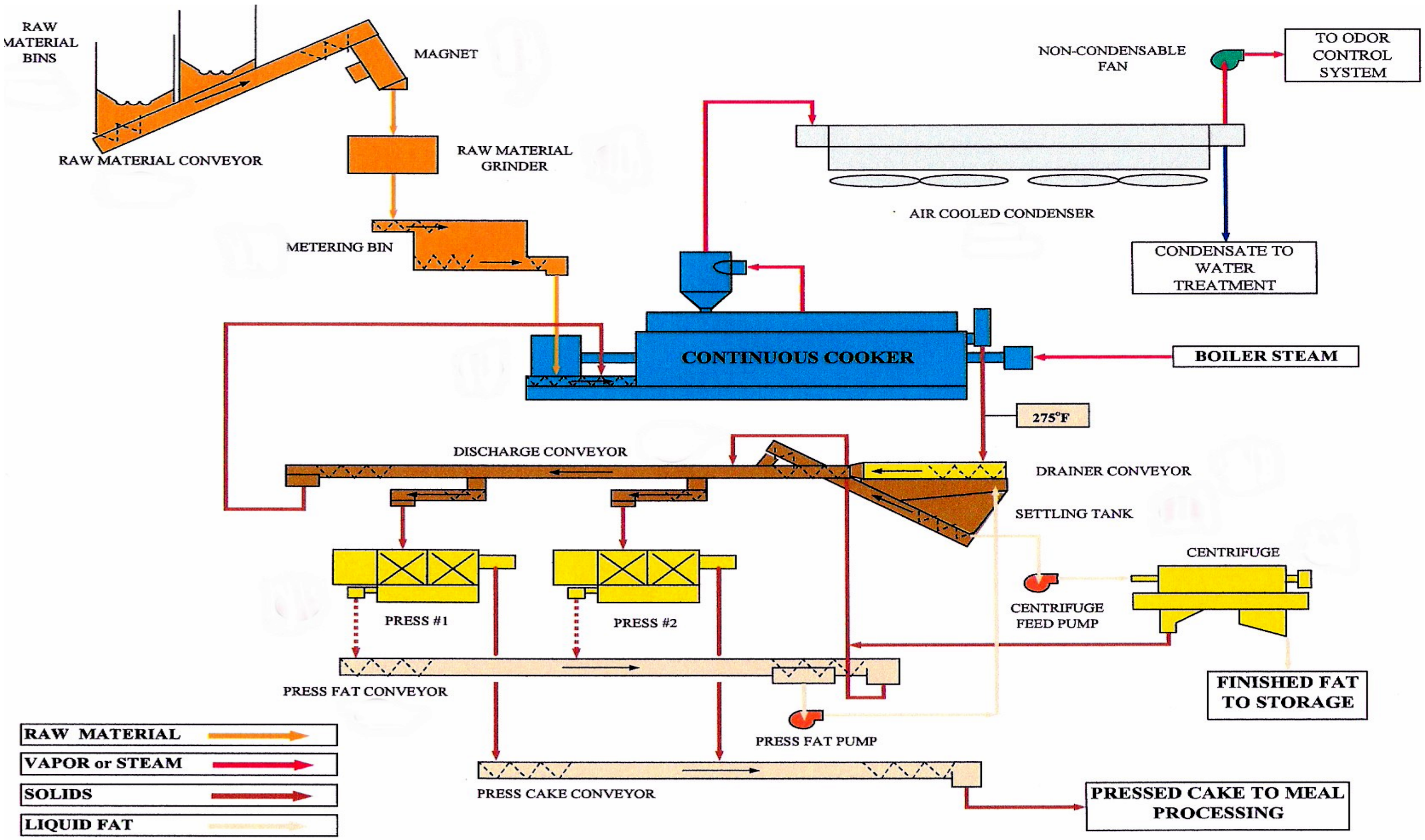

FIGURE 1. Schematic diagram of machinery, equipment, and material flow in a continuous dry rendering process (Hamilton, 2003).

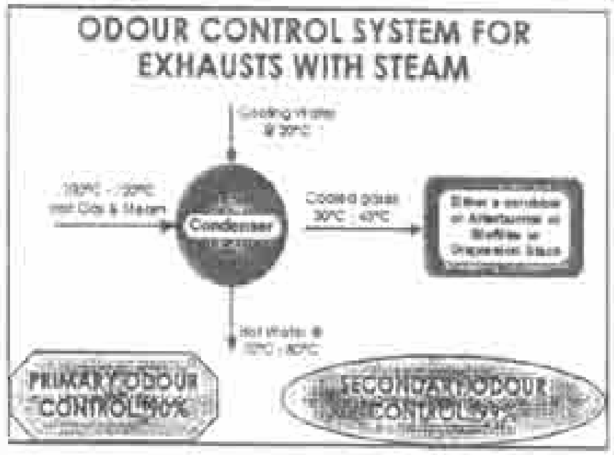

FIGURE 2. Schematic diagram of a typical condenser system used for condensation and odor control of exhausts vapors and gases of cooker with cooling water (Fernando, 1995).

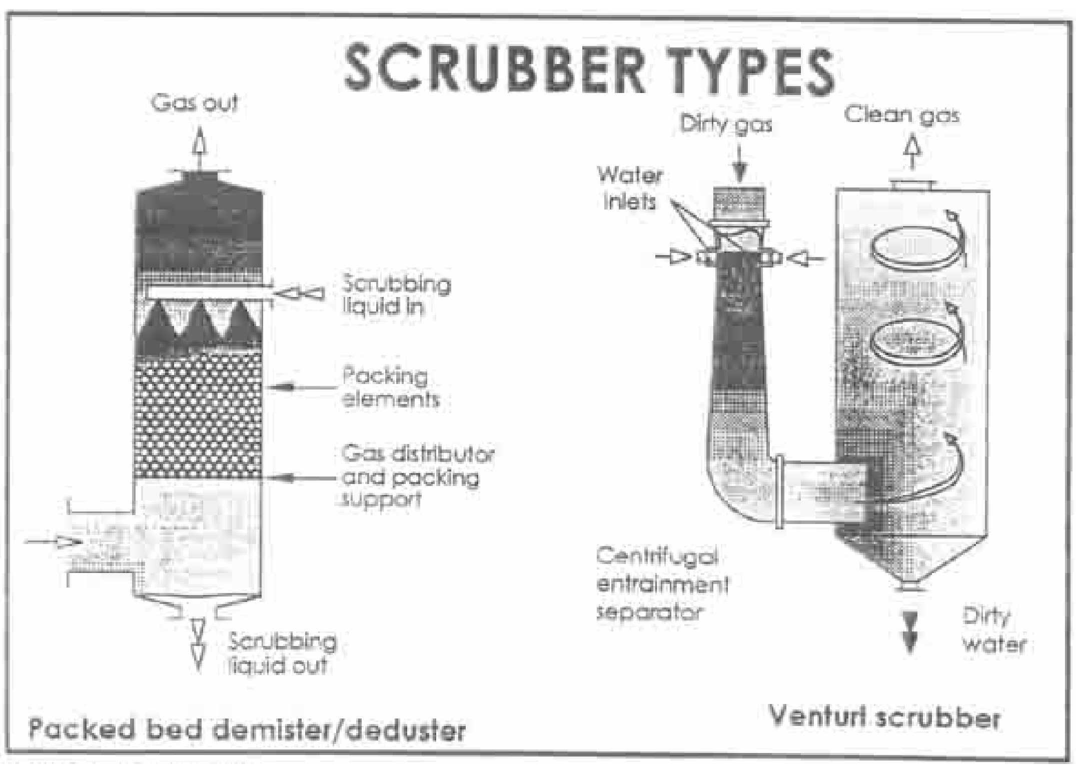

FIGURE 3a. Schematic diagram of two types of scrubbers used for chemical absorption of non-condensable gases leaving the condenser of rendering plants (Fernando, 1995).

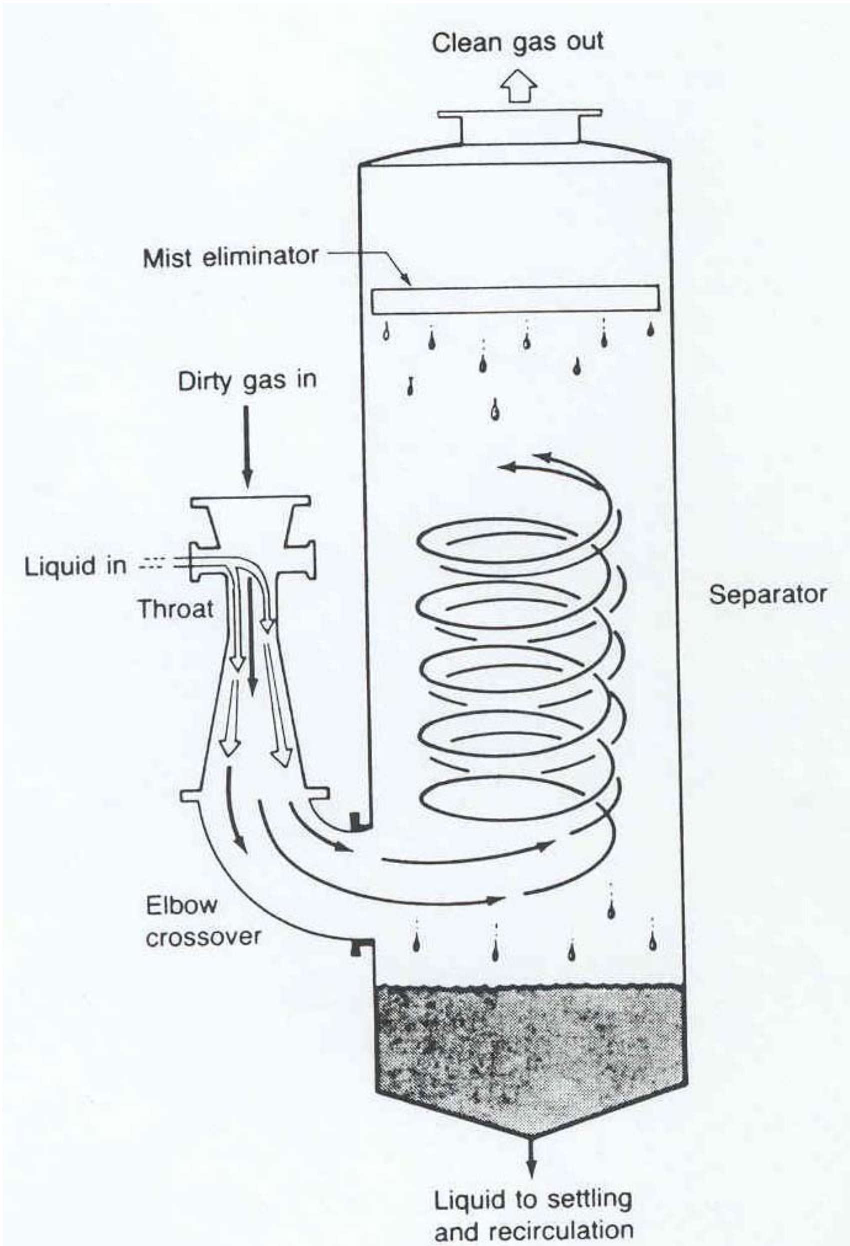

FIGURE 3b. Schematic diagram of an alternative venturi scrubber with a cyclone separator configuration (Cooper & Alley, 2002).

TABLE 2. Some results of packed tower experiments with various solutions (Fernando, 1995).

Odorant	Percentage of odorant removed in various solutions						
	Water	1% Sodium hypochlorite	3% Hydrogen peroxide	3% Potassium permanga nate	5% Sodium Bisulphite	5% Hydrochloric Acid	5% Sodium Hydroxide
Valeraldehyde (aldehyde)	30	10	>90	30	>90	0	10-30
Trimethylamine (amine)	80-90	>90		>90		>90	0
Dipropyl Sulphide (sulphide)	0	>90	0	10-25	10	0	0
Butyric Acid (fatty Acid)							>90
Butanedione (ketone)							>90
Amyl alcohol (alcohol)	80-90	80	75	40-80	75	80	0-60
Heptadiene (unsaturated alkane)	0	20	0	25			

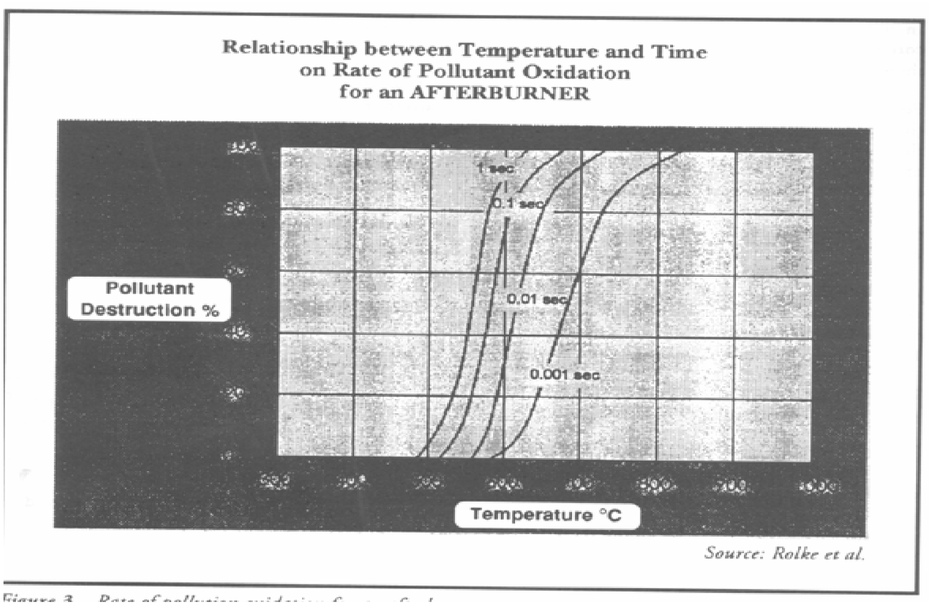

FIGURE 4. The relationship between temperature and time on the rate of complete oxidation of volatile gases in afterburners (Fernando, 1995).

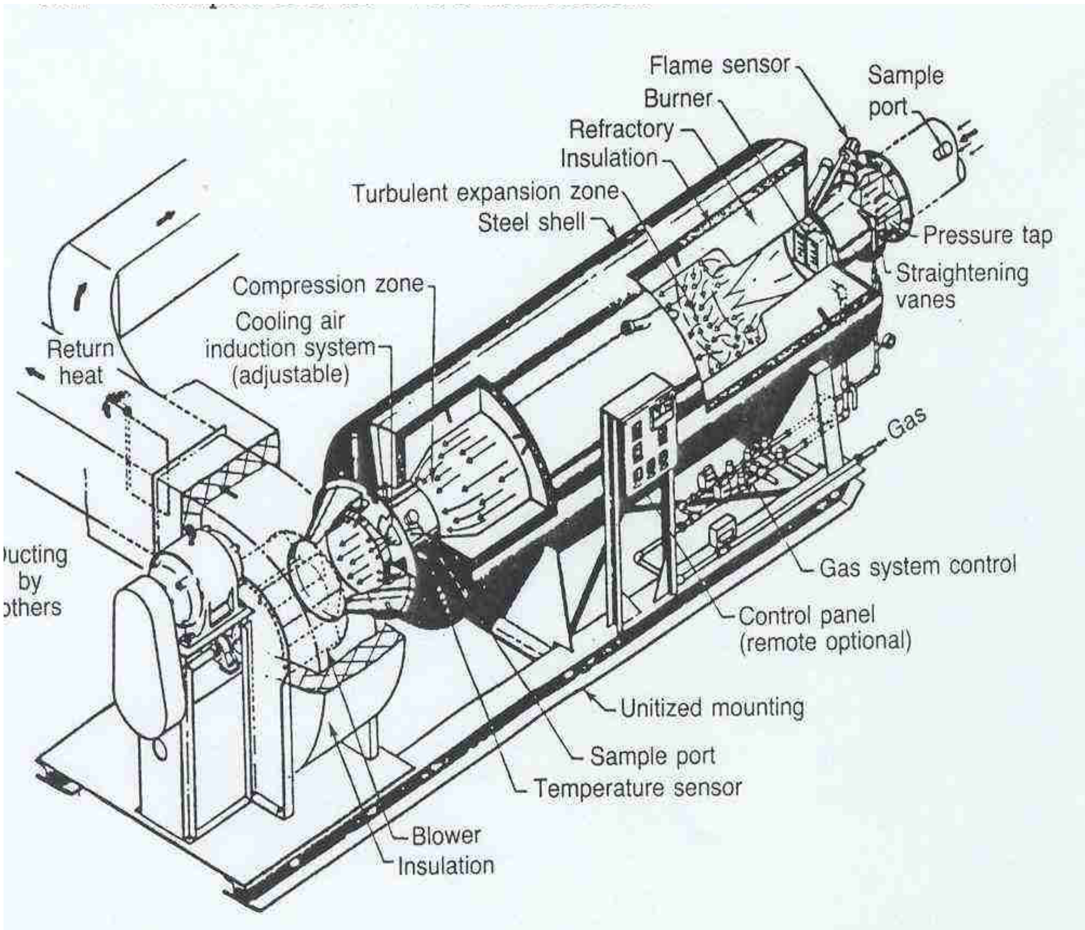

FIGURE 5. Sectional view of a direct-flame afterburner (Cooper & Alley, 2002).

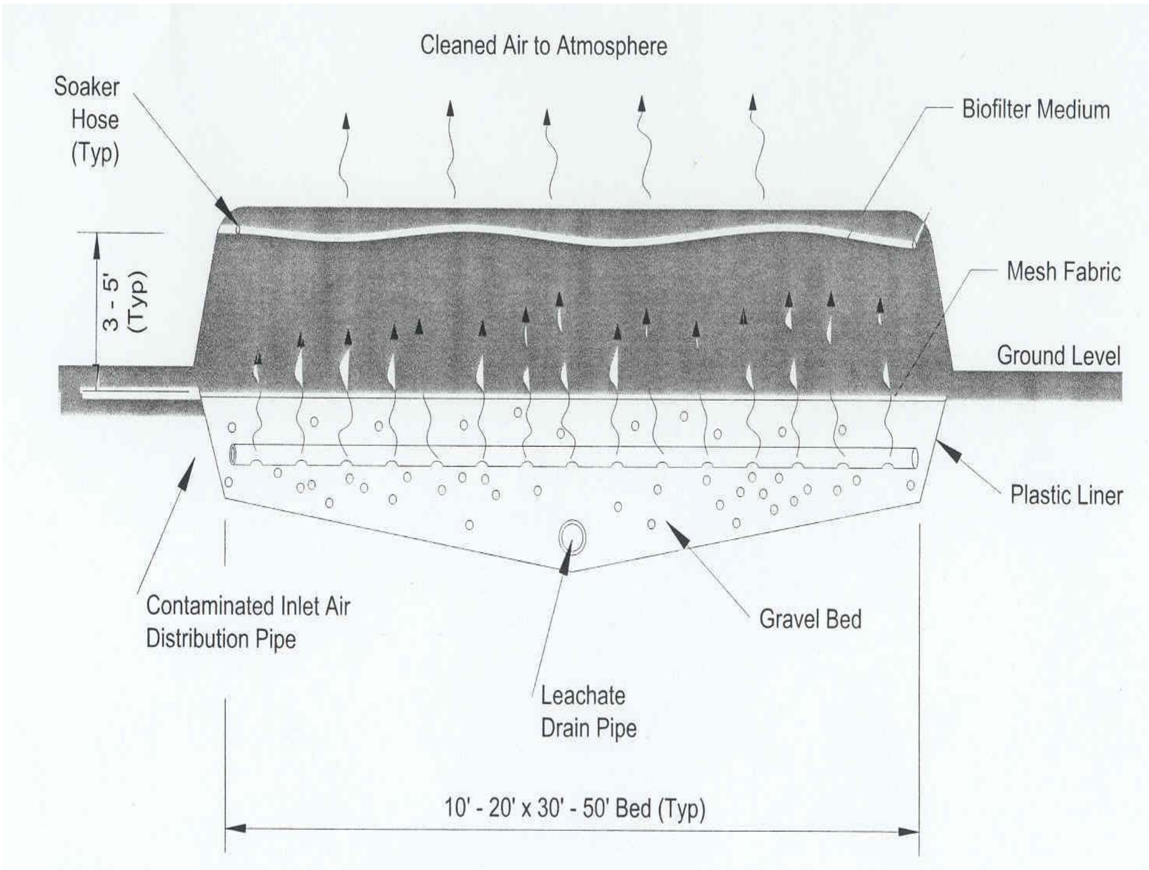

FIGURE 6. Cross section of a typical open-bed biofilter (Cooper & Alley, 2002).

TABLE 3. Quotation of The Dupps Company (2003) with the input capacity of approximately 80 metric tons/day (90 tons/day) assuming 20 working hr/day.

Item No.	Item Name	Quantity, HP	Description
RAW MATERIALS			
1	Raw materials storage bin	1; 7.5 HP	Type "A" raw material storage bin, approximately 70,000 pounds holding capacity
2	Raw material incline conveyor	1; H.P: 20	20" dia., type "D" screw conveyor.
3	Raw material storage sump pump	1; H.P: 0	Air operated, diaphragm type pump, for water removal at lower end of incline conveyor, complete with operating controls and valving
4	42" Electromagnet assembly	1; H.P: 7.5	Heavy duty electro magnet, specially designed for separation of ferrous metals from raw material, stepped face for trapping tramp metal, non-magnetic housing with hinged and latched access door, tramp metal receiver, rectifier to provide DC power and support staging
5	Prehogor feed conveyor	1; H.P: 20	20" dia., type "D" screw conveyor.
6	Prehogor - Model 180A-1	1; H.P: 150	Hard surfaced 1" rotor teeth and double row of replaceable 1" anvil teeth, heavy duty spherical roller bearings, flywheel and V-belt drive, up to 200 HP, 1750 RPM motor, 540 RPM rotor speed, drive guard, 1-1/2" thick steel plate housing with 25-3/4" x 36-3/8" charging opening, 22-3/4" x 36-3/4" discharge opening.
7	Prehogor staging and access platform	1; H.P: 0	Constructed of structural steel, included are: equipment supports, access platform, kickrails, handrails, and stairway that are required for the daily continuous operation of the system
8	Raw material metering bin	1; H.P: 5	A fully covered bin designed to control the raw material feed rate to a processing system and/or provide a surge of raw material ahead of the system. All reinforced carbon steel construction, variable pitch type bottom discharge screw(s) motor and drive. Access door for maintenance access and visual level checking
9	Raw material metering bin	1; H.P: 7.5	16" dia., type "B" screw conveyor
			TOTAL CONNECTED HORSEPOWER: 217.5
COOKING AND PRESSING			
10	Model NO. 70U Super cooker	1; H.P: 75	Steam heated shaft, un-jacketed shell.
11	Cooker upper level discharge gate	1; H.P: 0	Air operated slide gate designed for an upper level Cooker discharge
12	Cooker bottom discharge valve	1; H.P: 0	Air operated knife type gate valve, cast iron body, stainless steel seats, 500 degree F. "C" type packing, 4-way solenoid valve, all heavy construction. Designed for a bolted connection to the Cooker head plate
13	Control elevator	1; H.P: 10	Special slow speed elevator designed for metering applications such as Cooker discharge control, oil tight casing, heavy duty split type, positive discharge buckets mounted on a special 4"pitch chain, center of casing side discharge, bottom feed convey-or extended for bottom discharge of the Cooker and driven from the elevator tail shaft, motor, drive and mounting base
14	Drainer	1; H.P: 0	Special heavy duty screw with lifting paddles to turn the product for better drainage exposure, housed within a heavy carbon steel frame. Replaceable bottom drainage screens set in an adjustable frame to maintain a close tolerance between the screw and

			screen, latched aluminum side splash shields, bolted top cover with inspection openings, discharge box and support staging. Configured to mount on top of a sedimentor
15	Drainer discharge conveyor	1; H.P: 7.5	16" dia., type "B" screw conveyor
16	Sedimentor	1; H.P: 2	An enclosed tapered tank with an inclined bottom discharge screw, operating in a wrap-around type trough, sealed round sight glasses are mounted on the sides for viewing the tank contents, product and instrument connections, manually operated variable speed motor and drive. The top is configured for mounting the Drainer
17	Centrifuge feed pump	1; H.P: 3	Open impeller, centrifugal type, all carbon steel construction, mounted on a base and direct coupled to the motor
18	Centrifuge	1; H.P: 40	Keith 24 x 38 size, mild steel construction, solid bowl horizontal decanter type with a scroll that is hard surfaced on the outer-edge, vibro-isolators, 40 HP motor, v-belt drive, fluid coupling, appropriate safety guard(s), product and discharge chutes. Bearing oil recirculating and cooling system with a positive displacement type pump coupled to a 1.5 HP motor
19	Centrifuge support staging	1; H.P: 0	All welded construction, structural grade steel tubing, for mounting the Centrifuge approximately 4 feet high, adjustable legs and monorail type maintenance beam
20	Centrifuge discharge pump	1; H.P:5	Positive displacement type pump, all carbon steel construction, mounted on a base and direct coupled to the motor
21	Cooker priming pump	1; H.P:3	Consisting of a variable volume pump, mounted on a base and direct coupled to the motor
22	Pressor feed conveyor	1; H.P:2	9" dia., type "A" screw conveyor
23	Dupps 10-4 Pressor	1; H.P:200	Configured for 200 HP motor and drive, 12” dia. feed quill and feed assembly
24	Pressor cake discharge hood	1; H.P:0	1/8" thick stainless steel construction, directional flop-gate for two conveyor and floor discharge, vapor outlet with adjustable blast-gate
25	Hydraulic control console	1; H.P:2	Complete with hydraulic oil pump direct coupled to a 2 HP motor, pressure control valve, solenoid control valve, gauges, control relays and oil reservoir
26	Pressor pad access steps	1; H.P:0	Steps with hand-rails for access over discharge conveyors to the Pressor (s), all carbon steel construction.
27	Pressor ribbon recycle conveyor	1; H.P:3	9" dia., type "A" screw conveyor
28	Pressor fat pump	1; H.P:7.5	Style B, paddle type pump with a tapered feed screw, for handling large particle sizes, mounted on a base and direct coupled to a 7.5 HP., 1200 RPM motor. Configured for mounting to a screw conveyor screened drainage section
29	Pressor recycle cross conveyor	1; H.P:3	9" dia., type "B" screw conveyor
30	Pressor recycle conveyor	1; H.P:3	9" dia., type "A" screw conveyor
31	Pressor recycle incline conveyor	1; H.P:5	9" dia., type "B" screw conveyor
32	Pressor cake discharge conveyor	1; H.P:5	12" dia., type "A" screw conveyor
33	Vacuum protection of vapor lines	1; H.P:0	Consisting of a flanged rupture disc to be mounted directly on the vapor line

34	Plant process piping	1; H.P:0	All manually operated valves, special fittings, hoses, flexible hoses, expansion joints, etc., to interconnect the system process piping including steam and/or air product clean out blow lines
35	Special cooking controls	1; H.P:0	Part of "System Motor and Process Controls" listed below. a. Control Loop #1 - controls the discharge rate from the cooking unit. b. Control Loop #2 - controls the cooking unit discharge temperature by varying steam pressure. c. Control Loop #3 - controls the cooking unit level by varying the raw material feed rate to it. d. Control Loop #4 - Regulates the speed of the Non-Condensable Blower to maintain correct negative pressure in the cooking unit. TOTAL CONNECTED HORSEPOWER: 379.0
MEAL GRINDING			
36	Cake curing bin	1; H.P:5	All carbon steel construction except the top cover which is stainless steel, side wall and top reinforcing ribs, tapered bottom, 20"access door, heavy duty 12" variable pitch bottom discharge conveyor that extends at the discharge and drive ends in a U-shaped trough with angle type screw hold down when applicable and sealed 3/16" thick mild steel bolted covers. The bin is 8ft. wide x 10 ft. high x 17 ft. long, approximately 15 ton capacity, constant speed 5 HP motor and drive. 12" top leveling conveyor with extended U- shaped input trough, 3/16" thick mild steel bolted covers, constant speed 3 HP motor and drive
37	Vertical cake conveyor	1; H.P:7.5	12" diameter screw operating in a tubular housing, carbon steel construction except the top 2 ft. of the housing and the discharge chute which are #304 stainless steel, 3/8" thick sectional flighting continuously welded to a 4" #80 pipe, v-belt drive, 7.5 HP, 900 RPM motor
38	Grinder feed conveyor	1; H.P:3	9" dia., type "A" screw conveyor
39	Dupps meal grinder	1; H.P:150	Extra heavy carbon steel construction, replaceable alloy wear resistant cap and liners, 2 hard faced replaceable hammers attached to the rotor with heat treated bolts, split screens held in place with pivoting cradles that are secured by dual locking bolts, replaceable rotor shaft, heavy duty ball bearings, rotor shaft is direct coupled to the motor with a flexible type coupling,access doors permit screen and hammer changing without disturbing connecting chutes.
40	Grinder support structure	1; H.P:0	Constructed of structural steel, included are: equipment supports and access platform, kickrails, and stairway
41	Grinder discharge conveyor	1; H.P:3	9" dia., type "A" screw conveyor
42	Vibrating screen	1; H.P:3	40" X 84" size, all metal construction with aluminum screen deck and cover, automatic screen tensioning, cable suspension brackets, stainless steel bottom meal pan, nominal screening area 50.0 sq. ft., motor and drive.
43	Screen discharge conveyor	1; H.P:5	Tramco Bulk-Flow Heavy Duty Chain Conveyor. 1/4" thick AR carbon steel bottom and divider plates. 3/16" thick upper and lower side plates plus 3/16" thick cover. Carbon steel chain with carbon steel pins. Carbon steel support legs, 6" x 12" size. Carbon steel housing and cover. Teflon paddles.
44	Meal storage silo	1; H.P:10	A.O. Smith Permaglas Storage Silo , fused glass on carbon steel bolted panel construction, skirted shell, screened roof ventilators, roof opening cover plate, roof man way, slide inspection man

			way, sidewall accessory door, ladder and safety cage, flat profile roof with perimeter hand-rail
45	Silo discharge conveyor	1; H.P:7.5	Tramco Bulk-Flow Heavy Duty Chain Conveyor. 1/4" thick AR carbon steel bottom and divider plates. 3/16" thick upper and lower side plates plus 3/16" thick cover. Carbon steel chain with carbon steel pins. Carbon steel support legs, 10" x 15" size. Carbon steel housing and cover.
46	Truck-loading cross conveyor	1; H.P:5	16" dia., type "A" screw conveyor
47	Truck loading conveyor	1; H.P:7.5	16" dia., type "A" screw conveyor
			TOTAL CONNECTED HORSEPOWER: 209.5
MISCELLANEOUS EQUIPMENT			
48	Maintenance hoist #1	1; H.P:0	Pressor maintenance, one (1) ton capacity, low head room, trolley mounted, hand operated chain block.
49	Maintenance hoist #2	1; H.P:0	Centrifuge maintenance, 2 ton capacity, low head room, trolley mounted, hand operated chain block with a 20 ft. hook drop
50	Fat shipping pump	1; H.P:7.5	Centrifugal type pump, all carbon steel construction, direct coupled to the motor, mounting base, approximately 250 GPM capacities
51	Outside fat storage tank	2; H.P:0	10'-6" diameter tank of all carbon steel construction, 45 degree coned bottom, steam coils, covered top with 12" dia. top inspection opening with cover, 20" dia. Man way with hinged and bolted cover located in the cone, connecting pipe fittings for fat, steam, thermometer and overflow
52	Fat work tank	1	10'-0" diameter tank of all carbon steel construction, 45 degree coned bottom, support legs, steam coils, covered top with 12" dia. top inspection opening with cover, 20" dia. manway with hinged and bolted cover located in the cone, connecting pipe fittings for fat, steam, thermometer and overflow
53	Fat to storage pump	1; H.P:7.5	Centrifugal type pump, all carbon steel construction, direct coupled to the motor, mounting base, approximately 250 GPM capacities
54	Hot water pump	1; H.P:10	Centrifugal pump, double suction, ductile iron casing, bronze impeller, complete with motor, drive and mounting base
55	Hot water storage tank	1; H.P:0	32" 8" dia. X 16' nominal sidewall height factory coated bolted steel water tank, nominal level full capacity 100,000 US gallons, designed in accordance with AWWA D103-97 specifications, seismic zone 3,100 MPH wind load, 25 PSF live deck load and equipped as follows: ■ Anchoring stirrups with anchor bolts (if required). ■ Flat steel bottom. ■ 1:12 slope roof. ■ 24" X 46" flush type cleanout with two piece cover and handhole. ■ 20" dia. Center roof dome with screened ventilator. ■ 24" square hinged roof manway. ■ galvanized outside ladder with safety cage. ■ 8" overflow weir cone with external nozzle. ■ 6" inlet nozzle. ■ 8" outlet nozzle. ■ 1/2" thick fiber board furnished for placing between tank bottom and foundation ring wall.

			■ Level transmitter and high level alarm. Hardware: Galvanized bolts, nuts, washers and gasketing are standard. Plastic encapsulated head bolts for interior vertical and roof seams. Coating: Interior and both sides of bottom painted two coats Trico Bond thermoset corrosion resistant epoxy (5 mils average, DFT). Exterior epoxy primer with finish coat of baked on tan acrylic enamel (3 mils average, DFT) (color other than tan optional at an extra charge). Trico Bond epoxy is suitable for liquids with a pH range of 3 to 11.
56	Pressor maintenance impact wrench	1; H.P:0	1-1/2" drive, 90 psig @ approximately 137 cfm (25 HP air compressor minimum), 60Percent efficiency for 4,000 ft/lbs., torque, and maximum wrench torque is 10,000 ft/lbs
57	In-floor sump and pump	1; H.P:5	52" diameter x 72" deep tank with cover, configured for mounting the pump, access opening and ladder, coated for in-ground installation. Trash type open impeller pump direct coupled to the motor with a flexible type coupling, and is automatically actuated by a float operated switch. Pump capacity is 70 GPM; maximum particle handling size is 2-1/2" diameter
58	Mechanical catch basin	1; H.P:1	All carbon steel construction with mechanical skimmer for fat and sludge removal. Unit is equipped with screw conveyors to convey the reclaimed fat or sludge to either side of the unit. The conveyors are powered by the skimmer drive, motor and drive. The fat screw is fitted with a 1/2" pipe size rotary steam joint which requires 15 psig steams. Retention time is 40 minutes, water inlet and outlet nozzles are 6", speed of the drag chain is 3.25 FPM
59	Catch basin sludge conveyor	1; H.P:2	6" dia., type "A" screw conveyor
60	Pressurized condensate return system	1; H.P:20	The Mid-South Closed Loop System is a trapless condensate return system which is designed to return high pressure high temperature condensate directly to the boiler(s) or high pressure surge tank. Pumping the high pressure condensate directly to the boiler, ypassing the deaerator or feed tank, eliminates the loss of flash steam to atmosphere. Basic Features: ■ High efficiency, chemical duty motor. ■ Heavy duty process pumps, standard. ■ High temperature mechanical seal. ■ Condensate Receiver, ASME construction. ■ Level control with magnetic flag indicator. ■ Pneumatic actuated control valve. ■ Stainless steel control panel. ■ Stainless steel instrument panel. ■ Precision gauges, liquid filled. ■ Elevated Base for housekeeping. ■ Adjustable legs for leveling. ■ 2" calcium silicate insulation. ■ Stainless steel metal insulation jacketing TOTAL CONNECTED HORSEPOWER: 58
AIR POLLUTION & HOT WATER CONTROL			
61	Lot of condensable vapor piping	1; H.P:0	Stainless steel pipe, fittings, flanges and stiffener rings, to connect the Cooker exhaust vapors to the hot water condenser. Supports and hangers are carbon steel

62	Non-condensable blower	1; H.P:10	Type 304 stainless steel housing and impeller, 10 HP motor and drive, 3,423 RPM, 500 CFM at 24" static pressure
63	Lot of non-condensable vapor piping	1; H.P:0	Stainless steel pipe and fittings plus mild steel flow control slide gates to collect non-condensable vapors from the Condenser, Drainer, Centrifuge, Pressor and any other equipment requiring venting, into a common line which will terminate at a the input of the Non-condensable Control Equipment
64	Shell and tube hot water heat exchanger	1; H.P:0	1,700 sq. ft., all stainless steel construction. Vapor condensing is on the tube side and water is heated on the shell side
65	SCP Room air packed bed scrubber	1	For processing the room air within the processing area then exhausting it to the atmosphere. The following sub-systems are included: one (1) Packed Bed Scrubber, Interconnecting Ducting, and 110V Panel for automatic monitoring and control of chemical addition
66	SCP Two stage high intensity system	1	Equal Size Venturi/Packed Bed Scrubber for processing gases from selected equipment in the main processing area. The following sub-systems are included: one (1) Venturi Scrubber, one (1) Packed Bed Scrubber, Interconnecting Ducting, 110V Panel for automatic monitoring and control of the chemical addition
67	Grinder air cyclone separator	1	Fisher-Klosterman High Efficiency Cyclone Dust Collector to vent meal dust from the meal Grinder and discharge it into a meal conveyor
68	SCP Pre-incineration system	1	Designed to pre-treat high intensity odors as non-condensable gas or process gas prior to exhausting to the plants boiler for incineration
69	Scrubbing system ducting	1; H.P:0	The ducting required to interconnect the SCP air pollution control equipment. The ductwork to be constructed of 16 gauge 304 stainless steel with 304 stainless steel flanges and stiffeners. Straight runs will have one flange loose for field adjustment
70	SCP PVC Components	1; H.P:0	Pipe, fittings, valves, etc. for plumbing the SCP air pollution control system
			TOTAL CONNECTED HORSEPOWER: 279.5
SYSTEM ELECTRICAL CONTROL			
71	Motor control	1; H.P:0	Starter-breaker modules mounted and wired in an enclosure; 3-phase power wiring includes breaker to bus, breaker to starter and starter to terminal strip (size 1 and 2 starters). Motor control also includes AC frequency drives and soft starts mounted and wired (3-phase only) in an enclosure. Capacitors (for 50 HP and above), local disconnects (for all HPs), and Motor Control Electrical Engineering for all items above is also included
72	Process control - relay plant	H.P:0	Single phase control wiring for starter-breaker, AC frequency drive and soft start modules. Also includes mounting and wiring in an enclosure, items such as pushbuttons, relays, timers, motor load meters with CTs, recorders, and PID controllers. The process controls are mounted in a Panel Board or a Push Button Control Console. Includes all instrument and control items such as control valves, flow meters, and transmitters (level, pressure and temperature). Process Control Electrical Engineering is also included
SPECIAL SERVICES			
73	Engineering	1	Consisting of the basic items listed below, refer to Exhibit "B" for additional details.

			■ Layout of the above listed equipment within the Owners building. ■ Location of floor pits, building openings, access areas, and support staging. ■ Empty and operating equipment weights and their location to aid in the design of equipment support foundations. Actual foundation design is the responsibility of the Owner. ■ Wiring diagrams. ■ Size and locations of motors and control devices. ■ Schematic piping diagrams. ■ Advice as to utility requirements. ■ Provide technical information to assist the Owner or its agents, to remodel an existing building, with the special features required to house the equipment being furnished
74	System start up and operator training	1	Consisting of the basic items listed below, refer to Exhibit "B" for additional details. Provide the services of system start-up specialists to train the Owners personnel to operate and maintain the system. The training period will commence the day that raw material is initially processed and will consist of the following: ■ Maximum number of personnel ■ Maximum number of working hours per day per man ■ Maximum number of man-days including travel days without additional charges ■ Number of individual round trips to the job site ■ Per Diem and travel expenses for the above number of personnel. Any additional time required will be charged for according to the field service rates in effect at the time of service.
75	Installation	1	Consisting of the basic items listed below, refer to Exhibit "B" for additional details: ■ Rigging into place and interconnecting the equipment. ■ Piping - provide the labor and material to do the piping required to operate the equipment comprising the system, listed on Exhibit "A", within the processing area. ■ Electrical - provide the labor and material for the power and control wiring for all of the items listed on Exhibit "A". ■ Freight to the jobsite. ■ Insulation - of designated equipment and piping with a water-proof cover. ■ Paint - provide a shop coat of oxide primer. ■ Equipment Access - as required for the daily continuous operation of the equipment

TABLE 4. Quotation of Scan American Corporation (2003). Quantity & specifications of needed equipment for dry carcass rendering with feed capacity of 2,700 kg/head (6,000 lbs/head) and working 8 h/day.

Qty	Item	Description
RAW MATERIAL HANDLING		
1	Silo for dead carcasses and feathers	■ Each one with approximate volume of 15 m^3 and provided with one bottom screw conveyor (diameter 300 mm). ■ Each silo is manufactured in 5 mm mild steel plate and supported by frame. ■ The screw section of carcass silo is 6 mm with 10 mm wear plate and is driven by one gear motor 5.5 kW and chain drive. . ■ The base of the feather silo contains three screw conveyors. ■ Each screw has a diameter of 400 mm and is driven by one 5.5 kW gear motor.
1	Screw conveyor	Length= 9.5 m and diameter Ø400 mm
1	Screw conveyor	Two outlets each with Ø500 mm
2	Filling platform for dry-melter	■ With slide gate valve and electric motor ■ Manufactured in mild steel and includes handrail and steps.
1	Blood tank, 2,500 L with agitator	■ Manufactured in a form of cylindrical and vertical type. ■ All surfaces in contact with the product in stainless steel. ■ Supplied with a detachable top cover, partly hinged for inspection. ■ Side-mounted ladder gives access to this inspection. ■ Agitator with 1.5 kW motor. ■ The pump capacity is approximately 15 tons/hr with a motor of 2.2 kW (for pumping the raw blood from the blood tank to the dry rendering cooker, inclusive of pipes and flex hose).
1	Set of blood pipes NW50	
COOKING AND DRYING EQUIPMENT		
2	Dry melter type HM 5000	Assembled and delivered as a packaged unit mounted on a base frame. Volume: 5,000 l Inner shell: 25 mm (mild steel boiler plate DIN 17155) Steam jacket: 10 mm Charging dome: 20 mm Working pressure: Internal 5 bar, Jacket 10 bar, Agitator 10 bar Fittings: Steam inlet valve – manual, Sampling valve – manual, Pressure relief valve – safety, Vapor vent and by-pass valves – manual, Jacket pressure gauge, Internal pressure gauge, Internal vapor thermometer, Steam traps Drive: Shaft mounted gear box, V-belt drive, Hydraulic clutch, 37 kW squirrel cage motor Insulation: 50 mm rock-wool clad with stainless steel sheets
2	Pressure test certification (according to GOST rules)	
2	Automatic moisture control (with the following specifications)	■ Controls the instrument and stabilized DC supply unit for the measuring circuits. ■ The module accommodates two indicators for over set point and below set point. ■ One indicator for end point. ■ One reset button. ■ Selector for choosing different sensitivities.

		■ Characteristic with adjustable potentiometer. ■ Converter to be placed close to the moisture sensor. The box contains one set of electrical circuits. ■ Moisture sensor for mounting on the Dry Melter (special plug is standard on the dry melter0. ■ Power supply: 220 V AC +/- 10Percent, 50-60 cycles
1	Load cell system 4 x 10 ton	■ The 4 load cells system is placed between button frame and concrete foundation. ■ Four load cells with mountings. ■ Weight amplifier with autotara and two set points. ■ A terminal for recording instrument.
2	Terminal box and digital display	With front mounting in control panel
GREAVES HANDLING		
1	Collecting tank	■ With the capacity of approximately 8 m^3 . ■ Provided with two bottom screw conveyors, each with diameter 300 mm. ■ Manufactured in 5 mm mild steel plate with the screw section of 6 mm with 10 mm wear plate. ■ Each screw is driven by one gear motor 3 kW.
1	Screw conveyor Ø230 mm	■ Works with steam at pressure of 1 bar and its trough is made of 5 mm mild steel. ■ A 6 mm flight is welded on one center pipe 76 x 8 mm. This screw is driven by one gear motor 2.2 kW. The conveyor is steam heated on the trough and includes all valves and steam traps
1	Chute and magnet.	It is mounted with a permanent magnet to trap ferrous metal
1	Dosing screw conveyor Ø230 mm.	Its length is approximately 2 m and will be fitted with manual adjustable speed gear motor
1	Fat screw press (type HM1000).	It separates the fat solution from the protein materials. The fat content of the materials inside the press is approximately 10-14Percent (depending on raw material). It is constructed with a heavy-duty frame of all-welded construction. The shaft has sectional flights and steel cage with barrel bars and spacers. The press has a choke control unit and a conical choke to control the pressure in the cage. Its drive unit is integrated with planetary gearbox, v-belt system and electrical motor. Output meal capacity of screw press is about 700-800 kg/hr and total power consumption is about 37 kW
1	Cooling screw	Length = 8.2 m and Ø230 mm It is for cooling the meal prior to milling. It is equipped with a special cover with air inlet. The screw is complete with gear motor 3 kW. The cooling filter is for mounting on the screw conveyor. Capacity will be 1500-2000 m^3/hr
1	Milling plant (type 650/450)	This unit includes hammer mill with motor 45 kW, coupling and vibration dampers. It has supporting frame with platforms on both sides including handrail and staircase. It has a bag holder and underneath of its frame there is a collecting hopper mounted with spouts for direct bagging
1	Weighing scale	local supply
1	Bag closing machine	local supply
FAT HANDLING		
2	Balance tank	(V = 70 L). They equilibrate the fat flow from the screw press to settling/intermediate tank. The balance tanks are manufactured in mild steel plate with double bottom for steam heating and equipped with pump and motor. They are provided with automatic level controls. A pump which serves both

		tanks has a capacity of approximately 40 L/min and power of 1.1 kW.
2	Settling tank	(V =1000 L). They are manufactured in mild steel with outside steam spiral for heating, insulation and cover plate for same in stainless steel plate and equipped with all fixed accessories and fittings
CONDENSING EQUIPMENT		
1	Cyclone HM1000	It has a diameter of 1,000 mm and includes valve for discharging of the sludge and it is manufactured from stainless steel with captive loose flange connections
1	Air-cooled Condenser HM 3000 kg/hr	All materials in contact with vapor, condensate and/or non-condensable are stainless steel AISI 304. All other steel parts are hot dipped galvanized. The tube bundle consists of 4 rows of 32 mm stainless steel, finned tubes. The first pass is done in the 3 top rows. The second pass is in the bottom row in which the condensate is sub-cooled. Ambient air is blown through the tube bundle by 2 fans. Each fan is directly driven by a 15 Hp 11 kW, 480 rpm electric motor. To save energy, the cooling capacity can be automatically adjusted by switching the fans individually on or off. A temperature sensor in the condensate outlet controls the capacity adjustment.
1	Stainless Fan 500 m3/h.	It is manufactured in stainless steel, AISI 304 with a 250 mm VG, 1.1 kW motor and it is for non-condensable gases coming from the condenser
1	Frame for Fan	It is hot dipped galvanized
1	Set of blow off pipes with all fittings	It includes a blow-down pipe (from dry melters to the cyclone and further to the condenser and non-condensable gas fan – of stainless steel), a pipe for non-condensable gases (for interconnection of non-condensable gas fan and boiler – max 30 meters – of stainless steel).
VARIOUS ELECTRICAL DEVICES		
1	Electrical control panel.	It contains the following items: ■ Main switch ■ Motor contactors for all motors ■ Fuses ■ Start/stop buttons for all motors ■ Indication lamps for running machinery ■ Star delta starters for motors above 11 kW ■ Ammeters for motors above 11 kW ■ Terminal strips, etc. ■ Cabinets of mild steel – grey painted modules ■ Following IEC 439 and IEC 117-3
1	Electrical cables	They are necessary for connecting 2 x 5000 L dry melter
1	Distribution battery (with reduction unit, 10-1 bar)	It consists of a distribution battery with flange connection for live steam from the steam boiler, connection for live steam supply to the dry melters as well as a connection for reduction unit including stop valve, safety valve, pressure gauge and pressure pipe
1	Set of pipes with all fittings	It includes steam and condensate pipe (for inter-connection of boiler and distribution battery/reduction), a steam pipe (between dry melters, percolating tank, balance tanks, settling tanks and reduction unit – in mild steel), a steam condensate pipe (from dry melters, percolating tank, balance tanks, settling tanks, and reduction unit – in mild steel) and a fat pipe (between percolating tank, balance tanks and settling tanks). The pipes from the balance tank to the settling tank are supplied with electric heating cables.
STEAM BOILER PLANT		
1	Steam boiler with a steam capacity of 4000 kg/hr	This boiler has the following characteristics:

- Operating pressure 9 bar.
- 100 mm insulation.
- One ELCO oil burner light fuel.
- One electric and automatic control panel.
- Two feed water pump Grundfos including necessary valves.
- One feed water tank 2500 liter.
- Manufactured in mild steel (including steam heating).
- One water treatment plant with capacity of 3 m3/h, D= 4.5 m and H=4.5 m
- One dosing pump.
- One boiler test set.
- One steel chimney (10 m height).
- One blow down tank

COST

Price for Complete Plant: $1,065,200 USD

Includes Spare Parts for 2 years

Startup includes supervision, installation for 4 weeks, and start-up and training for 2 weeks

Appendix E

FIGURE 1. Typical appearance of meat and bone meal (MBM) and various tallow-products in jars (National Renderers Association, Inc., 2002).

TABLE 1. Typical analysis of meat and bone meal (Pocket Information Manual, 2003).

Constituent	Content
Protein	50% (or as specified)
Fat	10%
Fiber (max.)	3%
Calcium (max.)	8.8% (2.2 times actual phosphorus level
Phosphorus (min.)	4%
Moisture (max.)	10%
Pepsin indigestible residue (max.)	14%

TABLE 2. Comparison of yields obtained with traditional dry rendering (Fernando, 1984).

Yields	LTR	Dry Rendering
Fat (%)	99.5	95.0
Fat-free solids (%)	94.0	96.0
Fat in meal	8.0	12.0
Moisture in meal (%)	8.0	3.0
Tallow, metric ton[a]	4346.0	3909.0
Meal metric ton[a]	5371.0	5421.0

[a]To convert to US tons, multiply ton by 1.1.

TABLE 3. Amino acid digestibilities of rendered animal proteins (adapted from table citing various sources, available in Pocket Information Manual, 2003).

Amino Acid	Meat and Bone Meal		Whole Blood Plasma	Spray Dried Meal	Poultry By-product	
	Ileal	True			Ileal	True
Lysine	71	82	94	86	84	76
Tryptophan	57	-	92	92	74	-
Threonine	64	79	86	80	74	73
Methionine	84	87	84	63	-	88
Cystine	63	47	-	-	-	54
Isoleucine	68	89	67	83	79	67
Histidine	68	82	95	89	80	76
Arginine	80	86	90	86	87	82

Appendix F

TABLE 1. Estimated operating and total costs for various mortality disposal methods in the US (SCI, 2002). (Each estimate assumes all mortalities are disposed of by one method).

Species	Rendering[a]		Burial	Incineration	Composting
	MBM Sold for Feed	No MBM for Feed			
	Total (Sector-wide) Operating Costs ($ 1,000)				
Cattle and Calves	34,088	99,169	43,902	38,561	125,351
Weaned Hogs	48,020	79,061	51,450	16,906	58,018
Pre-weaned Hogs	5,533	7,786	8,300	1,226	4,209
Other	5,828	8,003	6,245	1,184	4,063
Total Operating Costs	$93,470	$194,470	$109,898	$57,879	$191,643
	Operating Costs, Dollars per Mortality ($/head)				
Cattle and Calves[b]	$8.25	$24.11	$10.63	$9.33	$30.34
Weaned Hogs	$7.00	$11.53	$12.45	$4.09	$14.04
Pre-weaned Hogs	$0.50	$0.70	$2.01	$0.30	$1.02
Other	$7.00	$9.61	$1.51	$0.29	$0.98
	Total (Sector-wide) Fixed Costs for Specialized Facilities ($ 1,000)				
Beef Cattle	N.A.	N.A	N.A	797,985	1,241,310
Dairy Cattle	N.A	N.A	N.A	333,630	518,980
Hogs	N.A	N.A	N.A	158,031	245,826
Other	N.A	N.A	N.A	90,000	140,000
Total Fixed Costs	N.A	N.A	N.A	$1,379,646	$2,146,116

[a]Assuming all dead stock were rendered.

[b]Under existing scenario, renderers are assumed to charge $10/mature cattle and $7/calf.

TABLE 2. US production, consumption, and export of rendered products 2001 & 2002 (adapted from US Census Bureau for Exports, 2003).

Category	2001 ('000 metric tons)	2002 ('000 metric tons)	Percent Change, 02/01
Production			
Inedible Tallow and Greases	3,116.2	3,272.6	5.0
Edible Tallow	836.9	892.7	6.7
Lard	182.9	175.1	-4.2
Total Fats	**4,135.9**	**4,340.4**	**4.9**
Meat Meal and Tankage MBM	2,508.7	2,514.2	0.2
Feather Meal	353.6	362.1	2.4
All Other Inedible Products	1,257.7	1,319.2	4.9
Total Rendered Products	**8,256.0**	**8,535.8**	**3.4**
Consumption			
Inedible Tallow for Feed Formulation	424.4	449.3	5.9
Grease for Feed Formulation	859.6	887.9	3.3
Inedible Tallow and Greases Used for Feed Formulation	**1,284.0**	**1,337.2**	**4.1**
Fatty Acids	**262.0**	**270**[a]	**3**
Soap	**136**[a]	**113.7**[a]	**-16.3**
Total Inedible Fat Used for Feed and Ind.	**1682**	**1720.9**	**2.3**
Edible Tallow For edible use	120.4	111.8	-7.2
Edible Tallow For inedible use	121.3	119.0	-1.9
Edible Tallow	**241.7**	**230.8**	**-4.5**
Lard For edible use	104.5	107.0	2.4
Lard For inedible use	31.5	30.6	-2.7
Lard	**136.0**	**137.1**	**0.8**
Subtotal	***2059.7***[b]	***2,088.8***[b]	***1.4***
Exports			
Inedible Tallow	605.4	779.4	28.8
Yellow Grease	184.3	287.5	56.0
Other Inedible Fats and Oils	190.3	206.7	8.6
Total Inedible Tallow and Grease	**980.0**	**1273.6**	**29.9**
Edible Tallow	165.3	209.3	26.6
Lard	46.8	38.1	-18.9
Total Fats	**1,192.1**	**1,521.0**	**27.6**
Meat and Bone Meal	451.6	564.8	25.1
Feather Meal	42.0	39.0	-7.5
Total Meals	**493.7**	**603.8**	**22.2**
Bone and Bone Products	**36.9**	**24.0**	**-35.0**
Total Exported Rendered Products	***1,722.7***	***2,148.8***	***24.7***

TABLE 3. Meat and bone meal (MBM) exports to Japan by different countries during 2000 and 2001 (Arnold, 2002).

	2000		2001 (9 Months Ending Sept -)	
	Metric Tons	Percent	Metric Tons	Percent
Australia	35,282	19.1	22,661	23.3
New Zealand	34,284	18.5	31,726	32.6
Italy	28,857	15.6	1,797	1.8
Denmark	25,768	13.9	4,554	4.7
Argentina	20,311	11.0	11,712	12.0
Uruguay	17,932	9.7	8,202	8.4
China	15,127	8.2	10,540	10.8
United States	3,489	1.9	3,164	3.2
South Korea	1,533	0.8	995	1.0
Hong Kong	1,144	0.6	765	0.8
Canada	944	0.5	638	0.7
India	108	0.1	85	0.1
Vietnam	105	0.1	-	-
Pakistan	66	0.0	43	0.0
Brazil	0	-	400	0.4
Mongolia	0	-	184	0.2
Total	**184,950**	**100.0**	**97,466**	**100.0**

Appendix G

TABLE 1. Odor threshold concentrations of selected compounds from a rendering plant (Fernando, 1995).

Compound	Chemical Formula	Odor Threshold (ppm by volume)
Acrolein	$CH_2.CH.CHO$	0.21
Butyric Acid	$CH_3CH_2CH_2CO_2H$	0.001
Ammonia	NH_3	46.8
Pyridine	C_5H_5N	0.021
Skatole	C_9H_8NH	0.220
Methyl Amine	CH_3NH_2	0.021
Dimethyl Amine	$(CH_3)_2N$	0.047
Trimethyl Amine	$(CH_3)_3N$	0.00021
Allyl Amine	$CH_2.CH.CH_2NH_2$	28
Ethyl Mercaptan	C_2H_5SH	0.001
Allyl Mercaptan	$CH_2.CH.CH_2SH$	0.016
Hydrogen Sulphide	H_2S	0.0047
Dimethyl Sulphide	CH_3SCH_3	0.0025
Dimethyl Disulphide	CH_3SSCH_3	0.0076
Dibutyl Sulphide	$(C_4H_9)_2S$	0.180