# Emission Factor Documentation for AP-42 Section 9.6.1

# Natural and Processed Cheese

## Final Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group

EPA Contract 68-D2-0159
Work Assignment No. 4-04

MRI Project No. 4604-04

July 1997

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Research Triangle Park, NC  27711

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NOTICE

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## PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment No. 4-04. Mr. Dallas Safriet was the requester of the work.

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# 1. INTRODUCTION

The document *Compilation of Air Pollutant Emission Factors* (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 9.6.1, Natural and Processed Cheese.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the cheese production industry. It includes a characterization of the industry, a description of the different process operations, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details how the new AP-42 section was developed. It includes the review of specific data sets and a description of how candidate emission factors were developed. Section 5 presents the AP-42 Section 9.6.1, Natural and Processed Cheese. Supporting documentation for the emission factor development is presented in the Appendices.

# 2. INDUSTRY DESCRIPTION

This section provides an overview of the U.S. production of natural and processed cheese. It is divided into four subsections: industry characterization (2.1), process description (2.2), emissions (2.3), and emission control technology (2.4). The production of natural and processed cheese, except for cottage cheese, is classified in Standard Industrial Classification (SIC) Code 2022; cottage cheese is classified in SIC Code 2026.

## 2.1 INDUSTRY CHARACTERIZATION[1-3]

Cheese represents the largest percentage of world milk consumption (34 percent), followed by butter (33 percent), liquid milk (27 percent), and powdered milk (6 percent). Approximately one-third of the cow's milk produced in the United States is used to make cheese. Most of the cheese produced in the United States is made from a type of cow's milk, such as cream, whole milk, lowfat milk, and skim milk. However, goat's and sheep's milk may also be used in cheese production.

The total value of shipments for the natural and processed cheese industry (SIC 2022) was $18.2 billion in 1992. This figure has steadily increased since 1977. The total number of industry establishments in the United States in 1995 was 432. The U. S. is one of the largest producers of cheese in the world. In 1995, natural cheese production in the United States, excluding cottage cheeses, totalled 6.9 billion pounds, and processed cheese production totalled 2.3 billion pounds. Wisconsin is the leading producer of cheese in the U. S., accounting for over 30 percent of all cheese production in the country. Table 2-1 presents 1995 production data for types of cheese and cheese products in the United States. Figure 2-1 shows the distribution of cheese manufacturing facilities in the United States (States with fewer than three facilities are not shown).

## 2.2 PROCESS DESCRIPTION[4-9]

The basic concepts behind the production of cheese have changed little over its history. The basic process in which curd is formed from milk either by bacterial fermentation or addition of rennin (or a combination of these) to develop lactic acid, the subsequent removal of whey from the curd, and the further treatment of the curd to produce the many varieties of cheese remains very much the same. Some small factories in the United States still rely on traditional cheesemaking procedures, with much of the work done by individuals. Most large-scale facilities, however, have mechanized the process, relying on sophisticated equipment and automated processes.

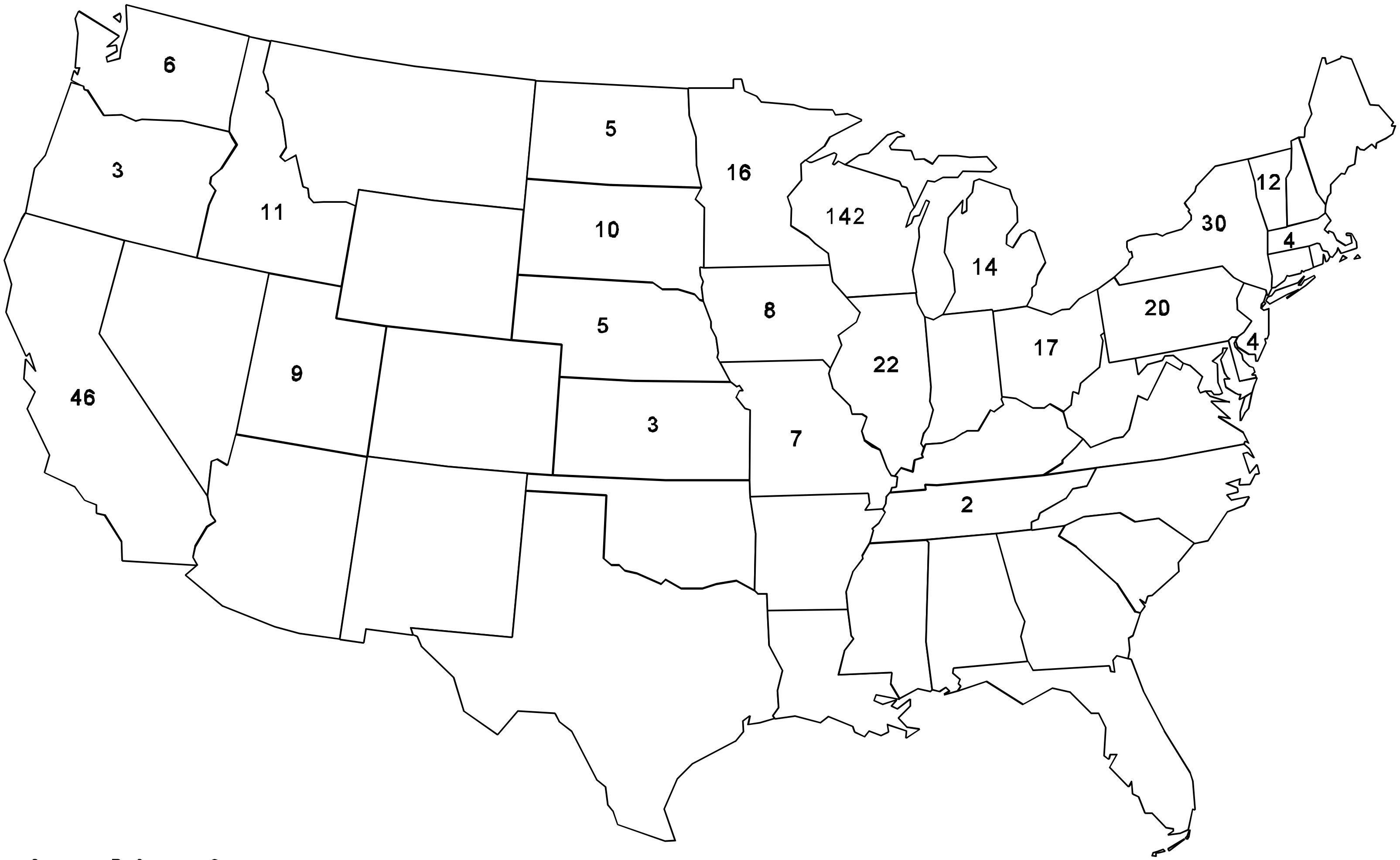
The modern manufacture of natural cheese consists of four basic steps: coagulating, draining, salting, and ripening. Processed cheese manufacture incorporates extra steps, including cleaning, blending, and melting. Dairy products, such as milk or butter, may also be added to the processed cheese especially if it is intended for spreading. No two cheese varieties are produced by the same method. However, manufacturing different varieties of cheese does not require widely different procedures but rather slight variations in one or more steps, a change in the order of the process steps, special applications, and/or different ripening practices. The character of a particular variety of cheese is influenced by moisture content, the types of microorganisms added, the temperatures and acidities of the production processes, the ripening conditions, and the percentage of fat in the milk used to make the cheese. Table 2-2 provides descriptions of several types of natural cheeses. Table 2-3 details variations in the cheesemaking process characteristic of particular cheese varieties. The process described in this section is a generic description; steps specific to a single cheese variety are mentioned but are not discussed in detail.

TABLE 2-1. PRODUCTION OF CHEESE AND CHEESE PRODUCTS IN THE UNITED STATES

| Type of cheese | No. of plants | Production (1,000 pounds) |
|---|---|---|
| Cheddar | 207 | 2,425,042 |
| Other American[1] | 14 | 703,526 |
| Part skim | 8 | 24,008 |
| Swiss | 44 | 221,713 |
| Muenster | 46 | 109,129 |
| Brick | 23 | 10,426 |
| Limburger | 1 | 868 |
| Blue[2] | 12 | 36,593 |
| Cream and Neufchatel | 33 | 602,219 |
| Mozzarella | 132 | 2,094,908 |
| Other Italian | 97 | 547,116 |
| Other types | 109 | 164,691 |
| Total natural cheese | 432 | 6,940,239 |
| Processed cheese | 35 | 1,472,213 |
| Processed cheese foods and spreads | 30 | 831,636 |
| Cold pack cheese and cheese foods | 20 | 35,699 |
| Total processed cheese | 57 | 2,339,548 |

[1]Includes Colby, Monterey, and Jack.
[2]Includes Gorgonzola.

Source: Reference 2




Source: Reference 2.

Figure 2-1. Locations of cheese manufacturing facilities in the United States.

TABLE 2-2. CHARACTERISTICS OF SEVERAL TYPES OF NATURAL CHEESES

| Processing | Characteristics | Typical varieties |
|---|---|---|
| Curd particles kept matted together | Close texture; firm body | Cheddar |
| Curd particles kept separate | More open texture | Colby, Monterey |
| Bacteria-ripened throughout interior with eye formation | Gas holes or eyes throughout the cheese | Swiss, Gouda, Samsoe, Edam |
| Prolonged curing period | Granular texture; brittle body | Parmesan, Romano |
| Pasta filata | Plastic curd; threadlike or flaky | Provolone, Mozzarella |
| Mold-ripened throughout interior | Visible grains of mold; piquant, spicy flavor | Blue, Roquefort, Stilton, Gorgonzola |
| Surface ripened primarily by bacteria and yeasts | Surface growth; soft, smooth, waxy body; mild to robust flavor | Brick, Limburger |
| Surface ripened primarily by mold | Edible crust; soft, creamy interior; pungent flavor | Camembert, Brie |
| Curd coagulated primarily by acid | Delicate, soft curd | Cream, Neufchatel, Cottage |
| Protein of whey or whey and milk coagulated by acid and heat | Sweetish cooked flavor of whey | Ricotta, Gjetost |

Source: Reference 6

TABLE 2-3. DIFFERENCES IN SELECTED CHEESEMAKING STEPS

| Type of cheese | Primary coagulating agent/time | Cooking temp., °C (°F) | Primary draining method | pH | Salting, % | Pressing | Ripening period |
|---|---|---|---|---|---|---|---|
| Blue | Rennin (30 min) | 33.3 (92) | Vat drain | 5.4 | Dry (5.0) | In molds, no surface weights | 60 days minimum; 3-4 mos usually; 9 mos for more flavor |
| Brick | Rennin (25 min) | 35.6 (96) | Vat drain | 5.4 | Brine (1.5) | In molds, surface weights | 4-8 weeks |
| Camembert | Rennin (45 min) | 32.2 (90) | Dip | 5.1 | Dry (1.5) | In molds, no surface weights | 4-5 weeks |
| Cheddar | Rennin (25 min) | 37.8 (100) | Vat drain | 5.2 | Dry (1.5) | Horizontal hydraulic press | 60 days minimum; 3 to 6 mos usually; 12 or longer for sharp flavor |
| Cottage | Acid (5 hr) | 48.9 (120) | Vat drain | 4.6 | Dry (1.0) | Vat packing | Unripened |
| Cream | Acid (5 hr) | 57.2 (135) | Hoop | 4.6 | Dry (1.0) | Bag packing | Unripened |
| Mozzarella | Rennin (30 min) | 32.2 (90) | Vat drain | 5.3 | Brine (0.7) | Bag packing | Unripened to 2 months |
| Provolone | Rennin (20 min) | 47.8 (118) | Vat drain | 5.3 | Brine (1.5) | Vat packing | 6-14 months |
| Ricotta | Acid (30 min) | 80.0 (176) | Hoop | 5.9 | Dry (0.5) | Can packing | Unripened |
| Romano | Rennin (20 min) | 46.7 (116) | Dip | 5.3 | Dry (5.0) | In molds, surface weights | 5 mos min.; 12 mos for grating |
| Swiss | Rennin (30 min) | 53.3 (128) | Dip | 6.2 | Brine (1.6) | Vertical hydraulic press | 2 mos min.; 2-9 mos usually |

Popular types of natural cheeses include unripened (e.g., cottage cheese, cream cheese), soft (e.g., Brie, Camembert), semi-hard (e.g., Brick, Muenster), hard (e.g., Colby, Cheddar), blue veined (e.g., Blue, Gorgonzola), cooked hard cheeses (e.g., Swiss, Parmesan), and pasta filata (stretched curd, e.g., Mozzarella, Provolone). Examples of processed cheeses include American cheese and various cheese spreads, which are made by blending two or more varieties of cheese or blending portions of the same type of cheese that are at different stages of ripeness.

### 2.2.1 Natural Cheese Manufacture

The following sections describe the steps in the manufacture of natural cheese. Figure 2-2 presents a general process diagram.

2.2.1.1 Milk Preparation. Cheese can be made from cow, ewe, goat, or buffalo milk. Table 2-4 shows the varieties of milk used to produce different types of cheese. Cow's milk is the most widely used milk in cheese processing. Cheese can be made from almost any form of milk, including whole milk, skim milk, buttermilk, or cream. In the past, raw milk was used almost exclusively in cheesemaking; however, a focus on public safety has forced manufacturers to use heat-treated or pasteurized milk.

The milk is stored in silo tanks at the cheesemaking plant. These tanks are insulated or cooled to keep the milk at the optimum storage temperature. In the tanks, the milk is agitated by a mechanical rotary blade from top to bottom to prevent cream formation. After storage, the milk is homogenized to ensure a constant fat level. A standardizing centrifuge, which skims off the surplus fat as cream through a control valve, is often used to obtain the fat levels appropriate for different varieties of cheese.

Homogenized milk is used in soft cheeses such as Brie, Camembert, and cream. This type of milk results in less moisture and fat loss during ripening and increased surface area of the fat globules; this increase accelerates hydrolysis of milkfat by mold enzymes. For other cheeses, milk is filtered or clarified to remove suspended matter. In Swiss cheese, clarified milk improves the size and uniformity of eye formation; in Cheddar cheese, clarification improves the texture and firmness of the cheese.

Following homogenization, the milk is ready for heat treatment (pasteurization), which is necessary to destroy harmful microorganisms and bacteria. Small volume factories are equipped with open and/or closed vats, presses, and a hot water or steam boiler for heat treatment. Large-scale factories rely on enclosed heat exchangers, which may be the tubular or multi-plate type. All equipment and systems involved in milk pasteurization are connected so that outside air does not come in contact with the milk being processed. Any disease-bearing bacteria present in the milk are destroyed by pasteurization, and the milk is ready for coagulation.

2.2.1.2 Coagulation. Coagulation, or clotting of the milk, is the basis of cheese production. Coagulation is brought about by physical and chemical modifications to the constituents of milk and leads to the separation of the solid part of milk (the curd) from the liquid part (the whey).

Coagulation is the physicochemical change of the casein (protein) in milk, due to the action of lactic acid and/or enzymes, into a protein network called a coagulum or gel. To initiate coagulation, milk is mixed with a starter, which is a culture of harmless, active bacteria that will impart certain characteristics and qualities to the cheese. The starter sours the milk by fermenting the lactose (milk sugar) to lactic acid, which creates the acid conditions necessary for a special enzyme, rennin, to act. Lactic acid causes the formation of calcium lactate and the conversion of the calcium caseinate in the milk to casein.

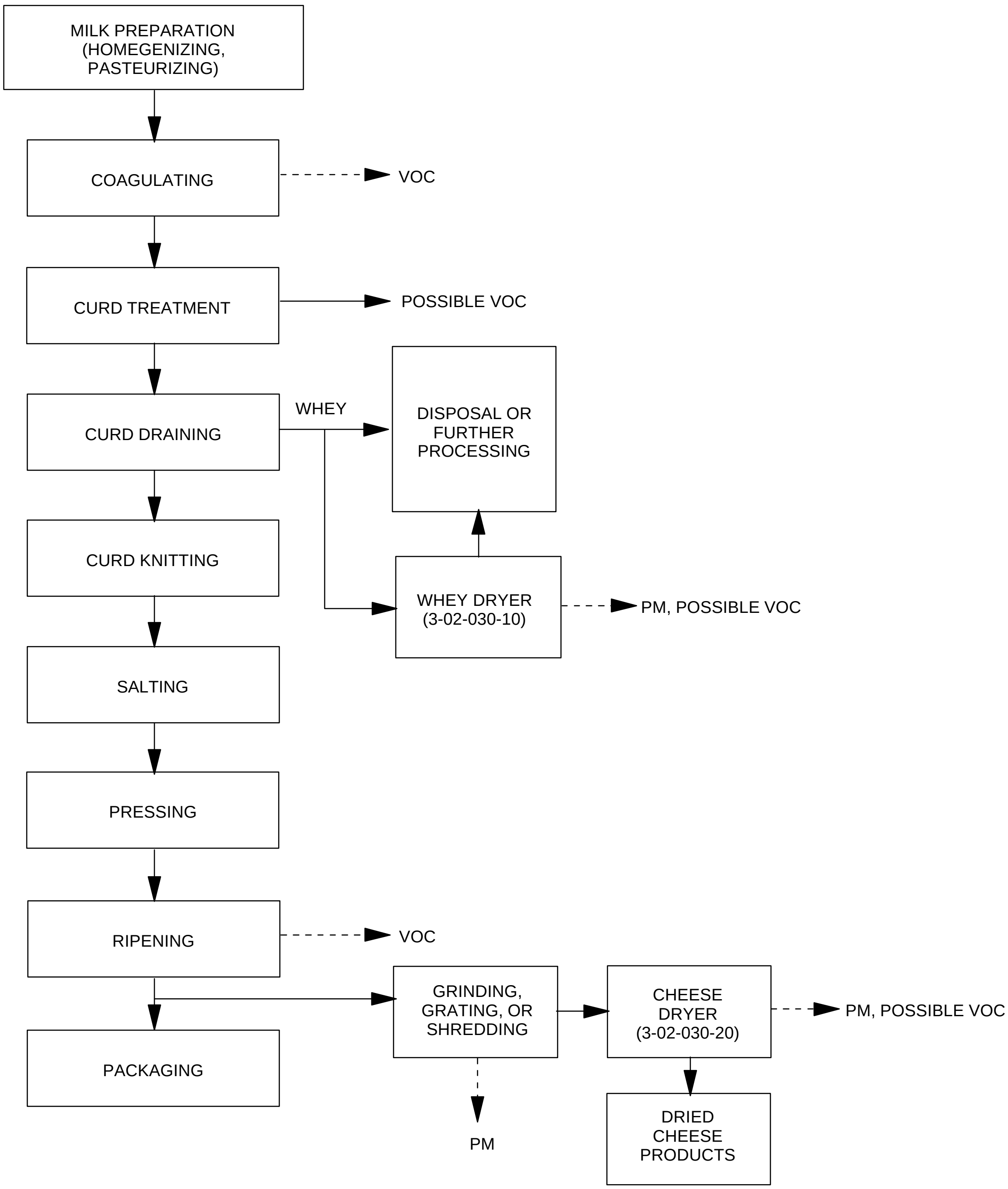



Figure 2-2. Natural cheese manufacture.

TABLE 2-4. TYPES OF MILK USED TO PRODUCE DIFFERENT VARIETIES OF CHEESE

| Cheese type | Cow's milk, whole | Cow's milk, lowfat | Cow's milk, skim | Goat's milk | Sheep's milk | Cream |
|---|---|---|---|---|---|---|
| Blue | X | | | X | | |
| Brick | X | | | | | |
| Camembert | X | | | | | |
| Cheddar | X | | | | | |
| Colby | X | | | | | |
| Cottage | | | X | | | X |
| Cream | X | | | | | X |
| Edam | | | X | | | |
| Feta | X | | | X | X | |
| Gouda | | X | | | | |
| Limburger | X | X | | | | |
| Monterey Jack | X | X | X | | | |
| Mozzarella | X | X | | | | |
| Muenster | X | | | | | |
| Neufchatel | X | X | | | | X |
| Parmesan | | X | | | | |
| Provolone | X | | | | | |
| Ricotta | X | X | X | | | |
| Romano | | X | | X | | |
| Roquefort | | | | | X | |
| Stilton | X | | | | | X |
| Swiss | | X | | | | |

Source: Reference 9.

During coagulation, whey droplets appear on the surface of the coagulum and grow into a liquid envelope; the curd is in a gel-like form. The coagulum decreases in volume as it expels water and solid constituents. Most of the fat and protein from the milk are retained in the curd, but nearly all of the lactose and some of the minerals, protein, and vitamins escape into the whey. Coagulation takes place in large pans, vats, or tanks, depending on the size of the cheesemaking facility.

Temperature and coagulation time vary and influence properties of the coagulum, such as cohesion. The temperature for milk coagulation is carefully controlled, varies with the type of cheese being made, and, for most kinds of cheeses, is between 22°C (72°F) and 35°C (95°F). Curd produced primarily by acid coagulation results in the delicate, soft curd in cottage and cream cheeses. Table 2-3 provides the primary coagulating agents and the coagulating times necessary for different varieties of cheese.

2.2.1.3 Curd Treatment. After formation in the coagulating vats, the curd is cut into small pieces. Cutting the curd speeds expulsion of the whey and contributes to a uniform cook-through of the curd by increasing the surface area. The cutting occurs in the process vessel and is accomplished by hand or by using mechanical cutting devices. The curd particles are cut into various sizes depending on the variety of cheese being made. For example, cutting the curd into small cubes reduces the moisture content of the curd, whereas creating larger cubes causes the curd to retain more moisture.

Following the cutting step, the curd is heated, or cooked, which contracts the curd particles to remove whey, develop texture, and establish moisture control. Cooking involves exposing the cut curds and whey to heat for specific time periods while agitating the product. Cooking may take place by different methods, including the use of direct steam, jacketed water, and radio-frequency. Cooking temperatures may vary depending on the variety of cheese being produced, from 32°C (90°F) for Mozzarella cheese (a high-moisture cheese) to 53°C (128°F) for Swiss cheese (a low-moisture cheese). For some high-moisture cheeses (for example, Colby and Monterey), the curds are washed with cool water to increase the moisture content of the curd. Table 2-3 provides the cooking temperatures required to produce typical varieties of cheeses.

2.2.1.4 Curd Drainage. The next step in cheese manufacture, drainage, involves separating the whey from the curd. Drainage reduces the curd to a definite water content and controls the demineralization (migration of calcium into the whey) and the removal of lactose from the curd. The process can be accelerated by either heat treatment or mechanical treatment, such as cutting, stirring, oscillating, or pressing.

In large-scale facilities, the draining system typically consists of a long rectangular tank with a moveable screen belt as a base. One end of the tank has a liquid-tight, but moveable door. The curd/whey mixture travels along a conveyor from the curd vat into the tank. The whey drains through the base screen, leaving the curd level and dry. After the curd is dry, it moves through the open end of the tank and is cut into blocks. These blocks can then be filled into cheese hoops for further draining and pressing.

Other types of draining methods include vat drainage, hoop drainage, and dipping. During vat drainage, cubes of curd are left immersed in the whey and agitated to prevent them from sticking together; the whey is later decanted and hoop drainage sometimes follows. For hoop drainage, a mass of curd is put into cloth-lined cylindrical metal hoops. The whey separates from the curd by draining through the cloth. This process is usually accompanied by lateral pressing. The dipping method involves ladling the curds out of the vat into perforated molds. The whey is slowly drained off through the activity of lactic acid bacteria within the cheese and the turning of the molds. Table 2-3 gives the primary draining methods for a variety of cheeses.

For some cheeses, special applications and procedures occur immediately before, during, or after the draining stage. For example, internally ripened, or blue-veined, cheeses (e. g., Blue, Roquefort) are usually seeded with penicillium powder prior to drainage. Cooked hard cheeses (e. g., Parmesan) are stirred and warmed to accelerate and complete the separation of the whey. Flavorings can also be added to cheeses during the drainage stage.

The separated whey may be treated and disposed of; shipped offsite in liquid or concentrated form for use as animal feed; used to make whey cheese; dried for lactose, mineral, or protein recovery; or dried for use as a food additive or in the manufacture of processed cheese. Fluid cheese whey is very rich nutritionally, retaining many of the nutrients of the milk used in the cheese manufacture. In the manufacture of whey cheese, the whey is strained, heated, and stirred; milk is added to facilitate formation of the curd; and stirring is stopped when a thick layer of curd forms on the surface. Heating is stopped when the curd layer breaks, and the curd layer is removed and drained. When drained sufficiently, the solid cheese is soft and has a short shelf life. The whey cheese may also be salted and dried.

2.2.1.5 Curd Knitting. Knitting, or transforming, the curd allows the accumulating lactic acid to chemically change the curd; knitting also includes salting and pressing. This step leads to the characteristic texture of different varieties of cheese and, therefore, varies according to the particular variety. During the curd knitting stage, Cheddar cheese is "cheddared"; Brick and Blue cheeses undergo preliminary packaging; Provolone and Mozzarella cheeses are pulled and processed (these cheeses are then kneaded, drawn, shaped, and smoothed); a bean gum or some other type of gum is added to cream cheese to stabilize and stiffen it; and a creaming agent (cream and/or milk) is added to cottage cheese. During this period, specific pH levels are controlled to produce different varieties of cheese (see Table 2-3).

After knitting, the cheese is salted. This step consists of manually or mechanically spreading coarse salt over the curd surfaces or immersing the pressed cheese in a salt solution or brine. In some instances, the cheese is loaded on racks that are lowered into brine tanks. Large tanks may circulate the brine throughout the tank to speed up the process.

Salting further completes the drainage of the cheese by helping remove residual water. It also affects rind formation, growth of microorganisms, and enzyme activity. Salting the cheese improves its flavor, texture, and appearance. When the salting process is finished, the salt is concentrated in the surface layers of the cheese but continues to migrate into the cheese over time, creating a concentration gradient. The salt content of most varieties of cheese varies from about one percent in cottage and cream cheeses to about five percent in Parmesan and Blue cheeses. Table 2-3 provides the salting method and salt percentage necessary to produce a particular variety of cheese.

The next step, pressing, determines the characteristic shape of the cheese by compacting the texture, extruding free whey from the curds, and completing the curd knitting. Pressing involves confining the wet, warm curds in a constricted wooden or metal form or cloth bag. Depending on the type of cheese, external weights (often hydraulic pressure plates) are used, or the curd is allowed to rest on itself in a vat for a fixed period of time. With some cheeses, vertical pressing is used; others require vacuum pressing to remove occluded air and give a close-knit body. Multi-row, tunnel automated presses have become common in large facilities. See Table 2-3 for the different pressing practices for various cheeses.

2.2.1.6 Ripening. During the ripening or curing stage, the varieties of cheeses acquire their own unique textures, aromas, appearances, and tastes through physical and chemical changes that occur in the body and rind. The cheese is populated by microorganisms and is transformed by the action of enzymes originally present in the curd or produced by bacterial synthesis. The complex biochemical reactions are controlled as much as possible by adjusting temperature, humidity, and duration of ripening. Unripened cheeses include cottage and cream cheeses and are generally ready for consumption after the curd has been collected. Because they are not ripened, they usually have a bland flavor and soft body.

Some cheeses require the application of a special ripening agent to create a particular taste or texture. For example, some cheeses rely wholly on surface bacteria and yeast applied to their exteriors for curing and ripening; these cheeses are called "surface-ripening" cheeses and include Brick, Brie, Camembert, Limburger, and Muenster. Others require injection of particular bacteria and molds (e. g., Blue) or gas-forming microorganisms (e. g., Swiss).

For those cheeses ripened primarily by surface bacteria, cheese makers massage the surface of a freshly salted cheese block to uniformly spread the desirable bacteria. In a mechanized process, the bacteria are smeared onto the surface of the cheese block with a cheese brushing machine. The bacteria break down part of the cheese protein during ripening, resulting in the characteristic flavor and aroma of Brick and Muenster cheeses.

For those cheeses ripened primarily by mold, mold spores are injected into the cheese after draining (e. g., Blue cheese) or smeared in a manner similar to those ripened by bacteria (e. g., Brie cheese). For those that are injected, air passages are bored into the cheese to encourage the growth of the mold. This process results in the crumbly texture and characteristic flavor of Blue and Roquefort cheeses.

Three types of rooms are used in succession for ripening cheeses: the drying room; the cellars or other premises for preripening or ripening; and the cold room for storage. Each room is thermally insulated and maintained at a constant temperature and humidity by an air conditioning system. After salting, the cheeses are placed in the drying room at 10° to 14°C (50° to 57°F) and 60 to 80 percent relative humidity. Excess water that appears on the surface of the cheese is quickly removed by the cool air. The cheeses are kept in this environment for several hours to several days. Preripening is sometimes carried out for soft cheeses at a slightly higher temperature and lower humidity than the end stages of ripening, but most of the time, ripening is carried out under constant conditions. It is important to maintain the ripening room at the atmospheric conditions and temperatures appropriate for the desired variety of cheese, since the ripening process has a major influence on the texture and taste of a cheese. Some ripening rooms are also equipped to function as cold storage rooms. In these, the unwrapped cheeses are kept at a very low temperature and high humidity to prevent them from drying out. For short term storage before shipment, it is more practical to have a specialized cold storage room that keeps wrapped cheeses at 1° to 5°C (34° to 51°F) without the need to maintain a high humidity, because maintaining a high humidity consumes a great deal of energy. Maintaining a controlled humidity and temperature is important, and most manufacturers have ripening rooms in which the temperature and humidity are automatically controlled with regulated ventilation. In facilities where large amounts of cheese are conveyed to and from storage, racks or grids on wheels are commonly used, which allow the cheese to be automatically turned.

It is during the ripening stage that the rind or crust forms on the cheese's surface. The rind first appears as an outer layer of curd that is denser and less moist than the rest of the curd. The rind controls the loss of moisture from the internal part of the cheese and regulates the escape of gases released during ripening.

Conditions during ripening vary for different cheeses. For example, soft cheeses are usually ripened 12 to 30 days at 10° to 14°C (50° to 57°F) and 90 to 95 percent humidity, while Cheddar cheeses can be ripened from 3 months to a year at 5° to 12°C (41° to 54)°F) and 87 to 95 percent humidity. Cheeses ripened by internal mold (blue-veined cheeses) usually require 15 to 60 days at 4° to 12°C (39° to 54°F) and

85 to 95 percent humidity. Changes in composition during ripening include lactose fermentation and degradation of lactic acid, hydrolysis of fats and conversion of fatty acids, and degradation of proteins and conversion of amino acids. See Table 2-3 for a list of the curing and ripening conditions for different cheeses.

2.2.1.7 Preserving and Packaging. Modern cheese packaging protects the food from microorganisms and saves on waste and moisture loss. Ripened cheeses must undergo special procedures during packaging for preservative reasons. Unripened cheeses (cottage and cream cheeses) are packaged immediately after the curd is collected. These cheeses are packaged by automatic machines in moisture-proof containers. Because these cheese are highly perishable, they must be immediately refrigerated.

Many ripened cheeses are coated in wax to protect them from mold contamination and to reduce the rate of moisture loss. Cheeses that naturally develop a thick, tightly woven rind, such as Swiss, do not require waxing. Before waxing, the cheese is dried on the cheese shelves at 10° to 16°C (50° to 60°F) at a relative humidity of 65 to 70 percent for 3 days and is turned daily. The waxing process takes place in a steam pressure, electric-heated wax tank into which a paraffin wax block is placed. The wax is heated and the cheese is then submerged in the wax for 5 to 6 seconds and allowed to dry for 1 minute. After the wax has cooled and solidified, it is rinsed with warm water to enhance surface luster. If necessary, the cheese may be rewaxed within a few days. The cheese is then ready for commercial packaging.

A second method of ripened cheese packaging involves applying laminated cellophane films to unwaxed cheese surfaces. The most common packaging film consists of two laminated cellophane sheets and a brown paper overlay necessary for shipping. A variation includes a metal foil wrap. During packaging, a mechanical lifter applies a sheet of film to a block of cheese traveling along a conveyor. The block then reaches an evacuator area where the air between the cheese and the film is removed, resulting in an air-tight seal. A similar process is used to vacuum-pack rindless cheese. This procedure involves wrapping the cheese in a film, subjecting it to a partial vacuum, and exposing the product to high heat (approximately 77°C [171°F]) which shrinks the film to tightly conform to the cheese.

2.2.2 Processed Cheese Manufacture

Nearly one-third of all cheese produced in the United States consists of processed cheese and processed cheese products. There are many different types of final products in processed cheese manufacture. These cheeses are distinguished from one another not only by their composition (cheese used, texture, additives, etc.) but by their presentation as individual portions, individual slices, rectangular blocks, or special presentation as cylinders or tubes.

Processed cheese was developed around the end of the 19th century when several European countries wanted to export cheeses to hot-climate countries but had problems keeping the product cool throughout manufacture and distribution. Soft cheese could simply be put into cans and heat treated to effectively pasteurize the cheese, but this process did not work for hard cheeses. To produce processed cheese from hard cheese, the rind must be removed and the cheese warmed to about 80°C (176°F) and stirred with sodium citrate or sodium polyphosphates to form a mixture, which can be packaged while hot and cooled to form a gel.

Processed cheese is made by pasteurizing, emulsifying, and blending natural cheeses only; it contains no other ingredients. Processed cheese foods, spreads, and cold pack cheeses, however, contain additional ingredients, such as nonfat milk solids and condiments. Several varieties of natural cheeses may be mixed (emulsifying salts are always added to this mixture) and powdered milk, whey, cream or butter, and water may be added. The mixture is then heated and stirred to evenly distribute the ingredients and create a homogenous mixture. The following section describes the basic steps necessary for producing pasteurized process cheese, the most common processed cheese.

2.2.2.1 Pasteurized Process Cheese. Cheeses are selected to be processed from both mild and sharp cheeses by choosing those whose flavor and texture will readily blend to produce a uniform product. For example, American cheese is made from Cheddar and Colby cheeses. Once selected, the cheeses must be analyzed for their fat and moisture contents to determine the proper amount of emulsifiers and salts to be added.

Cheese surfaces are cleaned by scraping and trimming, and the rinds are removed. After cleaning, the cheese blocks are ground. The cheese mixture then passes through continuous cookers, where the mixture is heated to 130° to 145°C (266° to 293°F) for 2 to 3 minutes. The temperature and time are closely monitored to avoid browning and thickening of the product. The melted cheese separates into a fat and serum and emulsifiers are added to disperse the fat. The cheese mass becomes uniform, homogeneous, and smooth in texture.

The molten cheese is removed quickly from the cookers and is pumped or dropped into packaging hoppers. The cheese is packaged in the absence of oxygen to inhibit the growth of mold. The cheese is usually wrapped in lacquered aluminum foil or in aluminum foil-lined cardboard or plastic boxes. For sliced processed cheese, the molten cheese is spread uniformly by chilled steel rollers and cut by rotary knives to consumer size.

2.2.2.2 Processed Cheese Foods. Other processed cheese products are manufactured using procedures similar to that for pasteurized process cheese. For example, to produce pasteurized process cheese food, one or more of the following optional dairy ingredients are added: cream, milk, skim milk, buttermilk, and/or cheese whey. The result is a processed cheese food that is higher in moisture and lower in fat than pasteurized process cheese. After heating, processed cheese intended for spreading undergoes a creaming step. This step includes mechanical kneading of the hot cheese and addition of various dairy products, such as milk, which promotes creaming, and whey, which reduces the viscosity of the mixture. An edible stabilizer and gums or gelatins are also added to give the food a spreading quality. Other processed cheese products include cold-packed cheese, cold-packed cheese food, and reduced fat cheeses. Processed cheeses may be enhanced with salt, artificial colorings, spices or flavorings, fruits, vegetables, and meats.

Grated and powdered cheeses are produced by removing the moisture from one or more varieties of cheeses and grinding, grating, or shredding the cheese(s). Mold-inhibiting ingredients and anticaking agents may be added as well. For example, a Cheddar cheese powder may contain aged Cheddar cheese, sodium phosphate, salt, lactic acid, and color, and have a moisture content of 3 to 4 percent. A grated cheese usually has 14 to 18 percent moisture. Dehydration takes such forms as tray drying, spray or atomized drying, and freeze drying. Popular types of grated cheese include Parmesan, Romano, Mozzarella, and Cheddar. Cheese powders, such as those made from Cheddar cheese, may be used to flavor pasta, or added to bread dough, potato chips, or dips.

## 2.3 EMISSIONS

Particulate emissions from cheese manufacture occur during cheese drying and whey drying, and may occur when cheese is grated or ground before drying. Cheese dryers are used in the manufacture of grated or powdered cheeses. Whey dryers are used in some facilities to dry the whey after it has been separated from the curd following coagulation. Emissions of $CO_2$ occur during drying, but may be primarily due to fuel combustion, especially if the dryer is direct-fired. VOC emissions may occur during the coagulation and/or ripening stages.

## 2.4 EMISSION CONTROL TECHNOLOGY

Particulate emissions from cheese and whey dryers are controlled by wet scrubbers or fabric filters. Cyclones are also used to control particulate emissions and for product recovery.

## REFERENCES FOR SECTION 2


1. *1992 Census of Manufactures: Dairy Products*, U.S. Department of Commerce, Bureau of Census, Washington, DC, 1994.

2. U. S. Department of Agriculture, National Agriculture Statistics Service, *Dairy Products 1995 Summary*, Washington, DC, April 1996. http://usda.mannlib.cornell.edu/reports

3. B. Battistotti, et al., *Cheese: A Guide to the World of Cheese and Cheesemaking*, Facts On File Publications, NY, 1984.

4. A. Eck, ed., *Cheesemaking: Science and Technology*, Lavoisier Publishing, New York, 1987.

5. A. Meyer, *Processed Cheese Manufacture*, Food Trade Press Ltd., London, 1973.

6. *Newer Knowledge of Cheese and Other Cheese Products*, National Dairy Council, Rosemont, IL, 1992.

7. M.E. Schwartz, *Cheesemaking Technology*, Noyes Data Corporation, Park Ridge, NJ, 1973.

8. F. Kosikowski, *Cheese and Fermented Milk Foods*, Edwards Brothers, Ann Arbor, MI, 1977.

9. New Standard Encyclopedia, Vol.4, "Cheese," Standard Educational Corporation, Chicago, IL, pp. 238-240.

# 3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

## 3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The Factor Information and Retrieval (FIRE), Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched for identification of the potential pollutants emitted and emission factors for those pollutants.

Information on the industry, including number of plants, plant location, and annual production capacities, was obtained from the *Census of Manufactures* and the USDA's *Dairy Products 1995 Summary*. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants. A number of sources of information were investigated specifically for emission test reports and data. The Source Test Information Retrieval System (STIRS) data base was searched for test reports from cheese manufacturing facilities. The EPA library was searched for additional test reports. Using information obtained on plant locations, State and Regional offices were contacted about the availability of test reports. In addition, representative trade associations, including the American Cheese Society, were contacted for assistance in obtaining information about the industry and emissions.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e. g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

## 3.2 DATA QUALITY RATING SYSTEM[1]

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A—Multiple test runs that were performed using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B—Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C—Tests that were based on an unproven or new methodology or that lacked a significant amount of background information.

D—Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

## 3.3 EMISSION FACTOR QUALITY RATING SYSTEM[1]

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed from A- and B-rated source test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A- or B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B- and/or C-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A-, B-, and/or C-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Section 4.

## REFERENCE FOR SECTION 3


1. *Procedures for Preparing Emission Factor Documents*, EPA-454/B-93-050, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1995.

# 4. REVIEW OF SPECIFIC DATA SETS

This section describes how the AP-42 section on natural and processed cheese was developed. First, descriptions of data sets that were reviewed for this report are presented, followed by a discussion of how candidate emission factors were developed from the data.

## 4.1 REVIEW OF SPECIFIC DATA SETS

Seven emission test reports containing data on particulate emissions from cheese and whey drying were reviewed. Emission factors were developed from all seven documents. A review of the references is provided in the following paragraphs.

### 4.1.1 Reference 1

This report documents a March 30, 1993, particulate emissions test conducted on a Parmesan cheese dryer controlled by a scrubber. The dryer is direct-fired with natural gas and has a rated capacity of 6,250 pounds of dry product per hour. Testing was performed at the both inlet and outlet of the scrubber. Particulate emissions were quantified using Method 5 and included measurements of both filterable and condensible PM (organic and inorganic). Orsat analysis was used to measure $CO_2$ emissions. Three test runs were performed at the control device inlet and outlet. Each run lasted 1 hour and no problems were reported. No details about the process were given and an average production rate during testing was reported. These data are rated B, except for the condensible inorganic PM (CIPM) data from the scrubber outlet testing. These data are not rated because they were higher than the CIPM data from the inlet testing. Therefore, the CIPM test data from the scrubber outlet were not used to develop emission factors.

### 4.1.2 Reference 2

This report documents a particulate emissions test conducted December 28, 1988, on a Cheddar cheese dryer controlled by a venturi scrubber. The dryer is direct-fired with natural gas. Particulate emissions were measured using Method 5 and included measurements of filterable, condensible inorganic, and condensible organic PM. Orsat analysis was used to measure $CO_2$ emissions. Three 1-hour test runs were conducted at the outlet of the control device, and no problems were reported during the test. No details on the process were given and an average production rate during testing was reported. These data are rated B.

### 4.1.3 Reference 3

This report documents a particulate emissions test on a Cheddar cheese dryer conducted on March 29, 1990. The dryer tested is a spray dryer direct-fired with natural gas. It is controlled by a venturi scrubber. Three one-hour runs were conducted using Method 5. Filterable, condensible inorganic, and condensible organic PM were measured, and no problems were reported during testing. Orsat analysis was used to measure $CO_2$ emissions. No details about the process were given. These data are rated B.

### 4.1.4 Reference 4

This report documents a particulate emissions test on a whey dryer. The whey is dried in two stages. First, the whey concentrate is sprayed under pressure into the primary dryer; then, the partially dehydrated powder passes to a secondary dryer for final drying. The emission source tested was the primary dryer, which is fired with natural gas. The production rate during the test averaged 5,549 pounds of dry product per hour.

Emissions from the dryer are controlled by two cyclones; no information was given on the types of cyclones or their operating parameters. Testing was stopped after two runs, when emissions did not look normal to plant personnel. It was discovered that a cyclone was plugged. Three more one-hour runs were then conducted, using Method 5 to measure filterable and condensible PM; runs 3-5 are reported in this document and were used to develop emission factors. Orsat analysis was used to measure $CO_2$ emissions. These data are rated B.

4.1.5 Reference 5

This report documents particulate emissions testing on a whey drying and bagging process on March 29, 1988. The dryer has a rated capacity of 2,500 pounds of dry product per hour (5,000 pounds per hour at 50 percent moisture) and is direct-fired with natural gas. The drying system emissions are controlled by a venturi scrubber followed by a cyclone. Emissions from the bagging operation are controlled by a baghouse, with emissions from the baghouse vented back to the main exhaust duct, just before the venturi scrubber. There are also four product recovery cyclones, but emissions from these cyclones are kept within the dryer system. Method 5 was used to measure filterable, condensible organic, and condensible inorganic PM emissions; three 1-hour runs were conducted. Orsat analysis was used to measure $CO_2$ emissions. No problems were reported during the test. These data are rated A.

This source test present results froma combination of two operations which cannot be separated into dryer emissions and bagger emissions. All other cited whey dryer test results are only for dryer emissions; therefore, the results of this test are cited in Table 4-1 but are not used for emission factor development.

4.1.6 Reference 6

This report documents particulate emissions testing conducted on a whey dryer on November 8, 1988. The dryer is direct-fired with natural gas and has a rated output capacity of 4,000 pounds per hour. Particulate emissions from the dryer are controlled by a fabric filter system. Method 5 was used to measure filterable, condensible organic, and condensible inorganic PM emissions; only two 100-minute runs were performed (the sampling time was increased because of poor flow distribution). Orsat analysis was used to measure $CO_2$ emissions. No details about the process were given. These data are rated B.

4.1.7 Reference 7

This report documents particulate testing on a whey dryer on April 20, 1989. The whey slurry is sprayed into the drying chamber of the dryer and falls onto a moving belt where additional drying and cooling take place. Emissions are controlled by a series of cyclones, followed by a wet scrubber. The dryer has a normal production rate of 22,000 to 27,000 pounds per hour at 50 to 54 percent solid whey concentrate. Measurements of condensible and filterable PM emissions were made using Method 5. Emissions of $CO_2$ were measured using Orsat analysis. Three 72-minute runs were performed. During Run 3, there were problems maintaining the spray pattern in the dryer and plugging in the dry powder receiver, but these events do not appear to have influenced the test results. The average production rate during testing was reported. These data are rated B. The condensible organic PM data are not rated because the tare weight of the particulate was less than the measured blank weight; a value of zero was used for that data.

## 4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

Table 4-1 summarizes the emission data used to develop emission factors for cheese and whey drying during natural and processed cheese manufacturing. The emission factors for natural and processed cheese manufacture are presented in Table 4-2. The following paragraphs describe how the data presented in Table 4-1 were used to develop emission factors for the AP-42 section on natural and processed cheese.

### 4.2.1 General Procedures

The data sets were screened and evaluated, and the candidate emission factors were rated according to the criteria presented in Sections 3.2 and 3.3 of this report. The candidate emission factors generally were developed by grouping the data from similar combinations of source and control device, discarding inferior data sets, and averaging the emission factor derived from each data set. Factors for particulate emissions from cheese dryers and whey dryers are presented in kg/Mg and lb/ton.

### 4.2.2 Cheese Dryers

Because there were only three tests for cheese dryers, the data were combined and emission factors for filterable PM, condensible organic PM, and condensible inorganic PM were developed for dryers controlled by a wet scrubber. The condensible inorganic PM factor from Reference 1 that was not rated was excluded from the emission factor calculations. All data used were rated B. Due to the small amount of data available, these factors are rated D. Data representing uncontrolled emissions (inlet data from reference 1) were available for only one test; emission factors were not developed based on this single test.

### 4.2.3 Whey Dryers

There were four tests with emissions data from whey dryers. Data from three tests were used to develop emission factors for filterable PM, condensible organic PM, and condensible inorganic PM emissions from whey dryers. Factors were developed from A- and B-rated data and are rated D. The factor for condensible organic PM emissions from whey dryers controlled by a scrubber was not rated because of analysis problems. Data from one test for whey drying and bagging operations were not used to develop emission factors.

TABLE 4-1. SUMMARY OF TEST DATA FOR NATURAL AND PROCESSED CHEESE MANUFACTURING

| Process | APCD | Pollutant | No. of runs | Data rating | Emission factor lb/ton Min | Emission factor lb/ton Max | Emission factor lb/ton Avg | Emission factor kg/Mg Avg | Ref. No. |
|---|---|---|---|---|---|---|---|---|---|
| Cheese drying | None | Filterable PM | 3 | B | 0.47 | 0.83 | 0.63 | 0.32 | 1 |
| Cheese drying | Wet scrubber | Filterable PM | 3 | B | 0.16 | 0.43 | 0.27 | 0.14 | 1 |
| Cheese drying | None | Condensible organic PM | 3 | B | 0.024 | 0.060 | 0.043 | 0.021 | 1 |
| Cheese drying | Wet scrubber | Condensible organic PM | 3 | B | 0.021 | 0.048 | 0.033 | 0.017 | 1 |
| Cheese drying | None | Condensible inorganic PM | 3 | B | 0.12 | 0.46 | 0.25 | 0.13 | 1 |
| Cheese drying | Wet scrubber | Condensible inorganic PM | 3 | NR | 0.26 | 0.58 | 0.47 | 0.23 | 1 |
| Cheese drying | Venturi scrubber | Filterable PM | 3 | B | 4.3 | 5.1 | 4.6 | 2.3 | 2 |
| Cheese drying | Venturi scrubber | Condensible inorganic PM | 3 | B | 0.30 | 0.47 | 0.39 | 0.19 | 2 |
| Cheese drying | Venturi scrubber | Condensible organic PM | 3 | B | 0.13 | 0.58 | 0.36 | 0.18 | 2 |
| Cheese drying | Venturi scrubber | Filterable PM | 3 | B | 2.0 | 3.6 | 2.6 | 1.3 | 3 |
| Cheese drying | Venturi scrubber | Condensible inorganic PM | 3 | B | 0.12 | 0.29 | 0.19 | 0.094 | 3 |
| Cheese drying | Venturi scrubber | Condensible organic PM | 3 | B | 0.73 | 1.1 | 0.92 | 0.46 | 3 |
| Whey drying | Cyclone | Filterable PM | 3 | B | 0.72 | 0.85 | 0.77 | 0.39 | 4 |
| Whey drying | Cyclone | Condensible PM | 3 | B | 0.63 | 1.0 | 0.75 | 0.38 | 4 |
| Whey drying and bagging | Venturi scrubber and cyclone | Filterable PM | 3 | A | 0.40 | 0.45 | 0.42 | 0.21 | 5 |
| Whey drying and bagging | Venturi scrubber and cyclone | Condensible inorganic PM | 3 | A | 0.14 | 0.44 | 0.28 | 0.14 | 5 |
| Whey drying and bagging | Venturi scrubber and cyclone | Condensible organic PM | 3 | A | 0.082 | 0.15 | 0.11 | 0.053 | 5 |
| Whey drying | Fabric filter | Filterable PM | 2 | B | 1.9 | 2.4 | 2.2 | 1.1 | 6 |
| Whey drying | Fabric filter | Condensible inorganic PM | 2 | B | 0.011 | 0.083 | 0.047 | 0.024 | 6 |
| Whey drying | Fabric filter | Condensible organic PM | 2 | B | 0.056 | 0.14 | 0.10 | 0.048 | 6 |
| Whey drying | Cyclone and Wet scrubber | Filterable PM | 3 | B | 0.65 | 0.86 | 0.76 | 0.38 | 7 |
| Whey drying | Cyclone and Wet scrubber | Condensible inorganic PM | 3 | B | 0.020 | 0.059 | 0.044 | 0.022 | 7 |
| Whey drying | Cyclone and Wet scrubber | Condensible organic PM | 3 | NR | 0.0 | 0.0 | 0.0 | 0.0 | 7 |

TABLE 4-2. PARTICULATE EMISSION FACTORS FOR NATURAL AND PROCESSED CHEESE MANUFACTURE[a]

| Source | Control | Pollutant | Average emission factor | | | |
|---|---|---|---|---|---|---|
| | | | lb/ton | kg/Mg | Rating | Ref. |
| Cheese dryer | Wet scrubber | Filterable PM | 2.5 | 1.2 | D | 1,2,3 |
| | Wet scrubber | Cond. inorg. PM | 0.29 | 0.15 | D | 2,3 |
| | Wet scrubber | Cond. org. PM | 0.44 | 0.22 | D | 1,2,3 |
| Whey dryer | Cyclone | Filterable PM | 0.77 | 0.39 | D | 4 |
| | Cyclone | Condensible PM | 0.75 | 0.38 | D | 4 |
| | Fabric filter | Filterable PM | 2.2 | 1.1 | D | 6 |
| | Fabric filter | Cond. inorg. PM | 0.047 | 0.024 | D | 6 |
| | Fabric filter | Cond. org. PM | 0.1 | 0.048 | D | 6 |
| | Wet scrubber | Filterable PM | 0.76 | 0.38 | D | 7 |
| | Wet scrubber | Cond. inorg. PM | 0.044 | 0.022 | D | 7 |
| | Wet scrubber | Cond. org. PM | 0 | 0 | NR | 7 |

[a]Emission factor units are lb/ton of dry product. To convert from lb/ton to kg/Mg, multiply by 0.5. NR = not rated.

REFERENCES FOR SECTION 4


1. *Air Emission Test Report: Results of Source Emission Test Performed on Parmesan Cheese Dryer, Kraft Foods, Inc., Wausau, WI*. Twin City Testing Corporation, St. Paul, MN. May 7, 1993.

2. *Results of the December 28, 1988 Particulate Emission Compliance Test on the Rogers Dryer at the Land O'Lakes Plant Located in Spencer, Wisconsin*. Interpoll Laboratories, Inc., Circle Pines, MN. December 30, 1988.

3. *Results of the March 29, 1990 Particulate Emission Compliance Test on the Rogers Dryer at the Land O'Lakes Cheese Division Plant Located in Spencer, Wisconsin*. Interpoll Laboratories, Inc., Circle Pines, MN. April 18, 1990.

4. *Whey Dryer Emission Test at Northland Food Cooperative, Shawano, WI, April 9-10, 1986*. Badger Laboratories and Engineering Co., Inc., Appleton, WI. April 30, 1986.

5. *Results of the March 29, 1988 Particulate Emission Compliance Test on the Whey Dryer at the F&A Dairy in Dresser, Wisconsin*. Interpoll Laboratories, Circle Pines, MN. April 12, 1988.

6. *Results of the November 8, 1988 Particulate Emission Compliance Test on the Whey Dryer at the Ellsworth Coop Creamery in Ellsworth, Wisconsin*. Interpoll Laboratories, Circle Pines, MN. December 9, 1988.

7. *Whey Dryer Emission Tests at Alto Dairy, Waupun, WI, April 20, 1989*. Badger Laboratories, Appleton, WI. June 9, 1989.

# 5. PROPOSED AP-42 SECTION

The proposed AP-42 Section 9.6.1, Natural and Processed Cheese, is presented on the following pages as it would appear in the document.