Emission Factor Documentation for AP-42
Section 9.9.5

Pasta Manufacturing

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. II-03

MRI Project No. 4602-03

August 1995

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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. II-03. Mr. Dallas Safriet was the requester of the work.

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EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 9.9.5
Pasta Manufacturing

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 9.9.5, Pasta Manufacturing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the pasta manufacturing 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 (and emission measurement) 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 emission factor development for pasta manufacturing. 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 9.9.5, Pasta Manufacturing.

2. INDUSTRY DESCRIPTION

This section provides a brief review of the trends in the pasta manufacturing industry and an overview of the pasta manufacturing process. No emission data exist for the pasta manufacturing industry.

2.1 INDUSTRY CHARACTERIZATION[1-2]

Pasta products were first introduced in Italy in the 13th century by the explorer Marco Polo after returning from a voyage to China. Although pasta products have been produced for centuries, efficient manufacturing equipment and high-quality ingredients have been available only since the 20th century. Prior to the industrial revolution, most pasta products were made by hand in small shops. Today, most pasta is manufactured by continuous, high capacity extruders, which operate on the auger extrusion principle in which kneading and extrusion are performed in a single operation. The manufacture of pasta includes dry macaroni, noodle, and spaghetti production.

In 1992, there were approximately 200 companies involved in pasta production (SIC 2098). These companies produced approximately 97 million dollars in inventory and employed approximately 6,100 people. These figures represent a decrease from 1987, when 218 companies employed 6,600 people.

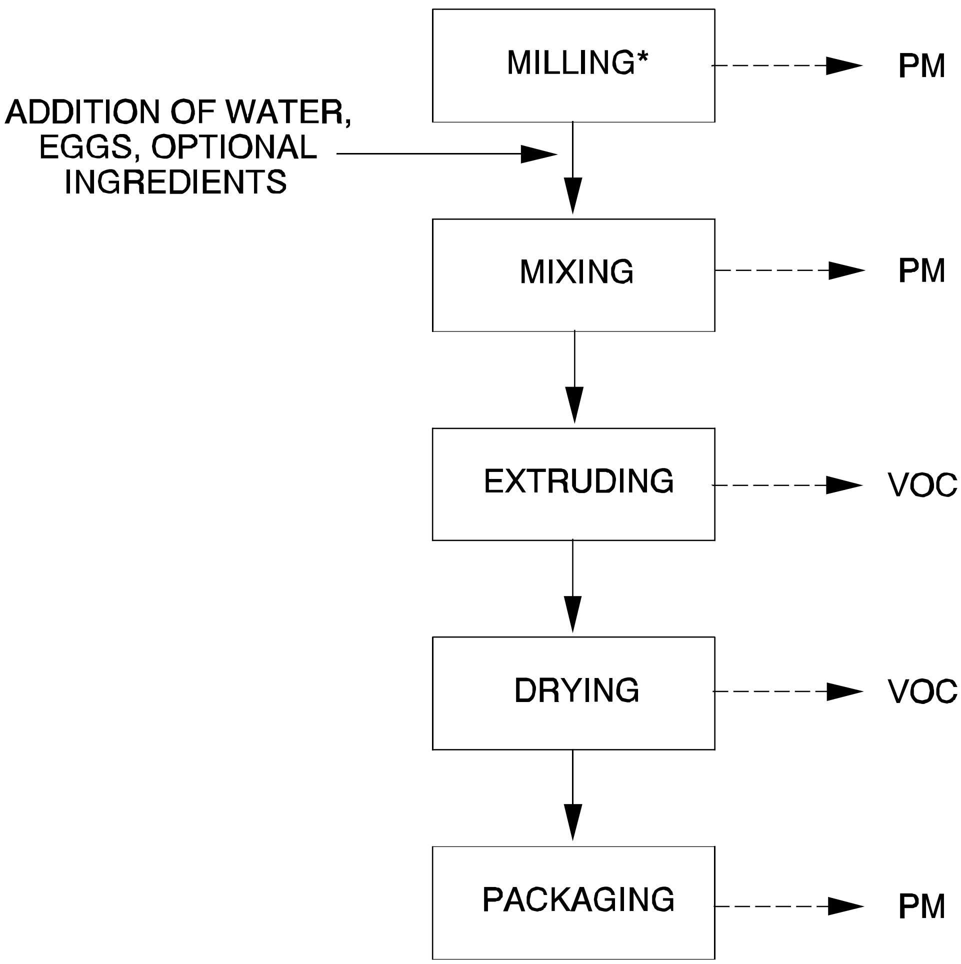
2.2 PROCESS DESCRIPTION[1-2]

Pasta products (e.g., dry macaroni, spaghetti, dry noodles) are produced by mixing milled wheat, water, eggs (for certain products), and sometimes optional ingredients. The mixed ingredients are then added to a continuous, high capacity auger extruder, which can be equipped with a variety of dies that determine the shape of the pasta. The pasta is then dried and packaged for market. Figure 2-1 shows a typical process diagram for pasta production.

2.2.1 Raw Materials

Pasta products contain few major ingredients: milled wheat, water, and eggs (for certain products). Manufacturers may also add optional ingredients to increase the flavor or nutritional value of the product. Pasta manufacturers usually use milled durum wheat in pasta production, although farina (a type of flour) and flour from common wheat are occasionally used.

Wheat. Three types of durum wheat (semolina, durum granulars, and durum flour) are used in most pasta products produced in the United States. Semolina is a granular product which is milled from the endosperm of amber durum and contains less than 3 percent flour. The highest quality pasta, which has a bright yellow color, is produced using semolina. Most pasta manufacturers prefer semolina that consists of fine particles of uniform size, rather than a course ground semolina, which is composed of both fine and course particles. If the semolina is not uniform in size, the smaller particles will absorb water faster than the larger particles resulting in the larger particles remaining relatively dry during mixing, which produces white specks when the pasta dries. Durum granular is also used in pasta production, although it is not as preferred by manufacturers because it contains as much as 20 percent flour. Durum flour is generally used only for noodles. Noodles produced from durum flour typically have good color but are less resistant to overcooking than products made from semolina or durum granular. Pasta products produced from farina and flour from common wheat tend to be pale or gray in color and are not as popular as products made from durum wheat.



*SEE AP-42 SECTION 9.9.1 FOR SCC FOR MILLING OPERATIONS

Figure 2-1. Typical pasta manufacturing process.

Water. The water used in pasta production should be pure, free from off-flavors, and suitable for drinking. Also, since pasta is produced below pasteurization temperatures, the bacterial count of the water is directly related to the bacterial count of the final product. Consequently, only water of low bacterial count can be used.

Eggs. Eggs are added to pasta to make egg noodles or egg spaghetti. Eggs improve the nutritional quality and richness of the pasta and can be added as fresh eggs, frozen eggs, dry eggs, egg yolks, or dried egg solids. In the United States, egg spaghetti and egg noodles must contain at least 5.5 percent egg solids by weight in the finished product. Only pasteurized egg products that have low bacterial counts, show negative Salmonella, and have less than 10 mold and yeast spores per gram of egg are used in pasta production. Special high yellow eggs are sometimes added to pasta to improve color.

Optional Ingredients. Small amounts of optional ingredients may also be added to pasta to enhance flavor. For example, salt, celery, garlic, and bay leafs may be added to season the pasta. Disodium phosphate may be used to shorten cooking time. Other ingredients, such as gum gluten, glyceryl monostearate, and egg whites, may also be added. Optional ingredients must be clearly labeled on the package.

2.2.2 Wheat Milling

Durum wheat has harder kernels than bread wheat and is used primarily to make pasta. It is milled into semolina, durum granular, or durum flour using a roll mill. Semolina milling is unique in that the objective is to prepare granular middlings (grains of medium size) with a minimum of flour production. The milling of durum flour is similar to conventional flour milling and consists of the following five main steps:

1. Grain reception and storage;
2. Grain cleaning;
3. Tempering or conditioning;
4. Grain milling into flour and byproducts; and
5. Storage and/or shipment of finished product.

Steps 1, 2, and 5 are essentially identical for durum and flour milling and are discussed in AP-42 Section 9.9.1, Grain Elevators and Processes. Steps 3 and 4 vary between bread wheat and durum milling and are discussed here.

The tempering of durum uses the same equipment as wheat, but the holding times are shorter because of the desire for middlings without flour production. Excessive tempering times soften the endosperm making it easier to make flour. Short tempering times maintain the hard structure of endosperm, which enhances the production of endosperm chunks.

Grain milling involves the use of break systems to crush the kernels into flour. The break system in a durum mill generally has at least five breaks and provides for the very gradual reduction of the stock necessary for good middlings production while still avoiding large amounts of break flour. In the break system, the kernel is broken open and the endosperm is separated from the bran and germ. The break system quite often involves four or more sets of corrugated rolls, each taking feed stock from the preceding one. After each break, the mixture of free bran, free endosperm, free germ, and bran containing adhering endosperm is sifted. The bran having endosperm still attached goes to the next break roll, and the process is repeated until as much endosperm has been separated from the bran as is possible.

The rolls in the reduction system are used for sizing only. None are used to produce flour. They function the same as the sizing rolls in a wheat flour mill reducing the coarse middling to a uniform particle size. In a wheat flour mill, the sizing is done to produce a uniform product for further grinding on the reduction rolls. In a durum mill, however, sizing is done to make a uniform product for sale.

The sifting system of a durum mill differs from that in a wheat flour mill by the heavy reliance on purifiers. In place of plansifters, conventional sieves are much more common and are used to make rough separations ahead of the purifiers. Additional information on grain milling can be found in AP-42 Section 9.9.1. The milled wheat is then mixed with water and other ingredients such as eggs and/or optional ingredients.

2.2.3 Mixing

In the mixing operation, pure water is added to the milled wheat (semolina, durum granular, or durum flour) in a mixing trough to produce dough with a moisture content of approximately 31 percent. Eggs and any optional ingredients may also be added. A special twin-shaft mixing chamber is used to obtain a uniform mixture. The special mixing chamber contains shafts that rotate in opposition to pull the dough simultaneously in two different directions, which minimizes the amount of balling that can occur. Most modern pasta presses are equipped with a vacuum chamber to remove air bubbles from the pasta before extruding. A vacuum is applied either by enclosing the entire mixer in the vacuum chamber or by drawing a vacuum on the pasta immediately prior to extrusion. If the air is not removed prior to extruding, small bubbles will form in the pasta which diminish the mechanical strength and give the finished product a white, chalky appearance.

2.2.4 Extruding

After the dough is mixed, it moves to the extruder. The extrusion auger not only forces the dough through the die, but it also kneads the dough into a homogeneous mass, controls the rate of production, and influences the overall quality of the finished product. Although construction and dimension of extrusion augers vary by equipment manufacturers, most modern presses have sharp-edged augers that have a uniform pitch (as opposed to an increasing pitch) over their entire length. The auger fits into a grooved extrusion barrel, which helps the dough move forward and reduces friction between the auger and the inside of the barrel. Extrusion barrels are equipped with a water cooling jacket to dissipate the heat that is generated during the extrusion process. The cooling jacket also helps to maintain a constant extrusion temperature, which should be held at approximately 51°C. If the dough is too hot (above 74°C), the pasta will be damaged.

Uniform flow rate of the dough through the extruder is also important. Variances in the flow rate of the dough through the die cause the pasta to be extruded at different rates and thus cut to different lengths. Products of nonuniform size must be discarded or reprocessed, which adds to the unit cost of the product. The inside surface of the die also influences the product appearance. Until recently, most dies were made of bronze, which were relatively soft and required repair or replacement periodically. Recently, dies have been improved by fitting the extruding surface of the die with Teflon inserts. These inserts extend the life of the dies and improve the quality of the pasta. Pasta extruded through dies with Teflon inserts are very smooth and tend to have a better appearance than similar products extruded through bronze dies.

2.2.5 Drying

Drying is the most difficult and critical step to control in the pasta production process. The objective of drying is to lower the moisture content of the pasta from approximately 31 percent to 12 to 13 percent so that the finished product will be hard, retain its shape, and store without spoiling. Most pasta drying operations use a preliminary drier immediately after extrusion to prevent the pasta from sticking together. Predrying hardens the outside surface of the pasta while keeping the inside soft and plastic. A final drier is then used to remove most of the moisture remaining in the product.

Drying temperature and relative humidity increments are important factors in drying. Since the outside surface of the pasta is exposed to the heated air, it dries more rapidly than the inside, causing moisture gradients to develop across the surface to the interior of the pasta. If dried too quickly, the pasta will crack, giving the product a poor appearance and very low mechanical strength. Cracking can occur during the drying process or as long as several weeks after the product has left the drier. On the other hand, if the pasta is dried too slowly, it tends to spoil or become moldy during the drying process. Therefore, it is essential that the drying cycle be tailored to meet the requirements of each type of product. If the drying cycle has been successful, the pasta will be firm but also flexible enough so that it can bend to a considerable degree before breaking.

2.2.6 Packaging

Packaging keeps the product free from contamination, protects the pasta from damage during shipment and storage, and displays the product favorably. The principal packaging material for noodles is the cellophane bag, which provides moisture-proof protection for the product and is used easily on automatic packaging machines. However, cellophane bags are difficult to stack on grocery shelves. Consequently, many manufacturers also utilize boxes to package pasta, which are easy to stack, provide good protection for fragile pasta products, and offer the opportunity to print advertising that is easier to read than on bags.

2.3 EMISSIONS

Air emissions may arise from a variety of sources in pasta manufacturing. Particulate matter (PM) emissions result mainly from solids handling and mixing. For pasta manufacturing, PM emissions occur during the wheat milling process, as the raw ingredients are mixed, and possibly during packaging. Emission sources associated with wheat milling include grain receiving, precleaning/handling, cleaning house, milling, and bulk loading. Applicable emission factors for these processes are presented in AP-42 Section 9.9.1, Grain Elevators and Processes. There are no data on PM emissions from mixing of ingredients or packaging for pasta production.

Volatile organic compound (VOC) emissions may potentially occur at almost any stage in the production of pasta, but most usually are associated with thermal processing steps, such as pasta extruding or drying. No information is available, however, on any VOC emissions due to the heat generated during pasta extrusion or drying.

2.4 EMISSION CONTROL TECHNOLOGY

Control technology to control PM emissions from pasta manufacturing is similar to that discussed in AP-42 Section 9.9.1, Grain Elevators and Processes. Because of the operational similarities, emission control methods used in grain milling and processing plants are similar to those in grain elevators. Cyclones or fabric filters are often used to control emissions from the grain handling operations (e.g., unloading, legs, cleaners, etc.) and also from other processing operations. Fabric filters are used extensively in flour mills. However, certain operations within milling operations are not amenable to the use of these devices and alternatives are needed. Wet scrubbers, for example, are applied where the effluent gas stream has a high moisture content. No information exists for VOC emission control technology for pasta manufacturing.

REFERENCES FOR SECTION 2

1. D. E. Walsh and K. A. Gilles, "Pasta Technology," *Elements of Food Technology*, N. W. Desrosier, Editor. AVI Publishing Company, Inc., 1977.

2. *1992 Census of Manufactures: Miscellaneous Food and Kindred Products*, Preliminary Report Industry Series. U.S. Department of Commerce, Bureau of Census. Issued August 1994.

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained primarily through literature searches. Because this is a new section, the AP-42 background files located in the Emission Factor and Inventory Group (EFIG) did not contain any information on the industry, processes, or emissions. Information on the industry was also obtained from the *Census of Manufactures*.

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 tests that were performed on the same source 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 untested or new methodology or that lacked a significant amount of background data.

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 only from A-rated 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-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- and 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 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- and B-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. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, EPA-454/B-93-050, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1993.

4. REVIEW OF SPECIFIC DATA SETS

This section describes the references and test data that were evaluated to determine if pollutant emission factors could be developed for AP-42 Section 9.9.5, Pasta Manufacturing.

4.1 REVIEW OF SPECIFIC DATA SETS

No source tests or other documents were located during the literature search that could be used to develop emission factors for this AP-42 section.

4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

No emission factors were developed because no source tests or emissions data were found. Particulate emission factors for durum wheat processing were obtained from AP-42 Section 9.9.1, Grain Elevators and Processes.