Emission Factor Documentation for AP-42
Section 6.13.3

Deep Fat Frying

Revised Draft Report

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

EPA Contract No. 68-D2-0159
Work Assignment No. 005

MRI Project No. 3605-M(02)

February 23, 1993

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For Emission Inventory Branch
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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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 EPA Contract No. 68-D2-0159, Work Assignment No. 005. Mr. Dallas W. Safriet was the requestor of the work. The report was prepared by Ms. Jill Guthrie. Contributing to the report were Mr. John Kinsey, Principal Environmental Scientist; Mr. David Reisdorph, Economist; and Ms. Margaret Thomas, Senior Resource Planner.

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February 23, 1993

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SECTION 1

INTRODUCTION

The document Compilation of Air Pollutant Emissions Factors (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been issued to add new emission source categories and to update existing emission factors. The EPA also routinely updates AP-42 in response to the needs of federal, state, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. Emission factors reported in AP-42 are used to:

1. Estimate areawide emissions;
2. Estimate emissions for a specific facility; and
3. Evaluate emissions relative to ambient air quality.

The purpose of this background report is to provide information to support preparation of a new AP-42 Section 6.13.3**C**Deep Fat Frying.

The remainder of this report consists of four sections. Section 2 gives a description of the potato chip and snack food industry. Section 3 describes the literature search, screening of emission source data, and the quality rating system for both emission data and emission factors. Section 4 presents the development of candidate emission factors, and Section 5 presents the proposed AP-42 Section 6.13.3**C**Deep Fat Frying.

SECTION 2

INDUSTRY DESCRIPTION

2.1 INDUSTRY CHARACTERIZATION[1,2,3]

The production of potato chips and other related snack foods (SIC 2099) is a growing, competitive industry. Sales of snack chips in the United States are projected to grow 5.7 percent between 1991 and 1995. Total U.S. consumption of potato chips grew from 976 x 10^6 lb in 1982 to 1,260 x 10^6 lb in 1987.

New products and processes are being developed to create a more health-conscious image for snack chips. Examples include the recent introduction of multigrain chips and the use of vegetable oils (noncholesterol) in frying. Health concerns are also encouraging the promotion and introduction of nonfried snack products like pretzels, popcorn, and crackers.

While a single company (Frito-Lay Inc.) dominates the industry, several new local and regional manufacturers have been introduced into the market in recent years. Competition from new national manufacturers is growing as well. Snack chip plants are widely dispersed across the country with the highest concentrations in high population states like California and Texas. Table 2-1 shows the geographical distribution of snack chip plants by EPA region.

2.2 PROCESS DESCRIPTION[4]

Vegetables and other raw foods are cooked by industrial deep fat frying and packaged for later use by consumers. When the raw food is immersed in hot oil, the oil replaces the naturally occurring moisture in the food as it cooks. Batch and continuous methods are the two processes used for deep fat frying. The batch frying process consists of immersing the food in the oil until it is cooked and then removing it from the oil. In the continuous frying process, the food is moved on a conveyor through the cooking oil.

The process used in deep fat frying is described below. Potato chips are provided as a representative example. Figure 2-1 (*missing*) provides an overview of the deep fat frying process.

The process begins with preparation of the raw material. Stones, decayed potatoes, and other debris are first removed in cleaning hoppers. The potatoes go next to washers and then to peelers. Abrasion, steam, or lye peelers are used, with abrasion being the most popular method. The abrasion method is done as a batch or continuous process, depending on the number of potatoes to be peeled.

Slicing, which is the next step, is performed by a rotary-type slicer that slices to various widths according to the condition of the potatoes and the type of chips being made. Rotating reels with high-pressure water separate the slices and remove the starch from the cut surfaces. Slices then move on to a tank for final rinsing.

Surface moisture must be removed next. This is accomplished by one or more of the following methods: perforated revolving drum, sponge rubber-covered squeeze roller, compressed air, vibrating mesh belt, heated air, and centrifugal extraction.

After preparation of the feedstock, the partially dried chips are fried. Most producers use a continuous process in which the slices are automatically moved through the frying kettle on a mesh belt. Batch frying is used for smaller numbers of chips and involves placing the chips in the frying kettle for a period of time and then removing them. A variety of popular oils are used for frying chips, including cottonseed, corn, and peanut oils. Animal fats are rarely used in this industry at present.

Following cooking, the product is typically seasoned with salt and other seasonings. The finished product is then packaged for distribution and sale.

2.3 EMISSIONS[5]

Particulate matter is the major air pollutant emitted from the deep fat frying process. Emissions are released when moist foodstuff, such as potatoes, are introduced into hot oil, which results in violent bubbling. Cooking oil vapors and droplets become entrained in the water vapor that is released. The emissions are exhausted away from the cooking vat and into the ventilation system. During ventilation, water and oil vapor condense in the exhaust stream to form fine droplets that are collected by control devices. The amount of particulate material emitted depends on process throughput, oil temperature, moisture content of the feed material, equipment design, and stack emission controls.

Volatile organic compounds (VOCs) are also produced in deep fat frying, but they are not a significant percentage of total emissions because of the low vapor pressure of the vegetable oils used. However, when the oil is entrained in the water vapor produced during frying, the oil may form volatile breakdown products.

2.4 EMISSION CONTROL TECHNOLOGY[5]

According to industrial information, emission control equipment for particulate matter is typically installed on fryer exhaust streams. Examples of control devices are oil mist eliminators, impingement devices, electrostatic precipitators (ESPs), and wet scrubbers. Sometimes exhaust stacks are equipped with dampers to adjust the flow of exhaust, resulting in emissions control. One manufacturer has indicated that catalytic and thermal incinerators are not practical because of the high moisture content of the exhaust stream.

REFERENCES FOR SECTION 2

1. 1987 Census of Manufactures Miscellaneous Food and Kindred Products, Report No. MC87-I-201, U.S. Department of Commerce, Bureau of the Census, April 1990.

2. Predicast's Forecasts, Predicasts Inc., Cleveland, OH, August 1991.

3. Standard & Poor's Industry Surveys: Food, Beverages & Tobacco, Current Analysis, Standard & Poor's Corp., New York, March 19, 1992.

4. O. Smith, Potatoes: Production, Storing, Processing, Avi Publishing, Westport, CT, 1977.

5. Characterization of Industrial Deep Fat Fryer Air Emissions, Frito-Lay Inc., Plano, TX, 1991.

SECTION 3

GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

MRI conducted an extensive search of the available literature relating to the emissions associated with potato chip and related snack food production. This search included data contained in the open literature (e.g., National Technical Information Service); source test reports and background documents from EPA's Office of Air Quality Planning and Standards (OAQPS); and MRI internal files (Kansas City and North Carolina offices).

After a thorough review of available reports, documents, and information, a set of reference materials was compiled. The quantity and quality of these materials were then evaluated to derive candidate emission factors for particulate and volatile organic compounds (VOCs) released during potato chip and related snack food production. This evaluation process is summarized in Sections 3.2 and 3.3.

3.2 DATA QUALITY RATING SYSTEM[1]

Based on OAQPS guidelines, the following data are always excluded from consideration in developing AP-42 emission factors.

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

2. Test series representing incompatible test methods; and

3. Test series in which the production and control processes are not clearly identified and described.

If there is no reason to exclude a particular data set, data are assigned a quality rating based on an A to D scale specified by OAQPS as follows:

A**C**This rating requires that multiple tests be performed on the same source using sound methodology and reported in enough detail for adequate validation. Tests do not necessarily have to conform to the methodology specified by EPA reference test methods, although such methods are used as guides.

B**C**This rating is given to tests performed by a generally sound methodology but lacking enough detail for adequate validation.

C**C**This rating is given to tests that are based on an untested or new methodology or that lack a significant amount of background data.

D**C**This rating is given to tests that are based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

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

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

2. Sampling procedures. The sampling procedures should conform to a generally accepted methodology. If actual procedures deviate from accepted methods, the deviations must be well documented. When this occurs, an evaluation should be made of how such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data should be documented in the report. Many variations can occur without warning during testing and sometimes without being noticed. Such variations can induce wide deviations in sampling results. 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 should contain original raw data sheets. The nomenclature and equations used are compared to those specified by EPA (if any) to establish equivalency. The depth of review of the calculations is dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn is 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]

EPA guidelines specify that the quality of the emission factors developed from analysis of the test data be rated utilizing the following general criteria:

! A**C**Excellent: The emission factor was developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category* was specific enough to minimize variability within the source category population.

! B**C**Above average: The emission factor was developed only from A-rated test data from a reasonable number of facilities. Although no specific bias was evident, it was not clear if the facilities tested represented a random sample of the industries. As in the A-rating, the source category was specific enough to minimize variability within the source category population.

! C**C**Average: The emission factor was developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias was evident, it was not clear if the facilities tested represented a random sample of the industry. As in the A-rating, the source category was specific enough to minimize variability within the source category population.

! D**C**Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there was reason to suspect that these facilities did 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 footnoted in the emission factor table.

* Source category: A category in the emission factor table for which an emission factor has been calculated.

! E**C**Poor: The emission factor was developed from C- and D-rated test data, and there was reason to suspect that the facilities tested did 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 the above criteria is somewhat subjective depending to a large extent on the individual reviewer. Details of how each candidate emission factor was rated are provided in Section 4.

3.4 EMISSION TESTING METHODS FOR DEEP FAT FRYING[2,3]

3.4.1 Particulates

Particulates in deep frying exhaust streams are generally sampled using an EPA Method 5 train. In this method, particulate matter is withdrawn from the source and collected on a glass fiber filter. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water. During testing of frying exhaust, samples collected on the filter are expected to consist primarily of oil droplets.

In source tests reviewed, the material collected in the impingers positioned after the filter of the Method 5 train also were analyzed. These samples either contained organic vapors that broke through the particulate filter during the test run and condensed after the filter, or were composed of very fine particles not retained by the filter. The volatility of this material was tested by using thermogravimetric analysis (TGA). Using this method, condensate samples collected in the impingers were subjected to increasing temperature, and the weight loss was measured.

3.4.2 Volatile Organic Compounds (VOCs)

Volatile organic compounds are collected from frying exhaust streams using several different methods. These include EPA Method 25 (Determination of Total Gaseous Nonmethane Organic Emissions as Carbon), EPA Method 25A (Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer), and EPA Method 18 (Measurement of Gaseous Organic Compound Emissions by Gas Chromatography).

REFERENCES FOR SECTION 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections, Draft, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 6, 1992.

2. Code of Federal Regulations, "Protection of Environment," Appendix A, Method 5, Revised July 1, 1988.

3. Characterization of Industrial Deep Fat Fryer Air Emissions, Frito-Lay Inc., Plano, TX, 1991.

SECTION 4

AP-42 SECTION DEVELOPMENT

This section describes the test data and methodology used to develop pollutant emission factors for deep fat frying. Section 6.13.3, Deep Fat Frying, will be entirely new to Chapter 6 of AP-42.

4.1 REVIEW OF SPECIFIC DATA SETS[1,2]

Only one source test was located during the literature search. It was the source testing that took place at a snack food manufacturing facility operated by the Frito-Lay Company.[1] The following outlines MRI's evaluation of that report.

The subject document reports the results of particulate and VOC emission tests performed on a range of fried food products, oils, and process conditions. Several firms participated in the emissions sampling. Samples were collected at several locations throughout the frying process (both before and after emission control devices). Thorough descriptions of the sampling sites were not provided, and the number of tests performed at a given site was not indicated, both of which reduced data quality.

The use of the Method 5 sampling train method was described in the document. Samples were collected from the front half of the train (the particulate filter) and the back half of the train (impingers). The volatility of the material collected in the impingers at the back half of the train was determined by using thermogravimetric analysis (TGA). Graphs of the TGA data are provided in the report.

Although several standard EPA methods were used to analyze for VOCs, it was not clear where or how the VOC emissions were sampled. However, a phone conversation with the individual responsible for summarizing the Frito-Lay emission data resolved some of the confusion.

Because of the deficiencies described above (i.e., lack of significant background data), this source test was given a C rating. A copy of the report is included in Appendix A.

4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS[1]

The candidate emission factors presented in Tables 4-1 and 4-2 were calculated from the following tables and figures contained in the source test report (Appendix A):

Table 1. Particulate Matter Emissions
Table 2. VOC Emissions
Figure 1. Thermogravimetric Analysis: Multigrain Chips**C**Canola Oil
Figure 2. Thermogravimetric Analysis: Potato Chips**C**Cottonseed Oil
Figure 3. Thermogravimetric Analysis: Corn Chips**C**Sunflower Oil
Figure 4. Thermogravimetric Analysis: Tortilla Chips**C**Soybean Oil

Each pollutant is discussed below.

4.2.1 Particulate Emissions

Table 4-1 presents particulate emissions (lb/h), testing conditions, and emission factors for the production of four types of fried chips. The emissions reported are for a continuous frying process. Reported values for particulate emissions were determined from the probe and filter of the Method 5 train (front-half particulate matter), and particulates condensed after the filter (back-half particulate matter).

These emissions were added together to calculate the total particulate emissions presented in Table 4-1 by the relationship:

$$TPE = F + B \qquad (4\text{-}1)$$

where: TPE = Total particulate emissions (lb/h)

F = particulate collected from the front half of the Method 5 train (particulate filter) in lb/h

B = particulate collected from the back half of the Method 5 train (impingers after the particulate filter) in lb/h

The emission factor was obtained by dividing the total particulate emissions (lb/h) by the process operating rate (ton/h). Each data set is described below.

4.2.1.1 Corn Chips/Sunflower Oil**C**

Emissions data presented in Table 4-1 for corn chips fried in sunflower oil were obtained in three tests. Each test used different control conditions:

! <u>Inlet</u>**C**The emissions were measured at a sampling site before the condenser and ESP (i.e., uncontrolled emissions).

! <u>ESP Outlet, Cond. Off</u>**C**Emissions were sampled at the ESP outlet while the ESP was operating and the condenser was off (i.e., ESP-controlled emissions).

! <u>ESP Outlet, ESP Off</u>**C**Emissions sampled at the ESP outlet while the ESP was off and the condenser was operating (i.e., condenser-controlled emissions).

The particulate emission factors calculated for the sampling locations "inlet," "ESP Outlet, Cond. Off," and "ESP Outlet, ESP Off" were 0.8, 0.6, and 0.34 lb/ton, respectively.

4.2.1.2 Potato Chips/Cottonseed Oil**C**

The particulate emissions for this test were measured at the "inlet" positioned before the scrubber. The uncontrolled emission factor calculated for this test was 2.04 lb/ton.

4.2.1.3 Corn Chips/Sunflower Oil, Tortilla Chips/Soybean Oil, Multigrain Chips/Canola Oil**C**

In the remaining tests, the particulates were measured in stack effluent. The emissions were uncontrolled except in the corn chips/sunflower oil test, where the emissions were measured after an oil mist eliminator. The controlled emission factor for that process was 0.85 lb/ton, whereas the uncontrolled emission factors for tortilla chips/soybean oil and multigrain chips/canola oil were 0.47 and 1.02 lb/ton, respectively.

4.2.2 VOC Emissions

Table 4-2 presents VOC emissions and emissions factors. VOC emissions were measured using the analytical methods described previously in Section 3.4.2. A brief description of the instrumentation used for each test is provided in Table 4-2. The VOC emissions are reported as total hydrocarbon (HC) or nonmethane hydrocarbon (NMHC), both expressed as a methane equivalent. The emission factors were obtained by dividing the HC or NMHC VOC emissions (lb/h) by the operating rate (lb/h). Each data set is described below.

4.2.2.1 Corn Chips/Sunflower Oil**C**

VOC emission data for corn chips fried in sunflower oil were obtained using many of the same process and control conditions as described above for particulate emissions. The VOC emissions data presented in Table 4-2 for corn chips fried in sunflower oil were obtained in three tests using the same three control conditions described in Section 4.2.1.1 for particulate matter. The NMHC emission factors calculated for the "inlet," "ESP Outlet, Cond. Off," and "ESP Outlet, ESP Off" were 0.44, 0.58, and 0.31 lb/ton, respectively.

4.2.2.2 Potato Chips/Cottonseed Oil**C**

In this test, VOCs were measured at the inlet before the scrubber control device. Three different analysis methods were used at the inlet sampling location in this test series. The total HC emission factors calculated for two of the tests are 0.015 and 0.13 lb/ton. The NMHC emission factor developed from the third test is 0.020 lb/ton.

4.2.2.3 Corn Chips/Sunflower Oil**C**

In this test, emissions were measured after the oil mist eliminator control device using the three different analysis methods described in Section 3.4.2. The controlled total HC emission factors calculated for two of the tests were 0.051 and 0.38 lb/ton. The controlled NMHC emission factor developed from the third test was 0.02 lb/ton.

4.2.2.4 Tortilla Chips/Soybean Oil**C**

In this test, uncontrolled emissions were measured in stack effluent three different times using one analysis method. In addition, the back half of the Method 5 train was analyzed for one test. The stack sampling resulted in uncontrolled total HC emission factors of 0.096, 0.11, and 0.17 lb/ton. The sample collected at the back half of the Method 5 train resulted in a total HC uncontrolled emission factor of 0.096 lb/ton.

4.2.2.5 Multigrain Chips/Canola Oil**C**

In this test, uncontrolled emissions were measured both in the stack and at the outlet of the Method 5 train. The uncontrolled emissions measured from the stack resulted in an uncontrolled total HC emission factor of 0.25 lb/ton. When the uncontrolled emissions were measured after the back half of the Method 5 train, the uncontrolled total HC emission factor was calculated to be 0.14 lb/ton.

4.2.3 <u>Candidate Emission Factors</u>

The candidate controlled and uncontrolled emission factors for deep fat frying are presented in Tables 4-3 and 4-4 for particulate matter and VOCs, respectively. The calculations of the candidate emission factors are discussed below.

REFERENCES FOR SECTION 4

1. Characterization of Industrial Deep Fat Fryer Air Emissions, Frito-Lay Inc., Plano, TX, 1991.

2. Telephone communication between Jill Guthrie, Midwest Research Institute, Kansas City, MO, and Robert Ajax, Robert L. Ajax & Associates, Cary, NC, August 31, 1992.

SECTION 5

PROPOSED AP-42 SECTION 6.13.3

A proposed new AP-42 section for deep fat frying is presented on the following pages as it would appear in the document.

6.13.3 **Deep Fat Frying**

6.13.3.1 Process Description.[1] Vegetables and other raw foods are cooked by industrial deep fat frying and packaged for later use by consumers. When the raw food is immersed in hot oil, the oil replaces the naturally occurring moisture in the food as it cooks. The two processes used for deep fat frying are batch and continuous. The batch frying process consists of immersing the food in the deep fat until it is cooked and then removing it from the oil. In the continuous frying method, the food is moved through the cooking oil on a conveyor.

Potato chips are one example of a food prepared by deep fat frying. To prepare the potatoes for frying, stones, decayed potatoes, and other debris are first removed. This action is performed in cleaning hoppers. The potatoes go next to washers, then peelers. Abrasion, steam, or lye peelers are used. Abrasion is the most popular method. This method is done as a batch or continuous process, depending on the number of potatoes to be peeled.

The next step is slicing, which is performed by a rotary-type slicer. The potatoes are sliced to various widths, according to the condition of the potatoes and the type of chips being made. Rotating reels with high-pressure water separate the slices and remove the starch from the cut surfaces. Slices then move on to the rinse tank for final rinsing.

Next, the surface moisture must be removed. This is accomplished by one or more of the following methods—perforated revolving drum, sponge rubber-covered squeeze roller, compressed air systems, vibrating mesh belt, heated air, and centrifugal extraction.

The partially dried chips are then fried. Most producers use a continuous process in which the slices are automatically moved through the frying kettle on a mesh belt. Batch frying, which is used for a smaller numbers of chips, involves placing the chips in the frying kettle for a period of time and then removing them. A variety of oils may be used for frying chips; cottonseed, corn, and peanut oils are the most popular. Animal fats are rarely used in this industry. Figure 6.13.3-1 provides a general process diagram for deep fat frying.

6.13.3.2 Emissions and Controls

6.13.3.2.1 Sources of emissions.[2] Particulate matter is the major air pollutant emitted from the vegetable oil frying process. Emissions are released when moist foodstuff, such as potatoes, are introduced into hot oil, resulting in violent bubbling. Cooking oil vapors and droplets become entrained in the water vapor that is released. The emissions are exhausted away from the cooking vat and into the ventilation system. During ventilation, water and oil vapors condense in the exhaust stream to form fine droplets which are collected by control devices. The amount of particulate material emitted depends on process throughput, oil temperature, moisture content of the feed material, equipment design, and stack emission controls.

Volatile organic compounds (VOCs) are also produced in deep fat frying, but they are not a significant percentage of total emissions from frying because of the low vapor pressure of the vegetable oils used. However, when the oil is entrained into the water vapor produced during frying, the oil may form volatile breakdown products.

6.13.3.2.2 Emission control techniques.[2] Particulate emission control equipment is typically installed on fryer exhaust streams. Examples of control devices are mist eliminators, impingement devices, electrostatic precipitators (ESPs), and wet scrubbers. Sometimes exhaust stacks are equipped with dampers to adjust the flow of exhaust, resulting in emissions control. One manufacturer has indicated that catalytic and thermal incinerators are not practical because of the high moisture content of the exhaust stream.

6.13.3.3 Emission factors. Tables 6.13.3-1, 6.13.3-2, 6.13.3-3, and 6.13.3-4 provide controlled and uncontrolled particulate emission factors in metric and English units. Tables 6.13.3-5, 6.13.3-6, 6.13.3-7, and 6.13.3-8 provide controlled and uncontrolled VOC emission factors in metric and English units for snack chip frying.[3] Where emission control devices were used on the exhaust stream, the type of control is noted.

TABLE 2-1. NUMBER OF SNACK CHIP PLANTS IN THE UNITED STATES BY EPA REGION

Region	Number of plants
I	10
II	8
III	38
IV	35
V	76
VI	45
VII	30
VIII	13
IX	53
X	6
Total	343

Source: 1987 Census of Manufactures Miscellaneous Food and Kindred Products, Report No. MC87-I-201, U.S. Department of Commerce, Bureau of the Census, April 1990.

TABLE 4-1. EMISSIONS FOR SNACK FOOD FRYING Data Quality Rating: C TOTAL PARTICULATE MATTER

Section reference	Product	Oil	Cooker design	Operating rate, lb/h	Cooker temp. °F(°C)	Stack temp. °F(°C)	Sample location	Particulate emissions (lb/h)[a] Front	Back	Total (TPE)	Emission factor[b] lb/ton (kg/Mg)
4.3.1.1	Corn chips[c]	Sunflower	Two fryers, each 950 lb/h	2,139	410(210)	240(116)	Inlet[d]	0.6	0.3	0.9	0.8 (0.4
			"U" fryers,[e] pan heat	1,846	410(210)	187(86)	ESP outlet, cond. off[d]	0.32	0.21	0.53	0.6 (0.3
				2,062	410(210)	147(64)	ESP outlet, ESP off[d]	0.24	0.11	0.35	0.34 (0.17)
4.3.1.2	Potato chips[f]	Cottonseed	5,000 lb/h, steam heat	4,039	360(182)	221(105)	Inlet	3.34	0.78	4.12	2.04 (1.02)
4.3.1.3	Corn chips[g]	Sunflower	2,200 lb/h, "U" fryer,[a] steam heat	1,970	410(210)	233(112)	Stack	0.50	0.34	0.84	0.85 (0.42)
4.3.1.3	Tortilla chips[h]	Soybean	2,200 lb/h, "U" fryer,[a] steam heat	2,089	370(188)	185(85)	Stack	0.35	0.14	0.49	0.47 (0.23)
4.3.1.3	Multigrain chips[h]	Canola	2,600 lb/h, surface fry, steam heat	2,420	370(188)	208(98)	Stack	0.98	0.26	1.24	1.02 (0.51)

TABLE 4-1. EMISSIONS FOR SNACK FOOD FRYING Data Quality Rating: C TOTAL PARTICULATE MATTER

[a] Particulate emissions**C**
Front**C**Particulate collected from the front half of the Method 5 train.
Back**C**Particulate collected from the back half of the Method 5 train.
Total (TPE)**C**Total front and back half.

[b] Expressed in the weight of particulate matter per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb.

[c] High temperature process.

[d] Sampling locations**C**
Inlet**C**Samples taken before the condenser and electrostatic precipitator (ESP).
ESP outlet, cond. off**C**Samples taken at the ESP outlet (ESP on, condenser off).
ESP outlet, ESP off**C**Samples taken at the ESP outlet (ESP off, condenser on).

[e] "U" fryers are horseshoe-shaped cookers designed by Frito-Lay.

[f] High moisture process, sampled at the inlet to the scrubber.

[g] High temperature process, sampled after oil mist eliminator.

[h] Uncontrolled process.

TABLE 4-2. VOC EMISSIONS FROM SNACK FOOD FRYING

Data Quality Rating: C

Section reference	Product	Oil	Cooker design	Operating rate, lb/h	Cooker temp. °F(°C)	Stack temp. °F(°C)	Sample location	Trap temp. °F(°C)	VOC emissions (as methane) Total HC (lb/h)	Total NMHC (lb/h)	Instrumentation method used	Emission factor[a] Total HC lb/ton (kg/Mg)	Total NMHC lb/ton (kg/Mg)
4.3.2.1	Corn chips[d]	Sunflower	Two fryers, each 950 lb/h, "U" fryers, pan heat[b]	2,139	410(210)	240(116)	Inlet[c]	~ 80(27)	**C**	0.47	Byron 301 HTGC/FID 1 sample/3 min	**C**	0.44 (0.22)
				1,846	410(210)	187(86)	ESP outlet, cond. off[c]	~ 80(27)	**C**	0.54	Byron 301 HTGC/FID 1 sample/3 min	**C**	0.58 (0.29)
				2,062	410(210)	147(64)	ESP outlet, ESP off[c]	~ 80(27)	**C**	0.32	Byron 301 HTGC/FID 1 sample/3 min	**C**	0.31 (0.15)
4.3.2.2	Potato chips[e]	Cottonseed	5,000 lb/h, steam heat	4,039	360(182)	221(105)	Inlet	~ 60(16)	0.03	**C**	OVA FID	0.015 (0.0074)	**C**
							Inlet	~ 120 (49)	0.26	**C**	Bechman FID	0.13 (0.064)	**C**
							Inlet, M-5 outlet	~ 60(16)	**C**	0.04	C2-C6 HC GC/FID	**C**	0.020 (0.0099)
4.3.2.3	Corn chips[f]	Sunflower	2,200 lb/h, "U" fryer,[a] steam heat	1,970	410(210)	240(116)	Stack	~ 60(16)	0.05	**C**	OVA FID	0.051 (0.025)	**C**
							Stack	~ 120 (49)	0.37	**C**	Bechman FID	0.38 (0.19)	**C**

							Stack, M-5 outlet	~ 60(16)	**C**	0.02	C2-C6 HC GC/FID	**C**	0.02 (0.01)
4.3.2.4	Tortilla chips[g]	Soybean	2,200 lb/h, "U" fryer,[a] steam heat	2,089	370(188)	157(69)	Stack	~ 60(16)	0.1	**C**	Bendix FID	0.096 (0.048)	**C**
					370(188)	190(88)	Stack	~ 60(16)	0.12	**C**	Bendix FID	0.11 (0.057)	**C**
					360(182)	190(88)	Stack	~ 60(16)	0.18	**C**	Bendix FID	0.17 (0.086)	**C**
							M-5 outlet	~ 60(16)	0.1	**C**	Bendix FID	0.096 (0.048)	**C**
4.3.2.5	Multigrain chips[g]	Canola	2,600 lb/h, surface fry, steam heat	2,420	370(188)	208(98)	Stack	~ 60(16)	0.3	**C**	Bendix FID	0.25 (0.12)	**C**
							M-5 outlet	~ 60(16)	0.17	**C** **C**	Bendix FID	0.14 (0.070)	**C**

[a] Expressed as equivalent weight of methane per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb.

[b] "U" fryers are horseshoe-shaped cookers designed by Frito-Lay.

[c] Sampling locations**C**
InletCSamples taken before the condenser and electrostatic precipitator (ESP).
ESP outlet, cond. off**C**Samples taken at the ESP outlet (ESP on, condenser off).
ESP Outlet, ESP off**C**Samples taken at the ESP outlet (ESP off, condenser on).

[d] High temperature process.

[e] High moisture process, sampled at the inlet to the scrubber.

[f] High temperature process, sampled after oil mist eliminator.

[g] Uncontrolled process.

TABLE 4-3. CANDIDATE PARTICULATE EMISSION FACTORS FOR SNACK CHIP FRYING
Emission Factor Rating: E

Control	Data quality rating	Emission factor[a] lb/ton (kg/Mg)	Standard deviation (σ)
None	C	1.1 (0.54)	0.59 (0.29)
Oil mist eliminator[b]	C	0.85 (0.42)	**C**
ESP[b]	C	0.6 (0.3)	**C**
Condenser[b]	C	0.34 (0.17)	**C**

[a] Expressed as weight of total particulate matter per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

[b] Based on a single test.

TABLE 4-4. CANDIDATE TOTAL GASEOUS VOC EMISSION FACTORS FOR SNACK CHIP FRYING
Emission Factor Rating: E

Control	Data quality rating	Emission factor[a] lb/ton (kg/Mg)	Standard deviation (σ)
None	C	0.18 (0.089)	0.17 (0.083)
Condenser[b]	C	0.31 (0.15)	**C**

[a] Expressed as equivalent weight of methane (CH_4) per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

[b] Based on a single test of corn chip frying. Control efficiency of condenser calculated to be 39 percent from Table 4-2.

5.0.0.1 Particulate Emission Factors**C**

The uncontrolled particulate emission factors (data quality rating of C) in Table 4-5 were averaged (arithmetic mean) to obtain the candidate uncontrolled particulate emission factor for snack chip frying. The standard deviation (σ) of the data set was also calculated as shown in the table.

TABLE 4-5. UNCONTROLLED PARTICULATE EMISSION FACTORS

			Emission factor[a]	
Product	Oil	Control	lb/ton	kg/Mg
Corn chips	Sunflower	None	0.8	0.4
Potato chips	Cottonseed		2.04	1.02
Tortilla chips	Soybean		0.47	0.23
Multigrain chips	Canola		1.02	0.51
	Average		1.1	0.54
	Std. deviation		0.59	0.29

[a] Weight of particulate matter per unit weight of vegetable cooked.

The three candidate controlled particulate emission factors for deep fat frying were: 0.85 lb/ton (0.42 kg/Mg) for oil mist eliminator control; 0.6 lb/ton (0.3 lb/ton) for electrostatic precipitator control; and 0.34 lb/ton (0.17 kg/Mg) for condenser control. These factors are based on single tests shown in Table 4-1. All candidate particulate emission factors are rated E because of the limitations of the test data relating both to quality and to representativeness.

5.0.0.2 VOC Emission Factors**C**

The VOC emission factors (data quality rating of C) in Table 4-6 were averaged (arithmetic mean) to obtain the candidate uncontrolled total VOC emission factor for snack chip frying. Total HC and total NMHC data from Table 4-2 were combined to obtain total VOC emissions (as methane), which were used to calculate the resulting emission factors. The standard deviation (σ) was also calculated for each data set as shown in Table 4-6.

TABLE 4-6. UNCONTROLLED VOC EMISSION FACTORS

			Emission factor[a]	
Product	Oil	Control	lb/ton	kg/Mg
Corn chips	Sunflower	None	0.44	0.22
			0.58	0.29
Potato chips	Cottonseed	None	0.015	0.0074
			0.13	0.064
			0.020	0.0099
Corn chips	Sunflower	None	0.051	0.025
			0.38	0.19
			0.02	0.01
Tortilla chips	Soybean	None	0.096	0.048
			0.11	0.057
			0.17	0.086
			0.096	0.048
Multigrain chips	Canola	None	0.25	0.12
			0.14	0.070
	Average		0.18	0.089
	Std. deviation		0.17	0.083

[a] Expressed as equivalent weight of methane per unit weight of vegetable cooked.

The candidate controlled total VOC emission factor for corn chip frying was 0.31 lb/ton (0.15 kg/Mg) for condenser control. This factor is based on a single test presented in Table 4-2. This value represents a 39 percent reduction in uncontrolled emissions based on tests at the same facility. All candidate VOC emission factors are rated E because of the limitations of the test data relating both to quality and to representativeness.

TABLE 6.13.3-1 (METRIC UNITS)
PARTICULATE EMISSION FACTORS FOR SNACK CHIP FRYING[a]
UNCONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] kg/Mg
Deep fat fryer (30203601)	0.54

[a] From Table 4-3 of Reference 3.
[b] Expressed as weight of total particulate matter per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

TABLE 6.13.3-2 (ENGLISH UNITS)
PARTICULATE EMISSION FACTORS FOR SNACK CHIP FRYING[a]
UNCONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] lb/ton
Deep fat fryer (30203601)	1.1

[a] From Table 4-3 of Reference 3.
[b] Expressed as weight of total particulate matter per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

TABLE 6.13.3-3 (METRIC UNITS)
PARTICULATE EMISSION FACTORS FOR SNACK CHIP FRYING[a]
CONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] kg/Mg
Deep fat fryer with oil mist eliminator[c] control (30203601)	0.42
Deep fat fryer with ESP[c] control (30203601)	0.3
Deep fat fryer with condenser[c] control (30203601)	0.17

[a] From Table 4-3 of Reference 3.
[b] Expressed as weight of total particulate matter per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.
[c] Based on a single test.

TABLE 6.13.3-4 (ENGLISH UNITS)
PARTICULATE EMISSION FACTORS FOR SNACK CHIP FRYING[a]
CONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] lb/ton
Deep fat fryer with oil mist eliminator[c] control (30203601)	0.85
Deep fat fryer with ESP[c] control (30203601)	0.6
Deep fat fryer with condenser[c] control (30203601)	0.34

[a] From Table 4-3 of Reference 3.
[b] Expressed as weight of total particulate matter per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.
[c] Based on a single test.

TABLE 6.13.3-5 (METRIC UNITS)
TOTAL VOC EMISSION FACTORS FOR SNACK CHIP FRYING[a]
UNCONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] kg/Mg
Deep fat fryer (30203601)	0.089

[a] From Table 4-4 of Reference 3.
[b] Expressed as equivalent weight of methane (CH_4) per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

TABLE 6.13.3-6 (ENGLISH UNITS)
TOTAL VOC EMISSION FACTORS FOR SNACK CHIP FRYING[a]
UNCONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] lb/ton
Deep fat fryer (30203601)	0.18

[a] From Table 4-4 of Reference 3.
[b] Expressed as equivalent weight of methane (CH_4) per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.

TABLE 6.13.3-7 (METRIC UNITS)
TOTAL VOC EMISSION FACTORS FOR CORN CHIP FRYING[a]
CONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] kg/Mg
Deep fat fryer with condenser[c] control (30203601)	0.15

[a] From Table 4-4 of Reference 3.
[b] Expressed as equivalent weight of methane (CH_4) per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.
[c] Based on a single test.

TABLE 6.13.3-8 (ENGLISH UNITS)
TOTAL VOC EMISSION FACTORS FOR CORN CHIP FRYING[a]
CONTROLLED EMISSIONS

Emission Factor Rating: E

Process (SCC)	Emission factor[b] lb/ton
Deep fat fryer with condenser[c] control (30203601)	0.31

[a] From Table 4-4 of Reference 3.
[b] Expressed as equivalent weight of methane (CH_4) per unit weight of vegetable cooked. 1 lb/ton = 0.4994 kg/Mg; 1 ton = 2,000 lb; 1 Mg = 10^6 g.
[c] Based on a single test.

References for Section 6.13.3

1. O. Smith, Potatoes: Production, Storing, Processing, Avi Publishing, Westport, CT, 1977.

2. Characterization of Industrial Deep Fat Fryer Air Emissions, Frito-Lay Inc., Plano, TX, 1991.

3. Midwest Research Institute, Emission Factor Documentation for AP-42, Section 6.13.3 Deep Fat Frying, Kansas City, MO, February 1993.