



National Pollutant Inventory

Emission Estimation Technique Manual

for

**Fruit and Vegetable
Processing Industry**

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**EMISSION ESTIMATION TECHNIQUES
FOR
FRUIT AND VEGETABLE PROCESSING INDUSTRY**

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FRUIT AND VEGETABLE PROCESSING INDUSTRY

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1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in fruit and vegetable processing.

EET MANUAL: Fruit and Vegetable Processing

HANDBOOK: Fruit and Vegetable Processing

ANZSIC CODES : 2130

This Manual was drafted by the NPI Unit of the Queensland Department of Environment and Heritage on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

2.0 Processes and Emissions

The following section presents a brief description of the fruit and vegetable processing industry and identifies likely sources of emissions.

2.1 Process Description

2.1.1 Dehydrated Fruits and Vegetables

Dried or dehydrated fruits and vegetables can be produced by a variety of processes. These processes differ primarily by drying method used, which depends on the type of food and the characteristics of the final product. Generally dried or dehydrated fruits and vegetables undergo the following process steps:

- predrying treatments such as size selection, peeling, slicing, dicing, blanching and colour preservation;
- drying or dehydration using natural or artificial methods; and
- post-dehydration treatments such as sweating, inspection and packaging.

2.1.1.1 Predrying Treatments

Predrying treatments prepare the raw product for drying or dehydration and include raw product preparation and colour preservation. This includes selection and sorting, washing, peeling (for some fruits and vegetables), cutting into appropriate form, and blanching (for some fruits and vegetables).

Fruits and vegetables are first selected and washed. Peeling or removal of any undesirable parts follows washing. The product is then cut into the appropriate shape or form. Some fruits and vegetables are then blanched by immersion in hot water or exposed to steam.

The final step in the prehydration treatment is colour preservation, also known as sulfuring. The majority of fruits are treated with sulfur dioxide (SO₂) for its antioxidant and preservative effects. The presence of SO₂ is very effective in retarding the browning of fruits. When the enzymes usually made inactive by the high heat applied at the drying stage, are still active, browning of fruits occurs. In addition to preventing browning, SO₂ treatment reduces the destruction of carotene and ascorbic acid, which are the important nutrients of fruit.

Although sulfur dioxide is commonly used to prevent browning of fruits, this treatment is not practical for vegetables. Instead most vegetables are treated with sulfite solutions to retard enzymatic browning. In addition to colour preservation, the presence of a small amount of sulfite in blanched, cut vegetables improves storage stability and makes it possible to increase the drying temperature during dehydration. This decreases drying time and increases the drier capacity without exceeding the tolerance for heat damage.

Drying or Dehydration

Drying or dehydration is the removal of the majority of water contained in fruit and vegetables and is the primary stage in the production of dehydrated fruits and vegetables. Several drying methods are commercially available. The selection of the optimum method is determined by quality requirements, raw material characteristics, and economic factors. These methods are:

- sun and solar drying
- atmospheric dehydration including stationary or batch processes (kiln tower, and cabinet driers) and continuous processes (tunnel, continuous belt, belt-trough, fluidised bed, explosion puffing, foam-mat, spray, drum, and microwave-heated driers); and
- sub-atmospheric dehydration (vacuum shelf, vacuum drum, and freeze driers)

Sun Drying and Solar Drying

This method uses the power of the sun to remove moisture from the product. Sun drying of fruit crop is limited to climates with hot sun and dry atmosphere, and to certain fruits such as prunes, grapes dates, figs, apricots and pears. These crops are processed in substantial quantities without much technical help by simply spreading the fruit on trays or racks and exposing them to the sun until dry. Advantages of this process are its simplicity and its small capital investment. Disadvantages include a complete dependence on the elements and the necessity for moisture levels to be at least 15 to 20 percent or above.

Solar drying may utilise black-painted trays, solar trays, collectors and mirrors to increase solar energy and to accelerate drying.

Atmospheric Forced-Air Driers

This process artificially dries fruits and vegetables by passing heated air with controlled relative humidity over the food to be dried, or by passing the food to be dried through the heated air. This is the most widely used method of drying fruits and vegetables. Various devices are used to control air circulation and recirculation. Stationary, or batch, processes include kiln, tower (or stack), and cabinet driers. Continuous processes are used mainly for vegetable dehydration and include tunnel, continuous belt, belt trough, fluidised-bed, explosion puffing, foam mat, spray drum, and microwave-heated driers. Tunnel driers are the most flexible, efficient, and widely used dehydration system available commercially.

2.1.1.2 Sub-atmospheric (or Vacuum) Dehydration

This process occurs at low air pressure and includes vacuum, shelf, vacuum drum, vacuum belt, and freeze driers. The main purpose of vacuum drying is to enable the removal of moisture at less than boiling point under ambient conditions. Because of the high installation and operating costs of vacuum driers, this process is used for drying raw

material that may deteriorate as a result of oxidation or may be modified chemically as a result of exposure to air at elevated temperatures.

There are two categories of vacuum driers. In the first category, moisture in the food is evaporated from the liquid to the vapour stage, and includes vacuum shelf, vacuum drum and vacuum belt driers. In the second category of vacuum driers, the moisture of the food is removed from the product by sublimation, which involves converting ice directly into water vapour. The advantages of freeze drying are high flavour retention, maximum retention of nutritional value, minimal damage to the product texture and structure, little change in product shape and colour, and a finished product with an open structure that allows fast and complete dehydration. Disadvantages include high capital investment, high processing costs, and the need for special packaging to avoid oxidation and moisture gain in the finished product.

2.1.1.3 Post-dehydration Treatments

Treatments of the dehydrated product vary according to the type of fruit and vegetable, and the intended use of the product. These treatments may include sweating, screening, inspection, instantisation treatments, and packaging. Sweating involves holding the dehydrated products in bins or boxes to equalise the moisture content. Screening removes dehydrated pieces of unwanted size, usually called “fines”. The dried product is inspected to remove foreign materials, discoloured pieces, or other imperfections such as skin, carpel, or stem particles. Instantisation treatments are used to improve the re-hydration rate of the low moisture product. Packaging of all dehydrated fruits and vegetables must protect the product against moisture, light, air dust, microflora, foreign odour, insects, and rodents. It must also provide strength and stability to maintain the original product size, shape, and appearance.

2.1.2 Canned Fruits and Vegetables

The canning industry is made up of establishments primarily engaged in canning fruits, vegetables, fruit and vegetable juices; processing ketchup and other tomato sauces; and producing natural and imitation preserves, jams and jellies.

The primary objective of food processing is the preservation of perishable foods in a stable form that can be stored and shipped to distant markets during all months of the year. Processing can also change foods into new or more useable forms and make foods more convenient to prepare.

The goal of the canning process is to destroy any micro-organisms in the food and prevent recontamination by micro-organisms. Heat is the most common agent used to destroy micro-organisms. Removal of oxygen can be used in conjunction with other methods to prevent the growth of oxygen-dependent micro-organisms.

In the conventional canning of fruits and vegetables, there are basic process steps that are similar for both types of products. However, there is a great diversity among those plants processing the same commodity. The differences include the combination of certain operations for some fruits or vegetables, the sequence of the process steps used in the

operations, and the cooking or blanching steps. Production of fruit or vegetable juice occurs by a different sequence of operations and this varies widely among these plants. Typical canned products include beans (cut and whole), beets, carrots, corn, peas, spinach, tomatoes, apples, peaches, pineapples, pears and apricots. Typical juices are apple, orange, pineapple, grapefruit and tomato. Generic process flow diagrams for the canning of fruits, vegetables and fruit juices are shown in Figure 1, Figure 2 and Figure 3. The steps outlined in these figures are intended to illustrate the basic processes in production.

A typical commercial canning operation may employ the following general processes: washing, sorting/grading, preparation, container filling, exhausting, container sealing, heat sterilisation, cooling, labelling/casing, and storage for shipment. In these diagrams, no attempt has been made to be product-specific and to include all process steps necessary for all products.

One of the major differences in the sequence of operations between fruit and vegetable canning is the blanching operation. Most of the fruits are not blanched prior to can filling whereas many of the vegetables undergo this step. Canned vegetables generally require more extensive thermal processing than do fruits because the vegetables have much higher pH and contain more heat-resistant soil organisms. Many vegetables also require more cooking than fruits to develop their most desirable flavour and texture. The methods used in the cooking step vary widely among facilities. With many fruits, preliminary treatment steps (eg. peeling, coring, halving, pitting) take place prior to any heating or cooking step but with vegetables, these treatment steps often occur after the vegetable has been blanched. Both fruits and vegetables are either mechanically peeled, or steam peeled. The choice depends on the type of fruit or vegetable or the choice of the company.

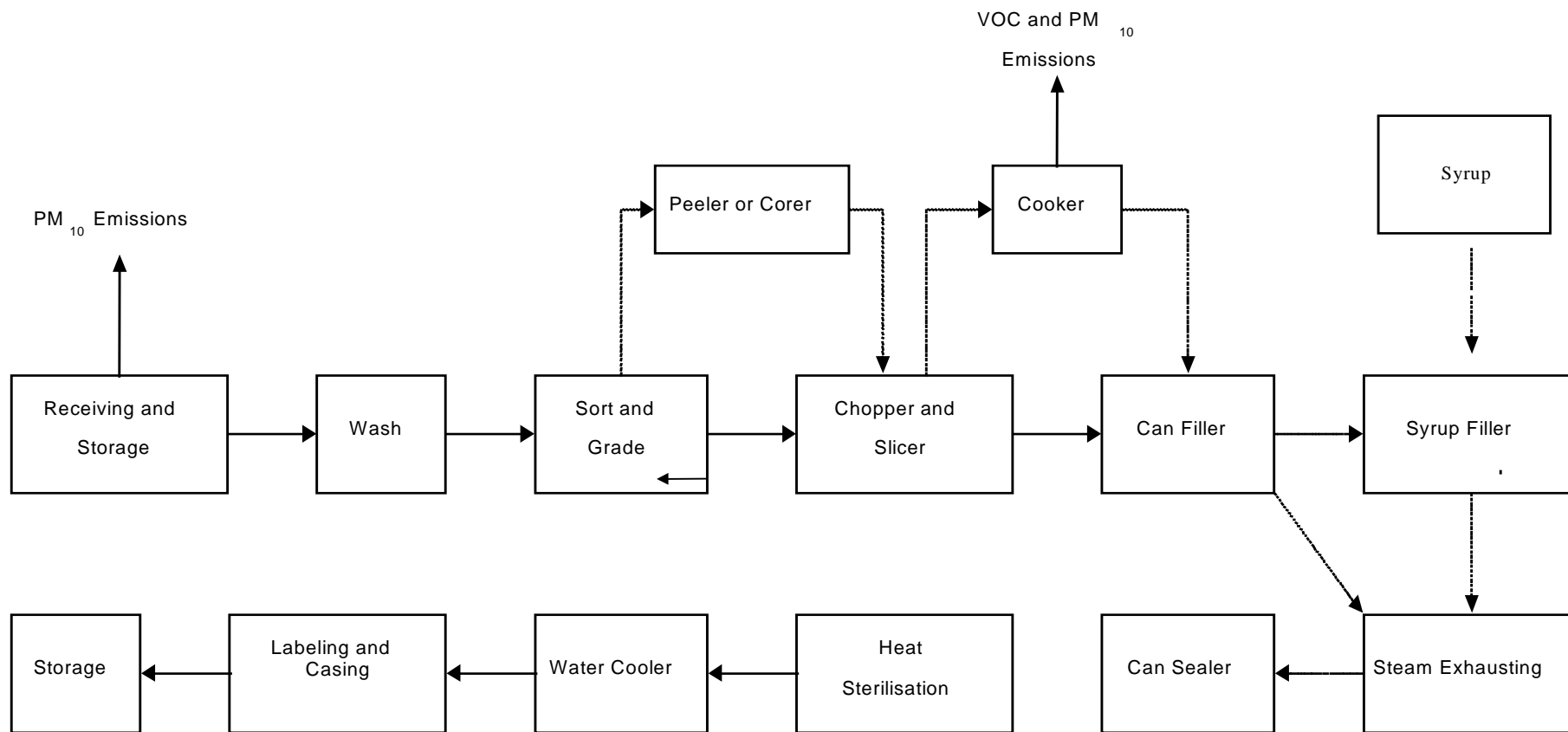


Figure 1 - Generic Process Diagram for Fruit Canning

Source: USEPA, AP-42, Section 9.8.1, 1995

Some citrus fruit processors produce dry citrus peel, citrus molasses and D-limonene from the peels and pulp residue collected from the canning and juice operations. Other juice processing facilities use concentrates. Raw commodity processing does not occur at the facility. The peels and the residue are collected and ground in a hammermill, lime is added to neutralise the acids, and the product pressed to remove excess moisture. The liquid from the press is screened to remove large particles, which are recycled back to the press, and the liquid is concentrated into molasses in an evaporator. The pressed peel is then sent to a direct-fired hot-air drier. After passing through a condenser to remove the D-limonene, the exhaust gases from the drier are used as the heat source for the heat molasses evaporator.

Equipment for conventional canning has been converted from batch to continuous units. In continuous units or retorts, the cans are fed through an air lock, then rotated through the pressurised heating chamber, and subsequently cooled through a second section of the retort in a separate cold-water cooler. Commercial methods for sterilisation of canned foods with a pH of 4.5 or lower include use of static retorts, which are similar to large pressure cookers. A newer unit is the agitating retort, which mechanically moves the can and the food, providing quicker heat penetration. In the aseptic packaging process, problems with slow heat penetration in the in-container process are avoided by sterilising and cooling the food separate from the container. Pre-sterilised containers are then filled with the sterilised and cooled product and are sealed in the sterile atmosphere (this is limited to liquid products with particulates < 20mm).

To provide an insight into the actual processes that occur during a canning operation, a description of the canning of whole tomatoes is presented in the following paragraphs.

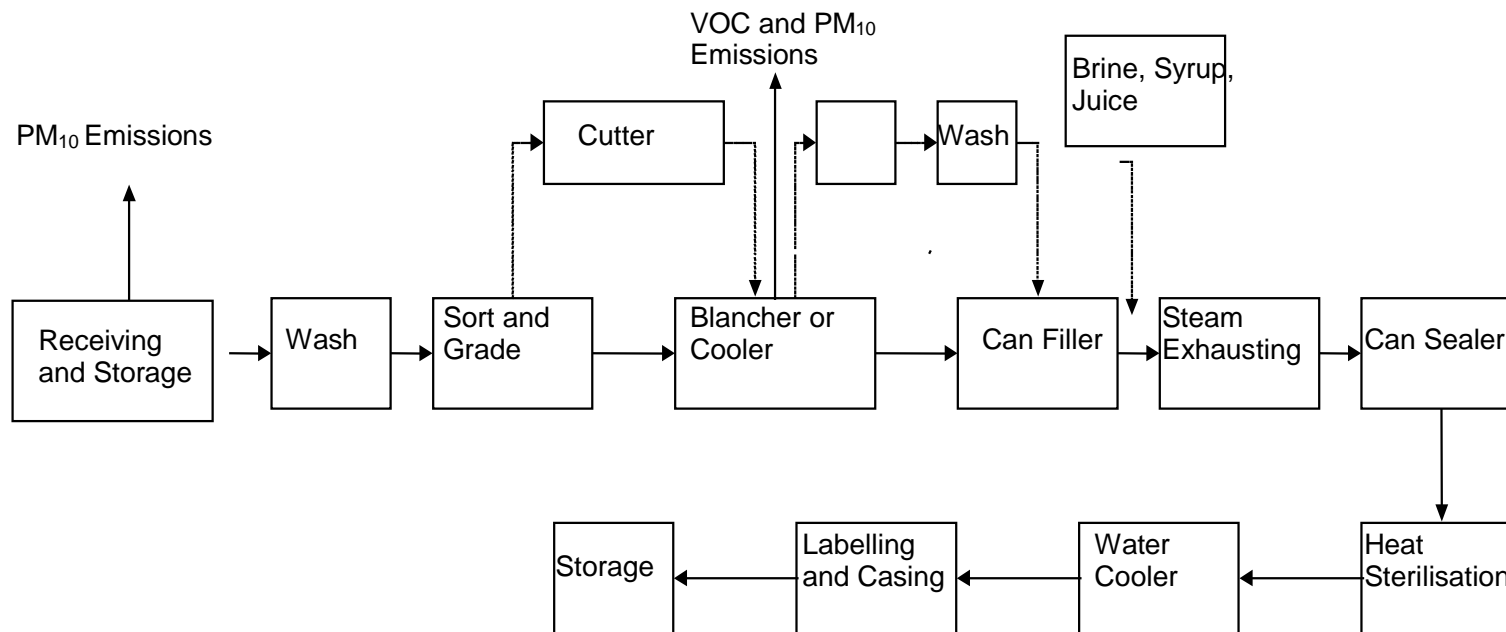


Figure 2 - Generic Process Diagram for Vegetable Canning

Source: USEPA, AP-42, Section 9.8.1, 1995

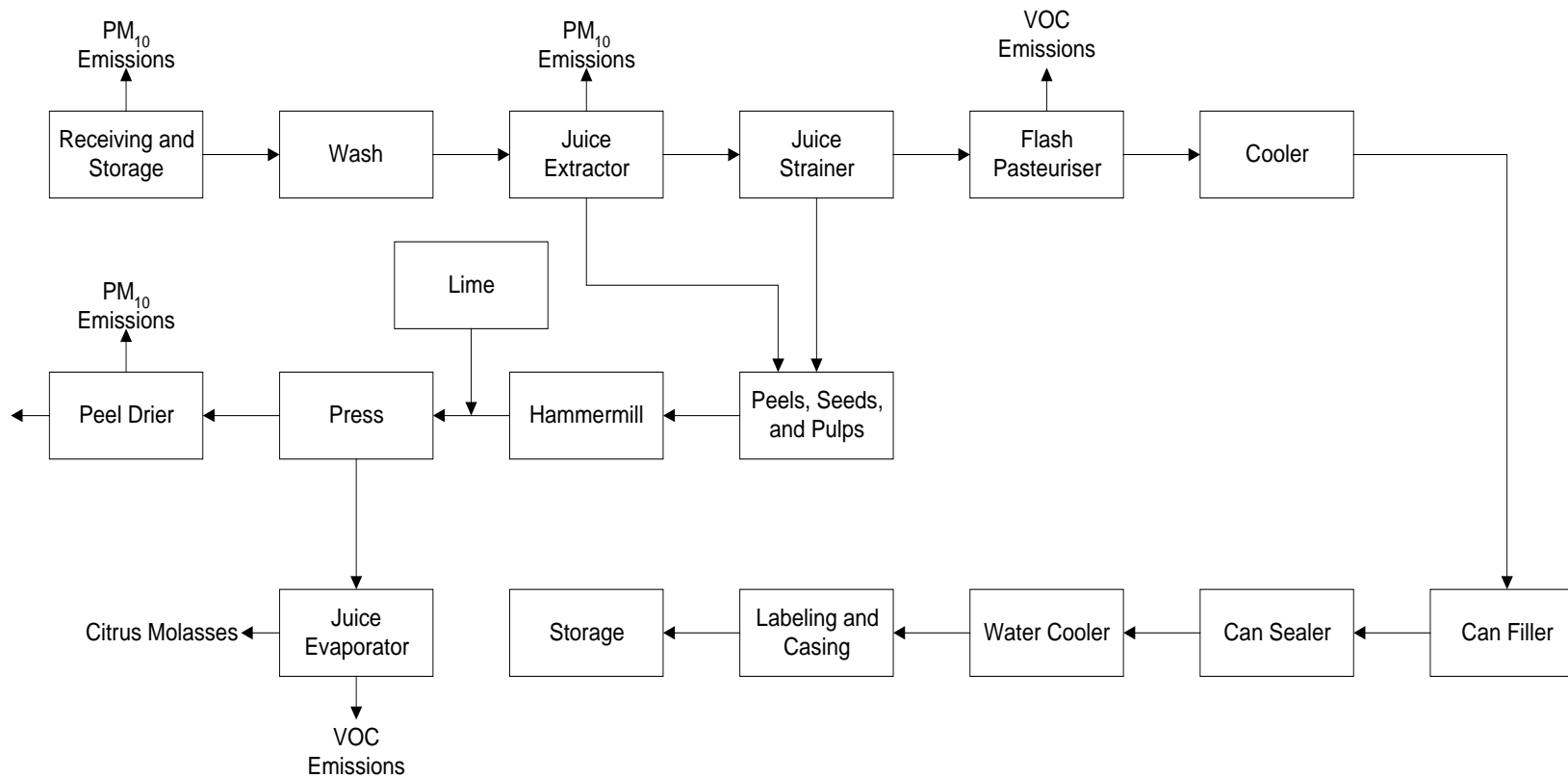


Figure 3 - Generic Process Diagram for Juice Canning
 Source: USEPA, AP-42, Section 9.8.1, 1995

2.1.2.1 Preparation

The principal preparation steps are washing and sorting. Mechanically harvested tomatoes are usually thoroughly washed by high-pressure sprays or by strong-flowing streams of water while being passed along a moving belt or on agitating or revolving screens. The raw produce may need to be sorted for size and maturity. Sorting for size is accomplished by passing the tomatoes through a series of moving screens with different mesh sizes or over differently spaced rollers. Separation into groups according to degree of ripeness or perfection of shape is done by hand; trimming is also done by hand.

2.1.2.2 Peeling and Coring

Formerly, tomatoes were initially scalded and then peeled by hand, but steam peeling and lye (a generic term used for an alkaline solution) peeling have also become widely used. With steam peeling, the tomatoes are treated with steam to loosen the skin, which is then removed by mechanical means. In lye peeling, the fruit is immersed in a hot lye bath or sprayed with a boiling solution of 10 to 20 percent lye. The excess lye is then drained and any lye that adheres to the tomatoes is removed with the peel through washing.

Coring is done by a water-powered device with a small turbine wheel. A special blade mounted on the turbine wheel spins and removes the tomato cores.

2.1.2.3 Filling

After peeling and coring, the tomatoes are conveyed by automatic runways, through washers, to the point of filling. Before being filled, the can or glass containers are cleaned by hot water, steam or air blast. Most filling is done by machine. The containers are filled with the solid product and then usually topped with a light puree of tomato juice. Acidification of canned whole tomatoes with 0.1 to 0.2 percent citric acid is a way of justifying pH to a safer and more desirable level. Because of the increased sourness of the acidified product, the addition of sucrose is used to balance the taste. The addition of salt is important for palatability.

2.1.2.4 Exhausting

The objective of exhausting containers is to remove air so that the pressure inside the container following the heat treatment and cooling will be below atmospheric pressure. The reduced internal pressure (vacuum) helps to keep the can ends drawn in, reduces strain on the containers during processing, and minimises the level of oxygen remaining in the headspace. It also helps to extend the shelf life of food products and prevents bulging of the container at high altitudes.

Vacuum in the can may be obtained by the use of heat or by mechanical means. The tomatoes may be preheated before being filled and sealed hot. For products that cannot be preheated before filling, it may be necessary to pass the filled containers through a steam

chamber or tunnel prior to the sealing machine to expel gases from food and raise the temperature. Vacuum may also be produced mechanically by sealing containers in a chamber under a high vacuum.

2.1.2.5 Sealing

In sealing lids on metal cans, a double seam is created by interlocking the curl of the lid and flange of the can. Many closing machines are equipped to create vacuum in the headspace either mechanically or by steam-flow before the lids are sealed.

2.1.2.6 Heat Sterilisation

During processing, micro-organisms that can spoil the product are destroyed by heat. The temperature and processing time vary with the nature of the product and the size and type of the container (scheduled process).

Most cooking processes take place at around 97-98°C (water bath cookers, for instance). The containers holding these products are processed in atmospheric steam or hot-water cookers. The rotary continuous cookers, which operate at 100°C, have largely replaced retorts and open-still cookers for processing canned tomatoes. Some plants use hydrostatic cookers and others use continuous-pressure cookers.

For pressure cooking in a retort or a rotary pressure cooker, it is necessary to have a slight pressure of steam for reliable temperature control. Depending on the equipment, 103-105°C is the minimum temperature.

Most emissions to air for the canning industry will result from combustion processes. The reader should therefore refer to the *Combustion in Boilers* EET Manual for more information.

2.1.2.7 Cooling

After heat sterilisation, containers are quickly cooled to prevent overcooking. Containers may be quickly cooled by adding water to the cooker under air pressure retorts or by conveying the containers from the cooker to a rotary cooler equipped with a cold-water spray.

2.1.2.8 Labelling and Casing

After the heat sterilisation, cooling and drying operations, the containers are ready for labelling. Labelling machines apply glue and labels in one high-speed operation. The labelled cans or jars are then packed into shipping cartons.

2.2 Emission Sources and Control Technologies

2.2.1 Emissions to Air

Air emissions may be categorised as:

Fugitive Emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats, open vessels, or spills and materials handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining losses through fugitive emissions.

Point Source Emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. Table 1 highlights common air emissions from fruit and vegetable processing. The *Combustion in Boilers* EET Manual, along with other Manuals in this series, is available from State and Territory environment agencies. The *Combustion in Boilers* EET Manual is designed to provide guidance on estimating emissions from combustion sources such as combustion of natural gas, oil, LPG or coal which may be of particular relevance to the fruit and vegetable processing industry.

Table 1 - Common Air Emissions of NPI-Listed Substances from Fruit and Vegetable Processing

Substances
Volatile Organic Compounds (VOCs)
Sulfur Dioxide (SO ₂)
Particulate Matter (PM ₁₀)
Ammonia (NH ₃) *
Chlorine (Cl ₂) *

Source: Queensland Department of Environment and Heritage, 1998

Ammonia and Chlorine are common substances used for refrigeration and disinfecting/cleaning purposes, hence a possible emission source.

Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of particulates in process off-gases before stack emission. Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimation, the collection efficiency of the abatement equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in later sections.

With regards to emission controls for PM₁₀ emissions, (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. ≤10µm), in the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 90% should be used in the emission factor equation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

2.2.2 Emissions to Water

Emissions of substances to water can be categorised as discharges to:

- Surface waters (eg. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and
- Stormwater.

Because of the significant environmental hazards posed by emitting toxic substances to water, most facilities emitting NPI-listed substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing sampling data can be used to calculate annual emissions.

If no wastewater monitoring data exists, emissions to process water can be calculated based on a mass balance or using emission factors.

The discharge of listed substances to a sewer does not require you to report to the NPI. However, leakage and other emissions (including dust) from a tailings storage facility are reportable. (See also Section Three of *The NPI Guide*.)

2.2.3 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids and may contain listed substances. These emission sources can be broadly categorised as:

- surface impoundments of liquids and slurries; and
- unintentional leaks and spills

3.0 Emission Estimation Techniques

Estimates of emissions of NPI-listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in *The NPI Guide* are:

- sampling or direct measurement;
- mass balance;
- fuel analysis or other engineering calculations; and
- emission factors

Select the EET, (or mix of EETs), that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of these EETs, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of EETs that are not outlined in this handbook, your data will also be displayed as being of 'acceptable reliability'.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this handbook does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site-specific emission factors, you may use these if approved by your relevant environmental authority.

You should note that the EETs presented in this manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, ie., the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

The **usage** of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, **emissions** of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

3.1 Direct Measurement

You may wish to undertake direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. However, the NPI does not require you to undertake additional sampling and measurement. For the sampling data to be adequate and able to be used for NPI reporting purposes, it would need to be collected over a period of time, and to be representative of operations for the whole year.

3.1.1 Sampling Data

Stack sampling test reports often provide emissions data in terms of parts per million (ppm) or grams per cubic metre (g/m^3) (dry standard). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (ie. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

This Section shows how to calculate emissions in kg/hr based on stack sampling data, and how to convert this to an annual emissions figure. Calculations involved in determining particulate emissions are used as an example, although the same calculations are applicable for most of the substances listed on the NPI. Use Equation 1 to calculate the concentration of PM_{10} in g/m^3 and use Equation 2 to calculate the hourly emission of PM_{10} in kg/hr .

Equation 1

$$C_{\text{PM}} = C_f / V_{\text{m,STP}}$$

where:

$$\begin{aligned} C_{\text{PM}} &= \text{concentration of PM or gram loading } (\text{g}/\text{m}^3) \\ C_f &= \text{filter catch (g)} \\ V_{\text{m,STP}} &= \text{metered volume of sample at STP } (\text{m}^3) \end{aligned}$$

Equation 2

$$E_{PM} = C_{PM} * Q_d * 3.6 * [273/(273+T)]$$

where:

$$\begin{aligned} E_{PM} &= \text{hourly emissions of PM in kg/hr} \\ C_{PM} &= \text{concentration of PM or gram loading (g/m}^3\text{)} \\ Q_d &= \text{stack gas volumetric flow rate (m}^3\text{/s)} \\ T &= \text{stack gas temperature (C)} \end{aligned}$$

The information from some stack tests may be reported in kilograms of particulate matter per cubic metre of exhaust gas (wet). Use Equation 3 to calculate the dry particulate emissions in kg/hr.

Equation 3

$$E_{PM} = Q_a * C_{PM} * 3.6 * \left(1 - \frac{\text{moist}_R}{100}\right) * \left[\frac{273}{273+T}\right]$$

where:

$$\begin{aligned} E_{PM} &= \text{hourly emissions of PM in kilograms per hour, kg/hr} \\ Q_a &= \text{actual (ie. wet) cubic metres of exhaust gas per second, m}^3\text{/s} \\ C_{PM} &= \text{concentration of PM or gram loading, g/m}^3 \\ 3.6 &= \text{3600 seconds per hour multiplied by 0.001 kilograms per gram} \\ \text{moist}_R &= \text{moisture content, \%} \\ 273 &= \text{273 K (0}^\circ\text{C)} \\ T &= \text{stack gas temperature, }^\circ\text{C} \end{aligned}$$

Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM₁₀ from total PM emissions, a size analysis may need to be undertaken. The weight PM₁₀ fraction can then be multiplied by the total PM emission rate to produce PM₁₀ emissions. Alternatively, assume that 100% of PM emissions are PM₁₀; ie assume that all particulate matter emitted to air has an equivalent aerodynamic diameter of 10 micrometres or less ie. ≤10µm.

To calculate moisture content use Equation 4.

Equation 4

Moisture percentage = 100 % * weight of water vapour per specific volume of stack gas/ total weight of the stack gas in that volume.

$$moist_R = \frac{100\% * \left(\frac{g_{moist}}{1000 * V_{m,STP}}\right)}{\left(\frac{g_{moist}}{1000 * V_{m,STP}}\right) + \rho_{STP}}$$

where

$moist_R$ = moisture content, %
 g_{moist} = moisture collected, g
 $V_{m,STP}$ = metered volume of sample at STP, m³
 ρ_{STP} = dry density of stack gas sample, kg/m³ at STP
{if the density is not known a default value of 1.62 kg/m³ may be used. This assumes a dry gas composition of 50% air, 50% CO₂}

Example 1 - Calculating Moisture Percentage

A 1.2m³ sample (at STP) of gas contains 410g of water. To calculate the moisture percentage use Equation 4.

$$moist_R = \frac{100\% * \left(\frac{g_{moist}}{1000 * V_{m,STP}}\right)}{\left(\frac{g_{moist}}{1000 * V_{m,STP}}\right) + \rho_{STP}}$$

$$\begin{aligned} g_{MOIST} / 1000 * V_{m,STP} &= 410 / (1000 * 1.2) \\ &= 0.342 \\ moist_R &= 100 (0.342 / (0.342 + 1.62)) \\ &= 17.4\% \end{aligned}$$

3.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system provides a continuous record of emissions over time, usually by reporting pollutant concentration.

Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate.

It is important to note that prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies your relevant environmental authority's requirement for NPI emission estimations.

Most food processing industries however, will not be required to use this method of EET for the reporting of substances.

3.2 Mass Balance

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

3.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (eg. vapour pressure) of the substance and mathematical relationships (eg. ideal gas law).

3.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO₂ and metal emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur, which may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

Equation 5

$$E_{kpy,i} = Q_f * \text{pollutant concentration in fuel} * (MW_p / EW_f) * \text{OpHrs}$$

where:

$$\begin{aligned} E_{kpy,i} &= \text{emissions of pollutant i, kg/yr} \\ Q_f &= \text{fuel use (kg/hr)} \\ MW_p &= \text{molecular weight of pollutant emitted (kg/kgmol)} \\ EW_f &= \text{elemental weight of pollutant in fuel (kg/kgmol)} \\ \text{OpHrs} &= \text{operating hours, hr/yr} \end{aligned}$$

For instance, SO₂ emissions from oil combustion can be calculated based on the concentration of sulfur in the oil. This approach assumes complete conversion of sulfur to SO₂. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO₂ (MW = 64) are emitted. The application of this EET is shown in Example 2.

Example 2 - Using Fuel Analysis

This example illustrates how SO₂ emissions can be calculated from oil combustion based on fuel analysis results and the fuel flow information from a processing facility. The facility is assumed to operate 1500 hours per year.

E_{kpy,SO_2} = may be calculated using Equation (4)

$$\begin{aligned} \text{Fuel flow} &= 2\,000 \text{ kg/hr} \\ \text{Weight percent sulfur in fuel} &= 1.17 \end{aligned}$$

$$\begin{aligned} E_{kpy,SO_2} &= Q_f * \text{pollutant concentration in fuel} * (MW_p / EW_f) * \text{OpHrs} \\ &= (2\,000) * (1.17 / 100) * (64 / 32) * 1\,500 \\ &= 46.8 \text{ kg/hr} * 1\,500 \text{ hr/yr} \\ &= 70\,200 \text{ kg/yr} \end{aligned}$$

3.4 Emission Factors

Presently there are no existing emission factors available for the fruit and vegetable processing industry

An emission factor is a tool that is used to estimate emissions to the environment. Emission factors are usually expressed as the weight of a substance emitted divided by the unit weight, volume, distance, or duration of the activity emitting the substance.

Emission factors are used to estimate a facility's emissions by the general equation:

Equation 6

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$

where :

$E_{kpy,i}$	=	emission rate of pollutant i (kg/yr)
A	=	activity rate (t/hr)
$OpHrs$	=	operating hours (hr/yr)
EF_i	=	uncontrolled emission factor of pollutant i (kg/t)
CE_i	=	overall control efficiency of pollutant i (%)

Emissions can be developed specifically for specific processes. Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources. You are required to have the emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

3.4.1 Predictive Emission Monitoring (PEM)

Predictive emission monitoring is based on developing a correlation between pollutant emission rates and process parameters. A PEM allows facilities to develop site-specific emission factors, or emission factors more relevant to their particular process.

Based on test data, a mathematical correlation can be developed which predicts emissions using various parameters.

4.0 Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the National Pollutant Inventory does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regards to accuracy.

Several techniques are available for calculating emissions from fruit and vegetable processing facilities. The technique chosen is dependent on available data, available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data, such as the emission factors presented in Section 3.4.1 of this Manual.

4.1 Direct Measurement

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from fruit and vegetable processing facilities. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation and may provide only one example of the facility's emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time, and to cover aspects of production of fruit and vegetable products.

In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

4.2 Mass Balance

Calculating emissions from a fruit and vegetable processing facility using mass balance appears on the surface to be a straightforward approach to emissions estimations. However, it is likely that few Australian fruit and vegetable processing facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking or other activities inherent in each material handling stage can often result in large deviations of total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only ± 5 percent in any one step of the operation can significantly skew emission estimations.

4.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from fruit and vegetable processes.

Use of emission equations to estimate emissions from fruit and vegetable processing facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions.

5.0 References

National Pollutant Inventory Homepage

<http://www.environment.gov.au/epg/npi/home.html>

USEPA, 1995, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 9.8.1, Canned Fruit and Vegetables*, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, USA.

<http://www.epa.gov/ttn/chief/ap42.html>

USEPA, 1995, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 9.8.2 Dehydrated Fruit and Vegetables*, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, USA.

The following Emission Estimation Technique Manuals referred to in this Manual are available at the NPI Homepage and from your local environmental protection agency (see the front of the NPI Guide for details):

- Emission Estimation Technique Manual for Combustion in Boilers; and
- Emission Estimation Technique Manual for Combustion Engines.